DVS | IS Institut de Soudure

Issue 01 2022

WELDING AND CUTTING

www.welding-and-cutting.info

Technical journal for welding and allied processes

- Friction stir welding of steel for shipbuilding and marine applications
- Weld overlay cladding offers enhanced performance
- Simulation of laser beam and gas-shielded metal arc welding

Uncertainty remains

After the Coronavirus pandemic severely restricted us for more than two years, signs of improvement begin to show, especially since vaccinations can prevent severe cases of the disease. There are legitimate expectations that the pandemic will weaken with the spring months to come, as was the case before, and that lifting or possibly termination of protective measures will be decided. This raises the possibility that by the middle of the year at the latest, trade fairs will be held "normally" again, i.e. can be attended in person.

In the field of thermal spraying – a regularly addressed topic also in this journal – attention is turning to the ITSC – International Thermal Spray Conference and Exposition, which will take place in Vienna, Austria, from 4 to 6 May 2022 and offers trade visitors a comprehensive programme as well as up-to-date information on all aspects of surface treatment technologies (see page 38 in this issue).

As far as welding technology is concerned, one of the next international highlights in Europe is the "EuroBlech" trade fair, which is scheduled for 25 to 28 October 2022 at the exhibition centre in Hanover and, in addition to its materials focus, will also place a distinct emphasis on welding technology. This event will be covered accordingly in WELDING AND CUTTING.

However, recent political developments with the war in Ukraine and the worldwide reactions to it are fuelling a new and unfortunately all too justified uncertainty. To what extent this may affect not only the state of the economy and thus also future trade fair events, but also our entire life situation, is currently completely up in the air. We all sincerely hope for an end to the horrible warfare and a return to peaceful negotiations. Until then, much remains uncertain.

Dietmar Rippegather
Editor-in-Chief

ITSC2022
INTERNATIONAL THERMAL SPRAY
CONFERENCE AND EXPOSITION

Photo: © vichie81 – stock.adobe.com

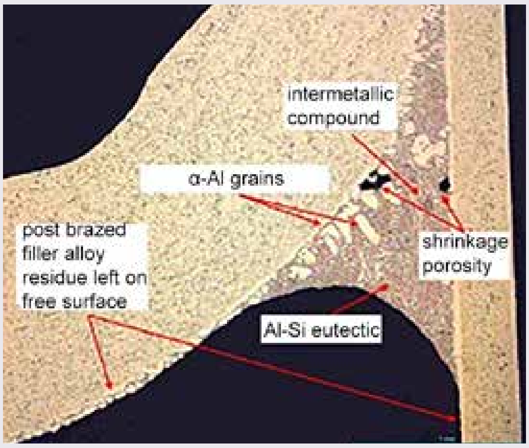
Photos: Mack Brooks Exhibitions

New data from ITU suggest "COVID connectivity boost", but the world's poorest being left far behind. (Picture: ITU)

9

Production is automated to the greatest possible extent and exclusively controlled from a control room.

14



Metallographic structure of a tube to header joint – etched with hydrofluoric acid (HF).

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WELDING AND CUTTING
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Technical journal for welding and allied processes

Technical journal for welding and allied processes of
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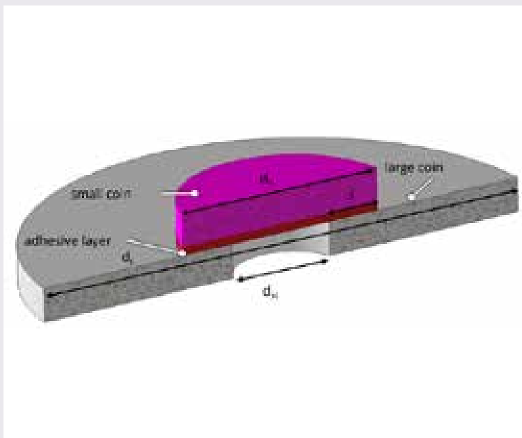
and the Institut de Soudure, Paris

Produced in Collaboration between

The ITSC 2022 in Vienna will offer a full spectrum of coating solutions. (Picture: DVS) 38

"µ-Habitat" product manufacture process framework. 43



Sectional view of a coin specimen for measuring hydrogen tightness. (Source: ifs TU Braunschweig) 52

What is required for a true digital transformation in materials science research and development (R&D)?

Digital transformation is a buzzword in almost every sector; materials science and chemistry research and development (R&D) is certainly no exception. The prospects are, of course, very attractive, but the reality is far harder. The status of this transformation, the enabling solutions and those unresolved pain points are all examined below.

The heart of this R&D transformation is the field of materials informatics; this is a data-centric approach to materials R&D that builds data infrastructures and leverages machine learning solutions. IDTechEx has released a new version of their leading report on the topic, "Materials Informatics 2022-2032" (www.IDTechEx.com/MaterialInformatics), which provides a comprehensive commercial overview of the field.

There are three main considerations to truly enable a digital transformation in materials science R&D:

- data entry and management,
- the physical or computation experimental data and
- AI-driven screening and analysis.

Data entry and management

This is the genesis of any digital transformation and shows quite how far chemistry and materials science must go. Before you get anywhere, you need to have your data electronically available in suitable formats, even today the jump to electronic lab notebooks and overcoming data silos is not widely employed. There are plenty of solutions out there, but until this is tackled the transformation can only go far, as Sasha Novakovich, CEO of Alchemy Cloud, stated to IDTechEx:

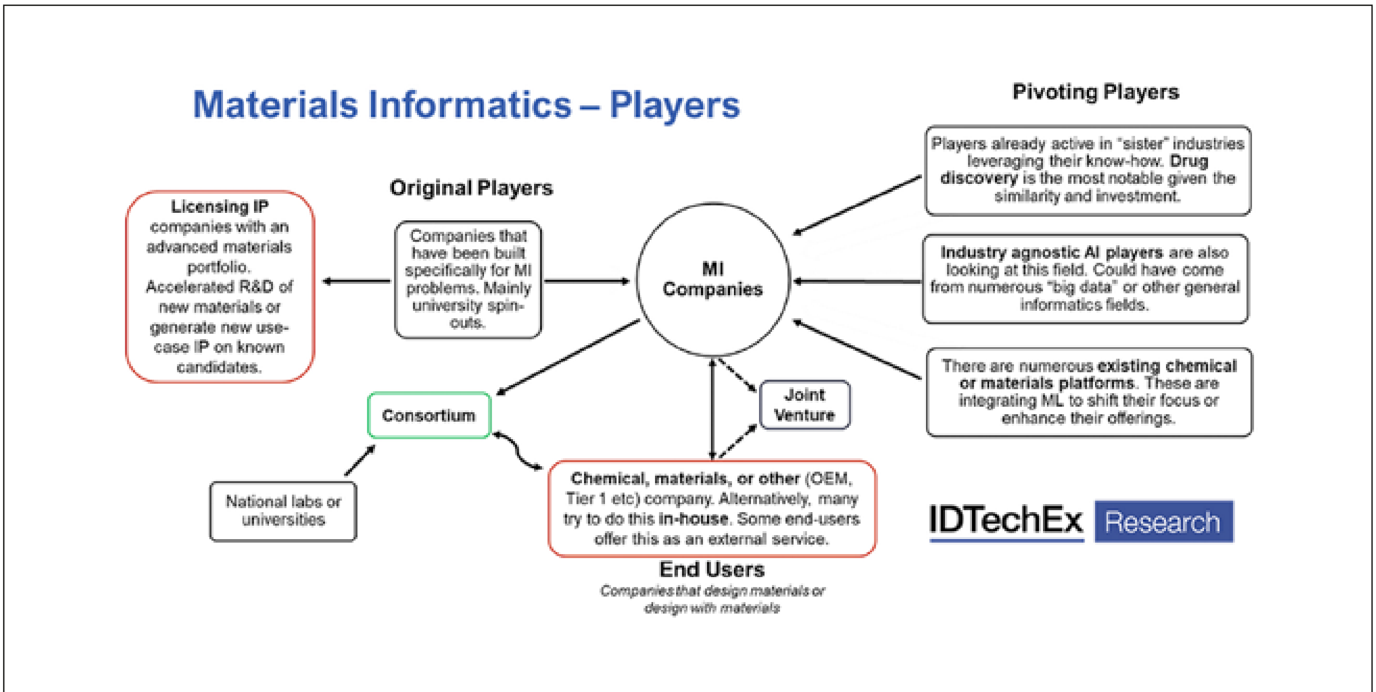
"For years firms have lauded the benefits of Artificial Intelligence (AI) in material science: accelerated discovery, faster derivative product development and streamlined material compatibility. The dirty secret you likely didn't hear: none of these outcomes are possible with mismanaged, unstructured data. If you bought into AI thinking that decades' worth of stitched together Excel files were the magic wand, you're likely on a longer – and more expensive – journey than required. From day 1, driven by our insight that better data quality yields better predictive accuracy, Alchemy has been building software solutions to optimise for AI-ready data. AI-ready, in the context of the lab, means data that is automatically validated, formatted, labeled based on your custom ontology and connected to other data in real-time without the need for chemists to do anything other than their routine work."

Many notable companies have made this change, most notably in Japan, with some even going back to get their extensive historical data in a usable format.

Internal data is an essential part of any companies IP, but there is also the ability to leverage external data sources within a digital approach to R&D. Public and private data repositories are increasingly common that vary from being highly specific to very broad. In addition, there are many consortia being established to pool knowledge and establish best practices even amongst traditional competitors. A prime example is the Materials Open Platform (MOP) which is a joint effort in establishing a polyolefin database and involves data sharing between Mitsubishi Chemical, Sumitomo Chemical, Asahi Kasei, Mitsui Chemicals and with NIMS at its core.

Physical and/or computational experimental data

How the data is stored is important, but materials informatics is nothing without the data itself. One routine challenge is sparse, high-dimensional, biased and noisy data. Combinatorial chemistry, high



Summary of different Materials Informatics players. (Source: "Material Informatics 2022-2032") throughput screening and general laboratory automation has become much more common for physical experiments with numerous tailored instruments available. However, this is still not mature and in many cases still an overly manual process that results in scientists carrying out repetitive tasks rather than applying their domain expertise. There are still innovations arising to tackle this solution, as shown by a spin-out from Northwestern University in the USA. Professor Chad Mirkin stated to IDTechEx that:

"In the race to bring AI to materials discovery, it is all about the size and quality of the datasets. Stoicheia, with its proprietary 'Meglibrary' technology (high-density chips that contain upwards of billions of positionally-encoded materials) and companion screening tools, is uniquely positioned to mine and monetise the materials genome."

Modifying the synthetic composition or process is essential but characterising and quality control also become key pieces of the puzzle that must not become a bottleneck. Computational chemistry and materials science has come a long way in the past decade and can provide key insights and data inputs to this data-centric approach. The challenge is the speed and degree of complexity that can be achieved with current computing technology, it is no surprise that chemistry is considered as one of the key applications for quantum computers. The modeling field continues to advance at pace, typified by the likes of OTI Lumionics who are initially applying their approach to advanced materials for OLED displays. Dr Michael Helander, President and CEO, stated to IDTechEx:

"The key bottleneck in materials informatics, regardless of the approach, algorithms or AI used, is access to large high-quality datasets, which is typically lacking in chemistry and materials science. Highly accurate simulations of chemical and materials properties are thus required to accelerate the digital transformation of these fields. Quantum computing techniques, which offer a path to high accuracy simulations in reasonable compute time, are therefore an essential element of future materials informatics roadmaps."

AI-driven screening and analysis

The third piece of the equation is the one that grabs the headlines, using artificial intelligence in R&D to drive the screening, guide experimentation and enhance the analysis. Machine learning can be used in several ways, it can be looking to optimise many multi-variable properties, it can be in learning new structure-property relationships or virtual screening for a desired candidate.

A wide range of bespoke supervised and unsupervised learning techniques have been deployed and although there are success stories, many are tackling the same challenging data problems. Two central themes arise across many approaches when handling challenging materials datasets, understanding the uncertainty in your model and leveraging domain knowledge. There are numerous emerging companies offering materials informatics platforms, one of the most prominent is Citrine Informatics and their CEO, Greg Mulholland, stated to IDTechEx that:

"At Citrine, our approach to AI is tailor-made for materials and chemicals. We know that our customers don't have enormous volumes of structured data like big tech companies, and often their data is sparse or incomplete, so we've developed a modeling approach that leverages uncertainty quantification for each prediction and allows our customers to incorporate their scientific knowledge into the modeling process in the form of analytical relationships and materials-specific descriptor libraries. These capabilities, plus 'no-code' AI model creation and deployment, allow our customers to develop new materials up to 98% faster than traditional product development approaches."

This problem is very different to the deep learning advancements many envisage when considering autonomous cars or search engines. Certain examples do have access to reasonable datasets and more known inputs, but this is not the case for most of the real-world problems and is perceived as an insurmountable barrier. Intellegens is another company tackling this problem for numerous sectors, Steven Warde commented on this problem:

"To fully leverage this technology there is a perception that vast amounts of data will be required. However, in the real world data is often limited and of poor quality, especially in industrial or experimental settings. Whilst many organisations are moving ahead with digitalisation strategies to collect and manage this data in an attempt to improve the quality, there are options for working with the limited data they do have now. Using techniques that clearly highlight uncertainty will enable insights from available data no matter how small, using models from limited data to help guide which data is most important to collect next and merging with other information sources, internal or external, will add more understanding to the models."

Interestingly both Citrine Informatics and Intellegens have partnered with large companies primarily in engineering software in Siemens and Ansys, respectively. This shows the capability of these processes progressing towards inverse design and reversing the relationship between design engineers and their material suppliers. It should also be noted that this analysis does not have to stop at physical properties, but could be content with supply chain variations, toxicity and price.

So, what's the end goal?

The ideal goal is where this transformation is not discussed and instead, a materials informatics solution is any scientist's toolkit. That is a long way to go, but not starting that journey could be catastrophic as more agile and disruptive R&D divisions emerge.

One idealised solution is a way in which all three solutions are combined into a self-driving or autonomous laboratory. There are a handful of exciting university demonstrations, but this is now starting to even come into the commercial sphere. The leading start-up at the forefront here is Kebotix, and their CEO, Dr Jill Baker, stated to IDTechEx that:

"Our secure cloud and data technologies coupled with AI, machine learning, physical modeling and automation enable Kebotix's revolutionary autonomous, 'self-driving' lab to deliver an efficient, optimised R&D process – something I like to call 'Fast R&D @Scale'. By discovering novel materials quicker, Kebotix offers inventive solutions that create new, disruptive chemistries and materials at a rapid pace while reducing costs. Even better, our sustainable solutions are addressing some of the world's most urgent needs."

Where are the early successes?

Many will read this article and think this is great, but how will they get involved? There are numerous strategic approaches to end-users and a range of business models being deployed by external providers, each with their respective strengths and weaknesses. As seen, this is an attractive place for young companies; not only is there plenty of interest in AI but rather than requiring considerable funds and taking 10+ years to generate any notable revenue to bring a new material to market, just a small amount of computing power and a start-up can start bringing in consulting revenue overnight or progress towards a MI subscription platform.

Lots of end-users are looking to build these capabilities in-house and there are even external companies, such as Enthought, looking to support this training. Many of these companies have been highlighted throughout the article and a full comprehensive list is available in the market report, but a more recent trend has been in companies more focussed on specific applications such as Matmerize and Polymerize (for polymers) and Aionics (for battery electrolytes).

The other key question that arises is: Where are the demonstrated success stories that have shown a clear value-add? Now, this is always challenging to prove, and despite claims from early adopters of rapidly reduced research hours and expenditures, a genuine side-by-side comparison is practically never seen. IDTechEx have reported on these case studies and believe that given the status of the technology the most promising fields are in thin film materials and liquid formulations, the latter is certainly where most of the commercial activity is seen in polymers, coatings, lubricants and electrolytes.

That is not to say we will not see increasing results and adoption elsewhere, there are some early wins in metal alloys, heterogeneous catalysts, superconductors and many more. Rather than considering the material families, it can also be beneficial to look at problems that this has seen success in such as screening for a band gap, mapping a phase diagram, or reducing your computational load.

The digital transformation of chemistry and materials science R&D is behind the times and in many ways only just waking up to all the technology advances the first two decades of the 21st century have offered. This will change a lot in the next two decades as the revolution begins. (According to press information from IDTechEx; www.IDTechEx.com)

EWF prepares personnel qualification for powder bed fusion processes

Additive manufacturing – also known as 3D printing – has an undeniable impact on manufacturing. Additive manufacturing by powder bed fusion with metal is a sustainable alternative compared to traditional forging and manufacturing. EWF – the European Welding Federation (www.ewf.be) is preparing qualification for powder bed fusion processes for all the interested.

Good quality and cheaper products

The speed and quality with which a product is placed on the market is the most important factor for the consumer in today's world. At the same time, the way in which this product is manufactured, the production costs, the time taken to market it, the sustainability of the raw material and energy that is spent are priority elements for any manufacturer. Both elements encompass the life cycle of a product. Both parties, consumer and manufacturer, are looking forward to the same result: good quality and cheaper products.

One of the elements that contributes to the new industrial sustainability, part of industry 4.0, is powder bed fusion (PBF): A 3D printing method that joins powdered material point by point using an energy source, typically a laser beam or an electron beam. It is one of the most common 3D printing techniques used for industrial additive manufacturing. PBF is possible with both metals and polymers. Manufacturers can benefit from substantial freedom of design considering that powder bed fusion presents several viable technologies and materials.

Electron beam manufacturing tends to produce parts with less thermal stress and deformation than laser-based systems. Associated with producing thicker finishes, it can easily manufacture thin-walled components. In addition to reducing large-scale production costs, the technology also allows for the elaboration of customised parts. For example, orthopedic components, in the case of the medical sector or turbochargers in "exotic" cars, with low production numbers. In these cases, it is less expensive to manufacture the part than the tool needed to produce the parts.

Creating training curricula

To answer the needs for qualified personnel in these processes, EWF's International Additive Manufacturing Qualification System (IAMQS) started by creating training curricula for "Powder Bed Fusion – Laser Beam", at the level of engineer and operator, also having a qualification for PBF process designers in general. In this way, it covers the chain of needs in this process.

Due to the bet/demand and advantages associated with PBF with electron beam, the need to create profiles associated with this technology arose. The first need identified was the operator – a profile that aims to train professionals with knowledge and skills to operate PBF-electron beam machines. This qualification was recently released into the system. Soon, the engineer profile for this technology will train professionals with the necessary skills to implement "Powder Bed Fusion – Electron Beam process" in the manufacturing chain assuring the efficient production and post-processing of additively manufactured parts.

Faced with an increasingly diversified sector with a particular need and goals of becoming increasingly independent and sustainable, EWF answers with solutions that satisfy every requirement of today's manufacturing. You can check for your qualification at https://www.ewf.be/qualification/iamqs.aspx. (According to press information from EWF)

2.9 billion people worldwide still offline

New data from ITU suggest "COVID connectivity boost", but the world's poorest being left far behind. (Picture: ITU)

An estimated 37% of the world's population – or 2.9 billion people – have still never used the Internet. The new report "Facts and Figures" (available for free download at https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2021.pdf) from the International Telecommunication Union (ITU), the United Nations specialised agency for information and communication technologies (ICTs), also reveals strong global growth in Internet use, with the estimated number of people who have used the Internet surging to 4.9 billion in 2021, from an estimated 4.1 billion in 2019. This comes as good news for global development. However, ITU data confirm that the ability to connect remains profoundly unequal.

96% of people offline live in developing countries

Of the 2.9 billion still offline, an estimated 96% live in developing countries. And even among the 4.9 billion counted as 'Internet users', many hundreds of millions may only get the chance to go online infrequently, via shared devices, or using connectivity speeds that markedly limit the usefulness of their connection.

"While almost two-thirds of the world's population is now online, there is a lot more to do to get everyone connected to the Internet," said ITU Secretary General Houlin Zhao. "ITU will work with all parties to make sure that the building blocks are in place to connect the remaining 2.9 billion. We are determined to ensure no one will be left behind."

The unusually sharp rise in the number of people online suggests that measures taken during the pandemic – such as widespread lockdowns and school closures, combined with people's need for access to news, government services, health updates, e-commerce and online banking – contributed to a "COVID connectivity boost" that has brought an estimated 782 million additional people online since 2019, an increase of 17%.

What it means for sustainable development

The 2021 edition of "Facts and Figures", ITU's annual overview of the state of digital connectivity worldwide, shows the number of Internet users globally growing by more than 10% in the first year of the pandemic. This was by far the largest annual increase in a decade. Strong growth since 2019 was largely driven by increases in developing countries, where Internet penetration climbed more than 13%. In the 46 UN-designated Least Developed Countries (LDCs), the average increase exceeded 20%.

"These statistics show great progress towards ITU's mission to connect the world," said Doreen Bogdan-Martin, Director of ITU's Telecommunication Development Bureau, which oversees ITU's data and analytics work. "But a vast 'connectivity chasm' remains in the LDCs, where almost three quarters of people have never connected to the Internet. Women in LDCs are particularly marginalised, with roughly four out of every five still offline." Many of these 'digitally excluded' face formidable challenges including poverty, illiteracy, limited access to electricity, and lack of digital skills and awareness.

"Digital solutions would be needed to re-energise sustainable development and help put countries back on track to meet the UN Sustainable Development Goals (SDGs) for 2030," Bogdan-Martin added.

"Unfortunately, the communities identified in the 2030 Agenda as most at risk of being left behind are the very same communities now being digitally left behind."

Key report findings

The digital gender divide is narrowing globally, but large gaps remain in poorer countries.

Globally, an average of 62% of men use the Internet compared with 57% of women. Although the digital gender divide has been narrowing in all world regions and has been virtually eliminated in the developed world (89% of men and 88% of women online) wide gaps remain in Least Developed Countries (31% of men compared to just 19% of women) and in Landlocked Developing Countries (38% of men compared to 27% of women).

The gender divide remains particularly pronounced in Africa (35% of men compared to 24% of women) and the Arab States (68% of men compared to 56% of women).

The urban-rural gap, though less severe in developed countries, remains a major challenge for digital connectivity in the rest of the world.

Globally, people in urban areas are twice as likely to use the Internet than those in rural areas (76% urban compared to 39% rural). In developed economies, the urban-rural gap appears negligible in terms of Internet usage (with 89% of people in urban areas having used the Internet in the last three months, compared to 85% in rural areas), whereas in developing countries, people in urban areas are twice as likely to use the Internet as those in rural areas (72% urban compared to 34% rural). In the LDCs, urban dwellers are almost four times as likely to use the Internet as people living in rural areas (47% urban compared to 13% rural).

A generational gap is evident across all world regions.

On average, 71% of the world's population aged 15-24 is using the Internet, compared with 57% of all other age groups. This generational gap is reflected across all regions. It is most pronounced in the LDCs, where 34% of young people are connected, compared with only 22% of the rest of the population.

Greater uptake among young people bodes well for connectivity and development. In the LDCs, for example, half of the population is less than 20 years old, suggesting that local labour markets will become progressively more connected and technology-savvy as the younger generation enters the workforce.

ITU continues monitoring the world's evolving digital divide

ITU figures also point to a glaring gap between digital network availability versus actual connection. While 95% of people in the world could theoretically access a 3G or 4G mobile broadband network, billions of them do not connect.

Affordability of devices and services remains a major barrier. The widely accepted target for affordable broadband connectivity in developing countries sets the cost of an entry-level mobile broadband package at 2% of gross national income (GNI) per capita. Yet in some of the world's poorest nations, getting online can cost a staggering 20% or more of per capita GNI.

Lack of digital skills and an appreciation of the benefits of an online connection is another bottleneck, compounded by a lack of content in local languages, as well as by interfaces that demand literacy and numeracy skills that many people do not possess. (According to press information from ITU; www.itu.int)

Global exhibition industry: UFI announces themes for 2022 Awards

UFI, the Global Association of the Exhibition Industry with headquarters in Levallois-Perret near Paris/France (www.ufi.org), has launched the 2022 UFI Awards, designed to acknowledge and honour best practices and outstanding activities across the industry. This prestigious award programme, globally recognised for more than a decade, is open to exhibition organisers, venue operators and service providers. Participants are encouraged to enter their best practice cases across five categories:

- Marketing,
- Industry Partner,
- Digital Innovation,
- Operations & Services,
- Sustainable Development.

Since the exhibition industry took a hit like never before when the COVID-19 pandemic hit, 2021 has seen an accelerating comeback for the exhibition industry in more and more regions across the globe. Throughout this, the industry is showing its adaptability to accommodate changing conditions on the road towards a post pandemic 'new normal'.

"Through the UFI awards, we can provide our members and the industry with a double win every year: The winners receive global recognition from what has become the most reputable global exhibition awards scheme. And the industry benefits from many best industry practices being shared," says Kai Hattendorf, UFI's Managing Director and CEO.

The entry deadline for all categories is 21 March 2022. Winners in each category will receive their awards during an official ceremony at the UFI Global Congress 2022, in

Muscat, Oman, scheduled for 14-17 November 2022. They will also have the opportunity to present their projects at the event. Winning entries will be displayed on the UFI website and will gain significant coverage in major international tradeshow publications.

Entries should reflect the theme of each category, decided upon by UFI Working Groups – industry experts who manage and lead the UFI Awards. The awards and themes for 2022 are:

- **Marketing Award:** The best marketing strategy in a changing exhibition world,
- **Industry Partner Award:** Success stories: Alliances shaping the future of the exhibition industry
- **Digital Innovation Award:** How does your Digital Innovation support physical events?
- **Operations & Services Award:** How to get back in operations with our services & providers in uncertain times
- **Sustainable Development Award:** Best carbon emissions reduction initiative

The UFI Awards are open to both UFI members and non-members. There is no participation fee. The 2021 Award winners as well as more information about the UFI Awards can found at www.ufi.org/awards. (According to press information from UFI)

Climate failure and social crisis as top global risks 2022

Climate risks dominate global concerns as the world enters the third year of the pandemic. According to the "Global Risks Report 2022", published by the World Economic Forum (https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2022.pdf), while the top long-term risks relate to climate, the top shorter-term global concerns include societal divides, livelihood crises and mental health deterioration. Additionally, most experts believe a global economic recovery will be volatile and uneven over the next three years.

Create policies that manage risks and shape the agenda for the next years

Now in its 17th edition, the report encourages leaders to think outside the quarterly reporting cycle and create policies that manage risks and shape the agenda for the coming years. It explores four areas of emerging risk: cybersecurity; competition in space; a disorderly climate transition; and migration pressures, each requiring global coordination for successful management.

"Health and economic disruptions are compounding social cleavages", said Saadia Zahidi, Managing Director, World Economic Forum. "This is creating tensions at a time when collaboration within societies and among the international community will be fundamental to ensure a more even and rapid global recovery. Global leaders must come together and adopt a coordinated multistakeholder approach to tackle unrelenting global challenges and build resilience ahead of the next crisis."

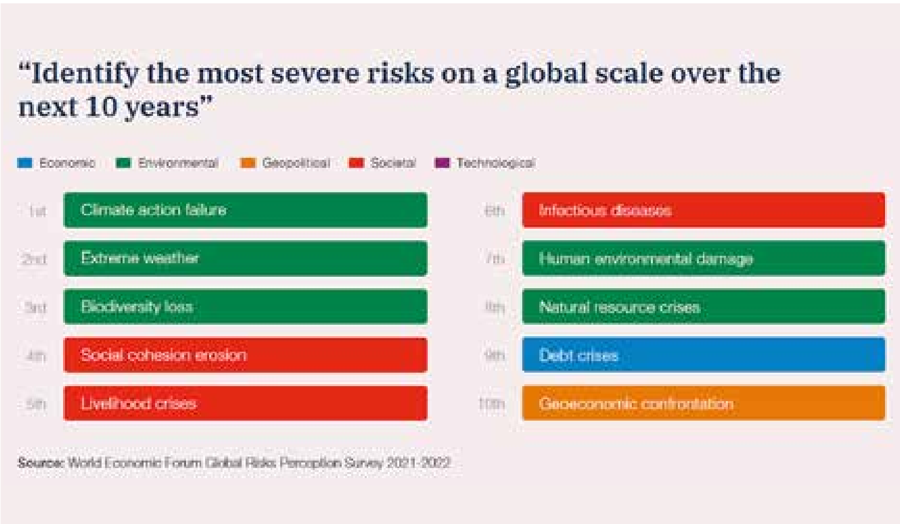
Sophisticated cyber risk management plans needed

Carolina Klint, Risk Management Leader, Continental Europe, Marsh, said: "As companies recover from the pandemic, they are rightly sharpening their focus on organisational resilience and ESG (Environmental, Social and Corporate Governance) credentials. With cyber threats now growing faster than our ability to eradicate them permanently, it is clear that neither resilience nor governance are possible without credible and sophisticated cyber risk management plans. Similarly, organisations need to start understanding their space risks, particularly the risk to satellites on which we have become increasingly reliant, given the rise in geopolitical ambitions and tensions."

Peter Giger, Group Chief Risk Officer, Zurich Insurance Group, said: "The climate crisis remains the biggest long-term threat facing humanity. Failure to act on climate change could shrink global GDP by one-sixth and the commitments taken at COP26 are still not enough to achieve the 1.5°C goal. It is not too late for governments and businesses to act on the risks they face and to drive an innovative, determined and inclusive transition that protects economies and people."

The report closes with reflections on year two of the COVID-19 pandemic, yielding fresh insights on national-level resilience. The chapter also draws on the World Economic Forum's communities of risk experts – the Chief Risk Officers Community and Global Future Council on Frontier Risks – to offer practical advice for implementing resilience for organisations.

The "Global Risks Report 2022" has been developed with the invaluable support of the World Economic Forum's Global Risks Advisory Board. It also benefits from ongoing collaboration with its strategic partners, Marsh McLennan, SK Group and Zurich Insurance Group, and its academic advisers at the Oxford Martin School (University of Oxford), the National University of Singapore and the Wharton Risk Management and Decision Processes Center (University of Pennsylvania). (According to press information from World Economic Forum; www.weforum.org)



PLEASE NOTE: Due to the worldwide spread of the Coronavirus, numerous events have been cancelled or postponed. This table shows the status as of February 2022. All information is subject to change due to the dynamic situation. For any updates please check the indicated websites of the events' organisers.

Conferences and Exhibitions

24.04.-29.04.2022	Munich/Germany	**"Laser World of Photonics" – 25th trade fair for components, systems and applications of photonics** Information: Messe München, Internet: www.world-of-photonics.com/en/
03.05.-05.05.2022	Monterrey/Mexico	**"Fabtech Mexico" – International Metal Forming, Fabricating, Welding and Finishing Event** Information: Fabtech, Internet: mexico.fabtechexpo.com
04.05.-06.05.2022	Vienna/Austria	**"ITSC 2022" – International Thermal Spray Conference and Exposition** Information: DVS, Internet: www.dvs-ev.de/itsc2022
04.05.-06.05.2022	Aachen/Germany	**"AKL'22" – 13th International Laser Technology Congress** Information: Fraunhofer ILT, Internet: www.lasercongress.org
10.05.-13.05.2022	Jönköping/Sweden	**"Elmia Welding & Joining Technology"** Information: Elmia AB, Internet: www.elmia.se/en/Welding/
11.05.-12.05.2022	Warsaw/Poland	**"Join Trans 2022" – 6th European Conference on Joining and Construction of Railway Vehicles (Hybrid Event)** Information: SLV Halle, Internet: www.slv-halle.de/en/tagungen/fachtagungen/join-trans
08.06.-09.06.2022	Online	**"ICWAM 2022" – Third International Congress on Welding, Additive Manufacturing and Non-destructive Testing** Information: Institut de Soudure, Internet: https://icwam.com
14.06.-16.06.2022	Toronto/Canada	**"Fabtech Canada" – International Metal Forming, Fabricating, Welding and Finishing Event** Information: Fabtech, Internet: canada.fabtechexpo.com
20.06.-24.06.2022	Düsseldorf/Germany	**International Trade Fairs "wire 2022" and "Tube 2022"** Information: Messe Düsseldorf, Internet: www.wire-tradefair.com / www.tube-tradefair.com
21.06.-24.06.2022	Düsseldorf/Germany	**"METAV" – 22nd International Exhibition for Metalworking Technologies** Information: Messe Düsseldorf, Internet: www.metav.com
21.06.-23.06.2022	Aachen/Germany	**"LÖT 2022" – 13th International Conference on Brazing, High Temperature Brazing and Diffusion Bonding** Information: DVS, Internet: www.dvs-ev.de/loet202
21.06.-23.06.2022	Stuttgart/Germany	**"LASYS" – International Trade Fair for Laser Material Processing** Information: Messe Stuttgart, Internet: www.messe-stuttgart.de/lasys/en/
17.07.-22.07.2022	Tokyo/Japan	**The 75th IIW Annual Assembly & International Conference** Information: Japan Institute of Welding, Internet: www.iiw2022.com
04.09.-07.09.2022	Graz/Austria	**13th International Seminar "Numerical Analysis of Weldability"** Information: Graz University of Technology, Internet: www.tugraz.at/events/seggau/
08.09.-09.09.2022	Miskolc/Hungary	**4th International Conference on Vehicle and Automotive Engineering** Information: University of Miskolc, Internet: http://vae2022.uni-miskolc.hu

ADVANCED THERMAL SPRAY SYSTEM

PLASMA SPRAY SYSTEM

MASS FLOW CONTROLLED
PLASMA SPRAY SYSTEM
Model - AP-2700

AP-2700 FEATURES :-

- Data logging.
- Recipe selection.
- Remote diagnostics.
- Slave / master / manual modes.
- Meet Requirement of Industry 4.0.
- Touch screen mass flow controlled.
- 80kw Standard, 120kw Optional Power Capacity.

MASS FLOW VIEW
PLASMA SPRAY SYSTEM
Model - MPS-80

MPS-80 FEATURES :-

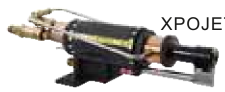
- "CE" Approved.
- PLC Controlled.
- Auto & Manual Modes.
- Support 2 Powder Feeder Operation.
- Can Be Integrated With Chiller, Door, External Interlock.

HIGH VELOCITY OXY FUEL SPRAY SYSTEM

Model - AK-2700

AK-2700 FEATURES :-

- Data logging.
- Recipe selection.
- Remote diagnostics.
- Slave / master / manual modes.
- Meet Requirement of Industry 4.0.
- Touch screen mass flow controlled.

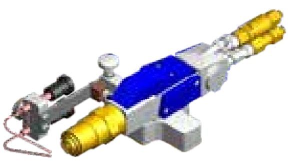


XPOJET-5250

XPOJET-5000

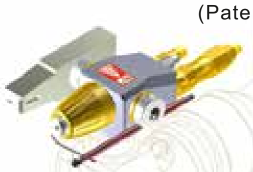
MJP-6000

FLAME SPRAY SYSTEM



POWDERJET-86 A

CERAJET GUN
(Patent Applied)



CONTROL PANEL, HV-3100

- Massflow controlled.
- Auto Ignition.
- Built in powder feeder.

SINCE 1967

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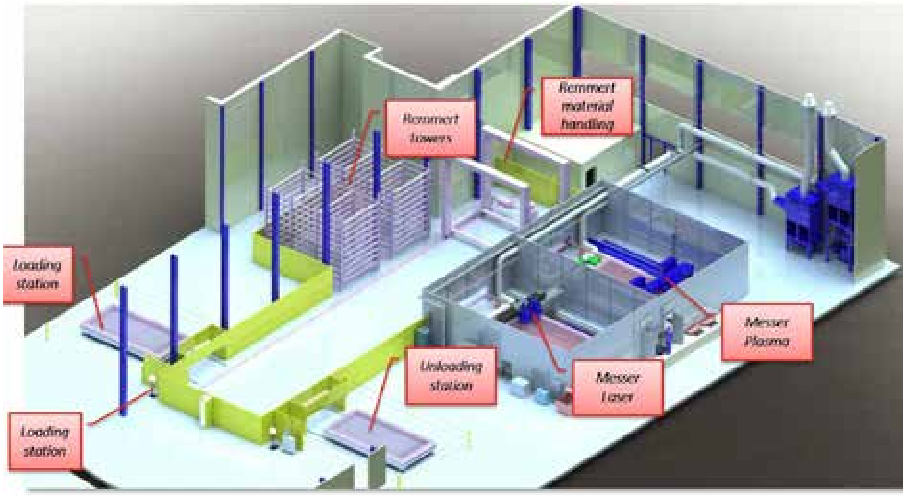
Industry 4.0: Dutch steelworker on a digital journey



Overview of the automation system in the production hall with Messer machines and Remmert material handling system. (All photos: Messer Cutting Systems)

Bart Kroesbergen, Managing Director at steel service centre Joop van Zanten in Veenendaal, the Netherlands is a visionary. In ten years at the latest, the entire production should be automated. "To achieve this, we have to break with standards and need courageous partners who can join us on the extraordinary journey towards Industry 4.0," he claims. This report shows why Messer Cutting Systems became the right travel partner and what "travel experiences" the team had.

The dawn of a new age

The family-owned company Joop van Zanten has been a full-service provider for plasma and oxyfuel cutting of steel since 1966. The steel service centre works in the segment from 2 to 350 mm including almost all finishing operations such as press braking, straightening, blasting, machining and welding. With over 40 employees, a turnover of more than Euro 12 million and a modern designed floor space of 10,000 m², the company is now one of the most modern in the Netherlands.

"When I joined the company in the summer of 2018, Joop van Zanten was a stable but very traditional company that focused on thick sheet metal and would certainly have survived with that for a while," recalls Bart Kroesbergen. "But in order to stand up to the high-cost pressure of the Asian markets, to compensate for the lack of skilled workers in the future and to meet the customers' demands for fast and high-quality one-stop shopping, a consistent break with the existing situation was necessary."

It soon became clear that individual actions, such as a new ERP system or optimising the hall layout, did not bring the desired strategical progress. For Kroesbergen, this meant that only the automation and digitalisation of the entire production process, including the business processes involved, could be an adequate solution. The idea of Joop van Zanten's "journey" to Industry 4.0 was born. The technology change from a traditional job shop to a high-tech company with completely automated 24/7 production within ten years was the new ambitious goal.

Too far ahead of the times

Having a vision is one thing, but finding the right partners is quite another. "We had to realise in many conversations that the providers of machine or software systems were stuck at the same, in our opinion, traditional approach as the entire industry. In terms of technology, they were not capable of embarking on the digitalisation journey with us. They believed our vision of fully automated production, for thicker steel up to 40 mm and larger plates up to 6 m × 3.5 m, was impossible to implement," Kroesbergen sums up. Initial approaches with existing suppliers failed completely until Messer Cutting Systems from Groß-Umstadt, Germany was brought on board.

For years, Messer Cutting Systems had been a set supplier of cutting machines with complete solutions from a single source, including maintenance, service and software. Due to the good relations with Messer's local staff in the Benelux countries, initial exploratory talks were held in which the company presented itself as innovative and flexible.

Production is automated to the greatest possible extent and exclusively controlled from a control room.

The "PowerBlade" fibre laser machine is characterised by its dynamic performance and accuracy.

Messer was surprised by the nature and scope of the enquiry, as no customer had previously requested such a solution. “We wanted a supplier capable of delivering the full range of specialised machine equipment. This includes state-of-the-art technologies for laser and plasma processes as well as software and material handling experience,” says Kroesbergen. “Above all, there was a clear willingness to go along the journey and do everything possible to find an innovative and working solution with us.”

After extensive discussions and meetings with internal specialists, Messer Cutting Systems offered a completely new automation system that was previously unique to the manufacturer and its partners. “It was clear to all of us from the start that we were in for a long journey that would require staying power, a lot of energy and a high level of concentration,” says Bas Sanders von Well, Business Unit Manager Benelux at Messer Cutting Systems. “After all, this was a project that we admittedly had not yet implemented to this extent and degree of innovation.”

Integration as a key component

The core of the solution is the software and 4.0 intelligence that links everything together. In workshops, a team with ERP manufacturer Ridder, the ISD Group as supplier of the 2D/3D CAD software “HiCAD” and Messer Cutting Systems with the digitalisation solutions from MesserSoft defined the integration of the various IT solutions. The goal was a process that maps and automates cutting and further processing in one workflow. The superordinate unit is the Ridder “IQ” ERP system. “HiCAD” functions as the CAD/CAM environment. MesserSoft’s “OmniFab” Software Suite digitalises the processes as an integration and data refinement tool.

“Integration was one of the most elementary steps towards digitalisation and complete automation. If we can implement the automation path consistently, the rest is as easy as baking cheesecake,” Kroesbergen says with a wink. “OmniFab” is thus the central element of automation. The suite connects the various software systems, the cutting machines and the material handling system via various interfaces.

Digital transformation

As soon as Joop van Zanten receives step files from the customers with the 3D models of the components to be manufactured, “HiCAD” checks and analyses how the component is to be manufactured. The software recognises whether the components are to be cut, edged, drilled or milled. The file is then imported into the design and nesting software “OmniWin” via “OmniFab ERP Connect”. “OmniWin” calculates the machining time with cutting times, drilling times and material consumption and sends back the results to the ERP system, which calculates the price from the data.

The “OmniMat” cutting machine equipped with the “Skew Delta” plasma bevel unit for weld preparation.

This fully integrated analysis and calculation software structure makes it possible to not only calculate the cost price for an offer but also the production preparation and machine programming has been done in the offer phase. If customers agree with the conditions, all preparations including planning are done and the production process can start immediately. This saves a lot of preparation time and creates the possibility for quick delivery.

If an order is placed, the data runs again via “OmniFab ERP Connect” to “OmniWin”, where the nesting plan is created. “OmniFab” generates the job from this, takes over the order control, process data selection and the automated production as well as loading and unloading processes. On the two new Messer machines, the scheduled jobs are displayed at the loading station. Here, the operator selects the job to be cut, brings the appropriate panel to the loading station, which moves the panel on a shuttle to the storage tower. As soon as the scheduled machine is available, “OmniFab Material Flow” automatically steers the matching pallet to the machine and initiates the cutting process. After cutting, the pallet then automatically returns to the tower.

“OmniFab” reports to the ERP system all the information about the nesting plan and confirms that it has been successfully cut. At the unloading station, the operator sees all the finished jobs and requests them from the tower for unloading at the unloading station. From there it goes to further processing such as blasting, sanding, edging, etc.

Everything under control

Today, production is automated to the greatest possible extent and is controlled exclusively from a control room. The plant operators always have an overview of the entire plant, including an interior view of the enclosed machines, via control monitors. In addition to the transmission of

Both machines are equipped with a drilling unit including 24 tool changer.

the machine work screens, there is also an “OmniWin” programming station for nesting as well as for order, material and job management.

“This way we always have an up-to-date overview of which jobs need to be cut, what is currently happening on the machines and which jobs have been cut and can be cleared,” explains Johnathan Jacobus, head of purchasing and project manager for automation at Joop van Zanten.

At the loading station, a control terminal reads out the required material, which is loaded onto the pallet and fed into the process. At the unloading station, an operator uses a tablet to monitor the finished cut panels on the transport shuttles so that they can be removed. Via the tablet, he queries information about the individual components, books good and bad parts into the system and confirms manual work. The operating terminals directly at the machine housing are now only used for maintenance or testing purposes and for setting complex new programmes.

Investment in the latest cutting technology

An important part in the digitalisation process are two new machines with the latest cutting technology: a “PowerBlade 6500” with laser, 6 KW bevel head, drilling unit with 24 tool changers and LNC nozzle changer, as well as an “OmniMat 6500” with 2* HiFocus 360I, Skew Delta plasma bevel head, OmniScript and drilling unit with 24 tool changers.

With the fibre laser technology, powerful drives, precise linear guides in both longitudinal and transverse directions and a multifaceted bevel head, the “PowerBlade” is equipped for a wide range of applications. As well as vertical cuts, a wide range of bevel cuts can be combined in one part, for example to produce optimum weld seam preparations all that in one operation.

The “PowerBlade” is characterised by dynamic performance and accuracy. With working widths of over 4 m and track lengths up to 50 m and more, the laser cutting machine is predestined for large format plates. The fibre laser is characterised by a high degree of efficiency as well as a robust and durable design.

“OmniMat” is a large size CNC cutting machine with a heavy-duty structure and multi axis control, suitable for a wide field of applications and complicated cutting jobs. Whether oxyfuel, underwater or dry plasma, whether vertical or bevel cutting or with drilling, the “OmniMat” is the ideal solution for large working areas and tough production conditions. A number of different tools are available, e.g. marking tools and drilling devices, strip cutting device, triple or rotating triple torch and plasma bevel unit.

Bart Kroesbergen, Managing Director, Joop van Zanten (left) and Matthias Breitwieser, Manager Advanced Engineering Global R&D, Messer Cutting Systems GmbH (right).

Excellent teamwork

The overall solution is characterised by a particularly high level of complexity. Not only was the integration of the software systems, the machines, and the material handling system from Remmert complex. The solution was completed by the large gas tanks from Messer, the gas supply technology from Spectron and the cutting tables from Beuting. Matthias Breitwieser, Manager Advanced Engineering Global R&D from Messer Cutting Systems, therefore took on the role of project manager and coordinated the teams involved until approval in spring 2021.

“We formed a development partnership with Joop van Zanten and learned a lot from each other. Characteristic were the high motivation, perseverance and competence of everyone involved,” Breitwieser sums up. Of course, there were always new challenges and some delays. The Coronavirus also made the work of the teams on site much more difficult. But all topics could be solved through joint commitment.

“It was an exciting journey with a few surprises. We knew that not everything would be perfect immediately. But setbacks have not affected us; they have advanced us. Things are developing and will work in the future,” explains Kroesbergen. Realistic planning and timely countermeasures in the event of developments in the wrong direction are important. Meetings at which the right questions are asked are goal-directing.

“Especially the 3D model of the entire project in the production hall requested by Bart Kroesbergen gave us decisive insights,” Breitwieser recalls. “It allowed us to see much better how we needed to optimally position the machine components, also in terms of cabling and gas supply.”

Far-reaching development

Only in use for a short time, everyone in the company – from sales to work preparation, production to logistics – benefited very quickly from the automation. Routine tasks are completed automatically in a noticeably short time without media disruption and without errors. A production planner monitors two machines simultaneously and becomes the automation controller responsible for the entire system. His tasks thus become more demanding.

Several work steps are completed on one machine. The reduction of logistical steps speeds up the completion of orders. Today, Joop van Zanten is going to a 24-hour production, so that orders can be processed overnight without dedicated personnel and are ready in the storage tower when the factory opens in the morning. Digitalisation has led to a considerable reduction in the overall production throughput times, to greater utilisation of the machines and to lower costs for personnel, logistics and consumables.

Breaking the rules

"We know where we want to be in ten years. To achieve that, we will continue to break existing industry rules and redefine standards if required for our strategical vision," Kroesbergen answers when asked about future developments at Joop van Zanten. "We have proven that cutting speed is not the main issue, but avoiding ways and achieving speed through process integration and optimisation as well as the use of smaller plates. In one shift we process a larger amount of 'raw material,' that is plates, with extremely high flexibility during changeover and minimal time loss. This significantly shortens the total time compared to long large machines. The logistical goal for 2022 is to deliver at least 80% of the orders within 48 hours after ordering."

In the future, he plans a completely integrated shop with all technologies for cutting, machining and material handling of larger parts. This includes system expansion with automated unloading including transport to the next production step, the deburring. Talks with Messer Cutting Systems are already underway. (According to press information from Messer Cutting Systems; www.messer-cutting.com)

"Tight weld-flatness tolerance" secures multiple sales of dual weld-head FSW machines

Just two years after the launch of its range of "Powerstir dual weld-head" friction stir welding machines, UK-based Precision Technologies Group (PTG) from Rochdale, Lancashire (www.holroyd.com) reports achieving double-digit sales of these specially developed FSW technologies for electric vehicle OEMs. Designed specifically for use in the volume production of automotive battery tray floor assemblies from extruded aluminium panels, the company's dual weld-head process is aimed directly at manufacturers of skateboard chassis structures and ensures that a tight weld-flatness tolerance is achieved during battery tray floor construction.

PTG has been a leading name in the manufacture of friction stir welding machine tools for transport applications ever since its "Powerstir" range was launched at the EMO Hannover trade fair some 20 years ago. More recently, however, it has used its considerable knowledge of the FSW process to assist automotive OEMs in producing lightweight, robust and aesthetic components for both battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV).

Even and stable welding process

A tight weld-flatness tolerance, as provided by PTG "Powerstir" dual weld-head machines, is essential to ensure that each EV battery cell sits perfectly level within its housing. The dual weld-head method achieves an even and stable welding process – something that is made possible thanks to PTG's unique 'matched' dual-force control systems and balanced upper and lower head welding parameters. The result is exceptionally stable friction stir welding by both the upper and lower weld heads, producing matched weld seams with balanced heat input. This, in turn, minimises post-weld distortion and equips each welded assembly with a significantly improved flatness tolerance when compared to existing conventional single-side FSW techniques.

As aluminium extrusion lines usually produce panels of 300 mm to 600 mm wide, PTG has also developed a fully automated, high-output "Powerstir" FSW production cell for the rapid friction stir welding of multiple extrusions, to create single structures for fabrication into battery tray floors. These structures are typically up to 2.4 m wide.

"Our dual weld-head FSW techniques, whereby both sides of an extrusion are welded simultaneously, not only remove the time-consuming process of lifting and turning extrusions between welds, but also allow for equal heat dispersion which results in minimal distortion," comments PTG sales director, Mark Curran. "In the PTG "Powerstir" dual weld-head FSW process, typically 4 to 12 individual child-part extrusions are brought together for assembly. Following gantry loading, each extrusion is automatically positioned and clamped ready for friction stir welding, after which the partially completed vehicle component is automatically repositioned, ready for the next panel to be welded in place. ►

PTG "Powerstir" friction stir welding machine (Photo: PTG Holroyd)

Reducing vehicle weight

"In addition to providing automotive OEMs with a state-of-the-art means of joining metals and achieving extremely high-strength results, it is also important to consider that in many instances, the use of friction stir welding also allows for reduced wall thickness – an important aspect in reducing vehicle weight," he adds. "As the friction stir welding process generates very little heat, the crystalline structure of the metal remains unchanged, retaining its original strength. There is no need for inert gas, no need for heat-treating post weld, and no requirement for additional surface finishing."

PTG is widely considered to be a leader in the development of FSW technologies for transport applications. Organisations involved in the manufacture of aerospace components and the production of aluminium carriage panels for high-speed trains were among the first to recognise the benefits of "Powerstir" friction stir welding. Working with 5000 and 6000 Series aluminium alloys and magnesium alloys from 3 mm to 6 mm in thickness, PTG is currently developing new FSW processes for several automotive OEMs.

Through the use of industry standard CNC systems, equipped with PTG "Powerstir" software, data-logging and interpolation technologies, 2D welding – guided by laser tracking – can be carried out on precise tool paths, with force control ensuring consistent welded seams. QR codes are used to identify each extrusion before welding commences. Each completed panel is then DMC coded to identify the panel, for complete and ongoing traceability throughout the manufacturing cycle.

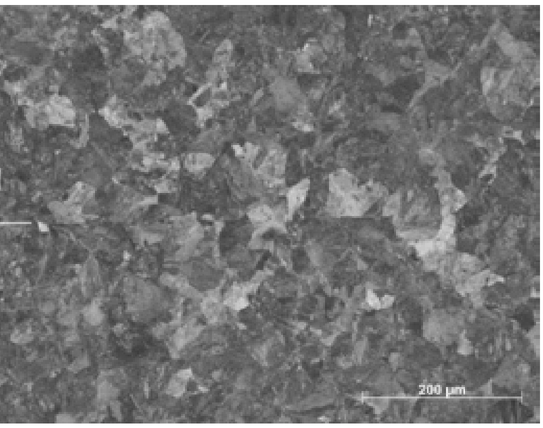
Coolant units and body panels

In addition to building "Powerstir" machines specifically for the production of battery tray floor assemblies, PTG is also creating FSW techniques for the production of coolant units, control box panels and car body panels, as well as body panels and components for commercial vehicles. Through its recently opened friction stir welding research centre, the company is also assisting a number of organisations in developing FSW processes for specific manufacturing challenges.

Friction stir welding combines frictional heat with precisely controlled forging pressure to produce extremely high-strength joints that are virtually defect free. Due to the very low welding temperature, mechanical distortion is practically eliminated, with minimal heat affected zone (HAZ) and an excellent surface finish. Friction stir welding transforms the parent metal from a solid to a plasticised state. This occurs during a process that involves mechanically stirring the materials to be joined together, to form a high integrity, full-penetration welded joint. The "Powerstir" FSW process is effective on flat plates, cylindrical components and even on parts of irregular thickness. Although used primarily for joining aluminium, the "Powerstir" process can also be applied to magnesium, copper, titanium and steel alloys. (According to press information from PTG Holroyd Precision; www.holroyd.com)

Diffusion welding: More variety in the production of tool inserts

A promising joining process for the production of large, segmented tools with large joining surfaces is diffusion welding. The bond between the components is realised by diffusion across the interfaces of two solid bodies under the influence of increased temperatures and compressive forces. The joining surface is dissolved in the process and after joining has the same properties as the base material with high mechanical strength and at the same time reduced susceptibility to corrosion.



Cross-section through the joining zone of a diffusion-welded specimen made of 1.2738 steel: The joining zone is indicated by a white line on the left and is completely dissolved. (Picture: ifw)

In the "Diffmold" project, which was funded by the former German Federal Ministry for Economic Affairs and Energy (BMWi) as part of the Central Innovation Programme (ZIM), the project participants investigated the entire process chain for manufacturing an injection mould using diffusion welding. In the defined project sequence, a demonstrator tool was built for the planned tests. The project consortium around the non-profit KIMW Forschungs-GmbH (KIMW-F) from Lüdenscheid/Germany used a series tool for the production of fan wheels, made of a polypropylene with glass fibre filling (PP GF40), from Formenbau und Kunststofftechnik GmbH (FKT), Triptis/Germany as a sample. In parallel to the design for welding, the tool was also optimised in the design phase using simulation tools with regard to rheology, tempering and warpage behaviour of the component.

Designing a demonstrator mould

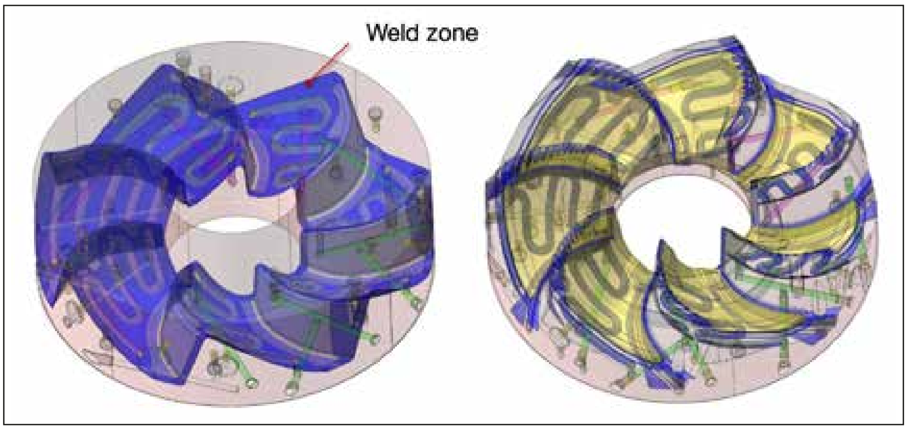
When designing the demonstrator mould, one of the main tasks was to keep the existing interfaces (temperature control connections, number and cross-sections of the temperature control circuits, sprue manifold) usable. In addition, the handling of the components during production also had to be taken into account.

To determine the force distribution at preset welding temperatures, the Günter-Köhler-Institut für Fügetechnik und Werkstoffprüfung GmbH (ifw Jena) developed a simulation model in coordination with the other project partners (Formenbau und Kunststofftechnik GmbH, Gemeinnützige KIMW Forschungs-GmbH and PVA Löt- und Werkstofftechnik GmbH). This model, consisting of press system and demonstrator component, was used to support adjustments and optimisations of the joining surface geometry.

The actual welding was done by the project partner PVA. A diffusion welding system with a pressing area of 900 mm × 1,000 mm, unique in its design, was used for this.

Deformations and the possibility of upsetting the component are shown after the welding process and this information can be used to make further optimisations in the process. The inserts were compressed by the pressing forces so that their thickness was 3 mm less after the welding process.

Testing of the diffusion-welded demonstrator tool was carried out with the same process parameters and identical materials used in series production. The results were impressive: The inserts met all strength requirements and the tempering channels remained absolutely tight under changing pressures and temperatures. In terms of surface quality, the sample parts were indistinguishable from the original parts. A thermography carried out after production showed a homogeneous finish with significantly less distortion of the sensitive fan blades.



Design of the prepress part (left) and the tool insert (right) (Picture: FKT)

Component performance and economic efficiency

The degrees of freedom gained in terms of strength properties and design options, for example by using different steels (1.2083, 1.2343, 1.2738, 1.1730), enable diffusion welding to achieve a high degree of component performance. Especially in areas of the tool where the joining zone comes into contact with the plastic melt, a uniform strength of the material plays an important role, which is achieved by diffusion welding technology.

With the tool demonstrator, the same component quality was achieved as with the series tool. However, the concentricity of the fan wheels could be increased compared to the reference part from the conventionally manufactured tool. The cycle time was also reduced by 10%, which means that production is more energy-efficient and saves CO_2. Compared to the series tool, the tempering channels have a more streamlined design, which allows the cooling water pressure to be reduced. The elimination of fluidic dead spaces virtually eliminates clogging of the cooling channels compared to conventional moulds. This extends the maintenance interval and thus increases productivity in terms of unit costs. The desired goal was thus achieved from an economic perspective.

Vanessa Frettlöh, KIMW Forschungs-GmbH, Lüdenscheid/Germany
and Volker Gogoll, agentur vogomedia, Meinerzhagen/Germany

Finished, diffusion-welded tool insert. (Picture: FKT)

Cloud-based CNC monitoring brought to the shop floor of an aerospace parts manufacturer

CNC machine from the company SNK.

With their 5-axis CNC machines already running 24 hours a day up to 7 days a week, Tech Manufacturing (www.techmanufacturing.com) – a supplier of machined metal parts for aerospace clients such as Boeing, Lockheed Martin, and Bombardier, based in Pennsylvania/USA – looked to Moxa (www.moxa.com), a leader in industrial computing and network infrastructure solutions, for smarter operation and real-time machine performance data. The company's goals were to raise the production capacity, to reduce the lead times for their clients' largest and most urgent orders, and to expand the useful service life of their existing machines. ▸

Tech Manufacturing diagram.

"We needed a better understanding of how our machines were actually performing for us in real-time. Live and historical machine performance data would also help us identify technical or process issues that were detrimental to productivity," said Jerry Halley, Chief Engineer of Tech Manufacturing, and one of the company's 70 employees.

Purchasing additional machines would, of course, be one way to achieve this. But Halley was interested in finding a smarter, more efficient approach that did not require a large capital investment. That "smarter way" was a CNC monitoring system that would collect, analyse and visualise necessary performance metrics. Before taking the next step, however, Halley carefully weighed the productivity gains of such a system against the cost and effort of deployment, especially if it involved a new and unfamiliar server-based IT infrastructure. The ideal system would be easily deployed without specialised IT equipment, knowledge or effort, and would not require repeated software installation, updates or configuration.

New life to older machines

Tech Manufacturing selected Shop Floor Automations (www.shopfloorautomations.com), one of the most prominent systems integrators in North America, to assist with a cloud-based CNC monitoring system. Each of Tech Manufacturing's CNC machines were connected to the existing local area network, so no additional IT infrastructure was required.

For legacy machines that did not have a readily available Ethernet port, Shop Floor Automations provided an easy-to-deploy solution that was developed based on "Moxa NPort W2150A" and "W2250A" wireless device servers that permit communications software to access serial and Ethernet devices over the wireless LAN. Being wireless, the device servers required far fewer cables and the users can roam between several access points. As such, the servers offered an excellent solution for devices that are frequently moved from place to place, as is the case in many factory settings.

Getting machines connected and monitored

"Getting our CNC machines connected and monitored has made it much easier for us to deliver on our clients' build-to-print orders with maximum efficiency and minimum lead time. It is a lot easier to get connected than a lot of people may realise," said Halley.

With the local network connected to the Internet, CNC machine performance data at Tech Manufacturing can now be easily viewed and analysed by cloud-based software such as "Scytec DataXchange" or "Predator Machine Data Collection". Key performance metrics are organised on a visual dashboard so the company's owners and machine operators are able to see exactly how productive each cell is performing, down to the machine level.

With a cloud-based monitoring system, Tech Manufacturing was able to minimise their upfront cost and deployment effort, explained a representative from Shop Floor Automations: "Many clients perceive it to be difficult and expensive to set up a CNC monitoring system. However, with today's cloud-based solutions, you can be set up in less than a day, with almost zero additional IT infrastructure or maintenance effort."

Moxa Device server.

Jerry Halley, Chief Engineer of Tech Manufacturing.

With the system now up and running, a live dashboard has made it easy for Tech Manufacturing to identify critical productivity issues. For example, one immediate finding was that set-up times on certain machines were unnecessarily long, leading to hours of lost productivity every day. By rearranging setup sequence and on/off times, Halley quickly achieved significant productivity gains with those machines.

Having comprehensive machine performance data on hand also provided an additional benefit: better service from CNC manufacturers. Service calls are now backed by a rich set of historical data, making it easier to identify and troubleshoot potential hardware issues. "Manufacturers have become more willing and able to provide support when we need it because we have the data to show abnormal operation," noted Halley. (According to press information from Moxa; www.moxa.com)

Laboratory at TU Braunschweig for residual stress analysis successfully accredited

Accreditation certificate. (Photo: Markus Köhler, TU Braunschweig)

At the Institute of Joining and Welding Technology at the Technische Universität (TU) Braunschweig in Brunswick/Germany, residual stresses can now be measured and analysed at the "Norddeutsches Zentrum für Spannungsanalytik" (North German Centre for Stress Analysis – NOSA) in the recently accredited test laboratory. This makes the TU Braunschweig the perfect contact for industry and companies of welding technology when it comes to X-ray residual stress determination.

Residual stresses are internal stresses that occur in the component without the action of external forces. They arise during production or manufacturing under the effect of plastic deformation of microscopic and macroscopic material areas. They also play a role when heat is applied to any type of component processing, e.g. gear components, turbines or other components in the automotive and aerospace industries. Therefore, they are also of high importance in welding technology and are mostly analysed in development.

Residual stresses can have both a positive and a negative influence on component behavior. Due to the broad knowledge of the effect of residual stresses accumulated over decades, they now represent an industrially used engineering tool for the optimisation of component properties, especially for high-strength and ultrahigh-strength materials.

High requirements for competence confirmed

For many years, the Institute of Joining and Welding Technology at TU Braunschweig has been involved in the determination of residual stresses in metallic materials and components as part of NOSA. Destructive and non-destructive testing methods are used for materials analysis. Since autumn 2021, NOSA has been accredited by the German Accreditation Office (DAkkS) as a testing laboratory for residual stress analysis according to DIN 17025. This confirms the high requirements on competence, the uniform working method as well as the quality standards.

Accreditation as basic prerequisite for many industry cooperations

A large number of residual stress-, phase- and texture analyses are carried out daily in various specially developed stationary and mobile X-ray diffractometers as part of basic and application-oriented research projects. With a diffractometer, non-destructive investigations of the

Test lab: Positioning of a sample in the X-ray diffractometer. (Photo: Paul Diekhoff, TU Braunschweig) structure of crystalline phases in materials can be carried out.

Since the determination of residual stress states has long been an industrially established method for quality control during series production and prototype development, the institute is also a service partner in this field of bilateral industrial projects. These tests are offered to companies that are interested in such analyses but do not have the necessary know-how or equipment themselves. "The accreditation of the testing laboratory is a basic requirement for many industrial partners for cooperative projects and represents a great development opportunity for NOSA," says NOSA director Dr. Thomas Nitschke-Pagel.

Equipment extended by a portable small size diffractometer

The laboratory has a large number of X-ray diffractometers for residual stress determination. The self-developed measuring stations are primarily designed to examine relatively large test specimens non-destructively with a high level of automatisation. This offers scientists the possibility of carrying out very detailed analyses of the residual stress state on different test specimens within an acceptable time frame. In addition to scientific applications, the facilities are also used for application-related work on behalf of the customers.

Since this year, the laboratory also has a new portable small size diffractometer, which can be used to perform residual stress analyses on test specimens and components for which non-destructive investigations using laboratory diffractometers are no longer possible due to their size and/or weight. The compactness of the instrument also allows, for example, direct application in test setups and in-situ measurement, e.g. in fatigue testing, and therefore offers the possibility of monitoring variable residual stress states in much greater detail over the service life of test pieces, whereby a more refined evaluation of the residual stress influence on the fatigue strength can be achieved. Due to a modified measurement and evaluation principle compared to laboratory diffractometers, considerable reductions in measurement times can also be achieved.

Portable X-ray diffractometer in use. (Photo: Paul Diekhoff, TU Braunschweig)

More information is available at https://www.tu-braunschweig.de/ifs/institut/forschung/abteilungen-und-kompetenzen/festigkeit-und-bauteilverhalten/nosa – or follow the QR code shown in the picture above. (According to press information from TU Braunschweig; www.tu-braunschweig.de/en/)

The right parts cleaning process ensures product quality and cost effectiveness

Meeting defined particulate and film-type cleanliness specifications that can be reproduced and at the lowest possible cost: These requirements can only be implemented with cleaning solutions that are optimally adapted to the task (in the picture: Detail of the cleaning system "Mega" from Ecoclean). (Photos: Ecoclean)

Today, parts cleaning has become a quality critical manufacturing step in all industry sectors. Often it takes great effort to reproducibly meet particulate and film-type cleanliness specifications. At the same time cleaning is to be done at the lowest possible cost. These contradictory requirements call for processes and machines tailored to specific needs.

From machine and plant engineering, electrical and power engineering to connecting elements, the so-called general industry contains a multitude of sectors. In these industry sectors, components made of materials like metals, plastics, ceramic and composite materials are manufactured and processed using different manufacturing technologies. Products include, for example, cast and machined parts, stamped, bent, pressed and deep-drawn parts, hydraulic parts and, more and more, additively manufactured components.

Although the parts are manifold, they have one thing in common: to ensure the quality of downstream processes such as machining, heat treatment, coating, bonding and assembly and to guarantee lasting functionality, they necessitate cleanliness levels in line with requirements. In many areas, ever higher requirements concerning particulate and film-type cleanliness must be met. And there are often additional challenges such as high throughput rates and weights, a strongly varying range of parts to be cleaned, short delivery times and also small margins in some cases.

Adapting cleaning processes to tasks on hand

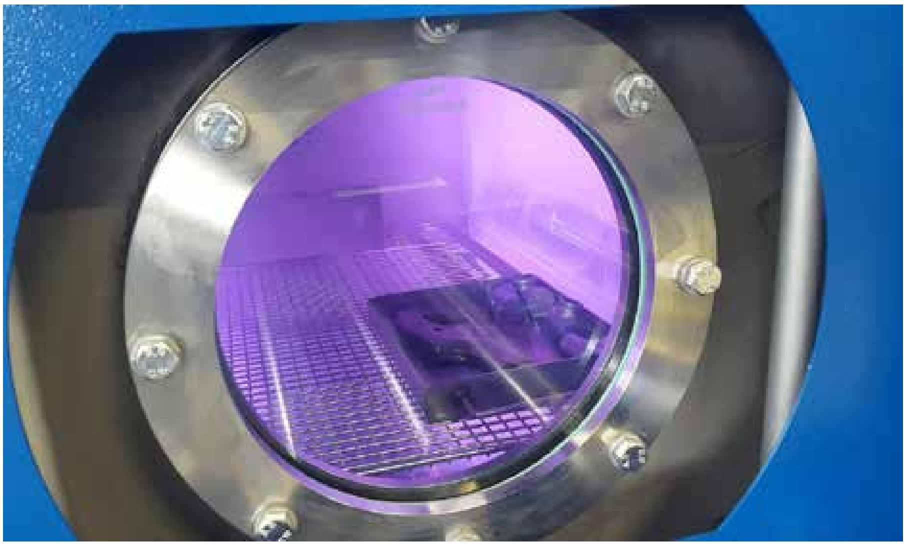
This means there are different requirements for part cleaning. As a supplier of flexible and energy-efficient solutions for industrial parts cleaning, Ecoclean GmbH from Filderstadt near Stuttgart/Germany (www.ecoclean-group.net) covers the complete range of wet-chemical procedures. Cleaning processes and systems for batch or single-part cleaning can be optimally adapted to the respective specifications.

To do so the following factors have to be taken into consideration: Material, size, geometry and weight of the part, type and quantity of contaminants, downstream process and the resulting cleanliness specifications and throughput requirements. On this basis it can be determined whether the contaminants can be removed most effectively with a water-based detergent, an environment-friendly solvent or a modified alcohol with lipophilic and hydrophilic properties. What is more, this information enables engineers to define the best suited process and drying technology.

A matching process technology minimises cleaning cost

In order to minimise the cost per cleaned part, it is necessary that the existing cleanliness specification is not only reliable, but also quickly reached. Therefore the systems are equipped with various application-specific treatment technologies such as spray, high-pressure, immersion, ultrasonic and plasma cleaning, vapour decreasing, injection flood washing, deburring, pulsated pressure cleaning (PPC) as well as a passivation/preservation process as required.

By combining these cleaning procedures, the cleaning result and duration for the specific parts can be influenced in a pinpointed manner. The PPC procedure in combination with an aqueous or solvent-based immersion cleaning for example, reliably and quickly removes contaminations from small cavities. In case of complex and bulk parts, spray processes and injection flood washing with adjustable nozzles between 10 and 16 bar also deliver markedly improved cleaning results and shorter process times in solvent cleaning processes.



By integrating two cleaning processes in one system, such as wet-chemical and low-pressure plasma cleaning, quality, cost and cycle times can be optimised.

Quality and cost can be optimised by combining processes that formerly required several machines in one single cleaning system. Among them are chamber machines designed for solvent-based or aqueous batch cleaning with a subsequent low-pressure plasma process. Among other things, this method effectively and efficiently prepares the part surface for a subsequent coating or bonding. Ecoclean's extensive product range also offers the respective solutions for pinpointed deburring and cleaning of single parts, for example hydraulic and motor components in one system.

Dry cleaning: selective or whole surfaces

Cleaning tasks also change along with changing manufacturing and joining technologies. The focus lies more and more on dry-cleaning processes, be it for removing film-type contaminations from joint surfaces in a pinpointed manner, cleaning electronic components and assemblies, removing powder residues from additively manufactured components or cleaning integrated in assembly.

For this and many more applications, Ecoclean has developed a special toolbox for cleaning processes with atmospheric pressure plasma, laser, CO_2 snow, conditioned vacuum air as well as saturated and dry water vapour. Depending on the specific application, these 'tools' too are applied alone or combined. This extensive portfolio of cleaning solutions is supplemented by technology centres around the world. They perform tests with original soiled parts under conditions similar to production for all the different tasks existing in part cleaning.

Doris Schulz (Journalist), Korntal/Germany

Dry cleaning methods such as vacuum air cleaning can be integrated into assembly lines and used for depowdering of additively manufactured parts.

Oerlikon Metco: Enhancing the customer experience through digitalisation

"myMetco" process chain.

For nearly 90 years, Oerlikon Metco (www.oerlikon.com/metco) has provided customers with advanced materials for industrial processes, as well as thermal spray application technology. Today, the company offers these materials and spare parts for their thermal spray equipment online 24/7.

Oerlikon Metco successfully launched their "myMetco" e-commerce site to its US customers in 2020, and has now expanded this online ordering platform to its European customers in five languages. Sign up (at https://mymetco-europe.oerlikon.com) is easy for new and existing customers.

The platform offers customers a digital way to simplify and accelerate their ordering process. As the market leader and original manufacturer of innovative solutions for critical processes such as thermal spray, metal additive manufacturing, and others, myMetco customers can trust that they will receive products with the same quality and benefits they have come to expect from Oerlikon Metco. Customers benefit from:

- Current product pricing and availability,
- Strong product search and compare capabilities,
- Free access to expert product technical support,
- Increase in efficiency with quick ordering and 24/7 shopping service,
- Easily track orders and order fulfillment online.

In addition to online ordering, the company offers users an easy way to search and find materials digitally. The "Materials e-Guide" (https://mymetco-europe.oerlikon.com/en-us/?utm_source=brochure&utm_medium=print&utm_campaign=2022-Mar) provides query fields based upon chemistry, process, primary function, service environment, specification and other filters. Whether the goal is better durability from wear or corrosion, thermal protection, surface restoration, additive manufacturing, dimensional control or other desirable properties for a component or system, the "Materials e-Guide" will help find the right material for the application. It can be used by anyone whether they are a "myMetco" customer or not. This powerful combination allows users to confidently search and shop solutions at their convenience. (According to press information from Oerlikon Metco)

Oerlikon Metco "Material Finder".

High-performance cold gas coating for wear protection and emission reduction for brake discs

Brake disc with high performance cold gas coating after grinding (Photos: Impact Innovations GmbH).

Brake discs are subjected to extremely high loads and are among the most stressed parts of a car. Not only do they have to be replaced at relatively short intervals, due to the high level of wear and tear they create an immense environmental impact through particulate matter. Thanks to improved emission control, a reduction in exhaust gas emissions can be achieved in modern cars.

However, it is still neglected how much particulate matter is caused by the abrasion of tires and brakes. A good half of the particulate matter in German road traffic is caused by tire and road abrasion and another quarter by brake pad abrasion. Emissions from brake wear, such as brake dust and particulate matter, are a growing concern for the automotive industry due to more stringent and environmental EU regulations.

Grey cast iron with embedded graphite as most common material for brake discs

Grey cast iron with embedded graphite is the most common material from which brake discs are produced. Grey cast iron brake discs are not only cheap to manufacture, they also have all the necessary mechanical properties that are required. However, poor corrosion resistance and excessive wear of the brake disc during operation are the main problem areas. Since no material can yet compete with grey cast iron for vehicle brake discs from a cost perspective, the coating of cast iron discs represents a practical and cost-efficient solution. But conventional thermal coating processes are still very material- and cost-intensive and the required properties in terms of coating adhesion, corrosion resistance and cracking behaviour cannot yet be fulfilled. In contrast to laser cladding, the cold spray process is free of patent protection from any major automotive manufacturer.

With a high-performance cold gas coating with the Cold Spray System “EvoCSII” by Impact Innovations (www.impact-innovations.com), there is no delamination or severe cracking in the coating and the particle emission is reduced drastically. The performance of the coating was evaluated in terms of corrosion resistance, wear resistance and tensile bond strength between the coating and the brake disc. The cold gas sprayed composite coating of the cast iron brake disc showed a 95% reduction in wear in the SAE J2522 test. In addition, the coating showed excellent adhesion even after extreme bench test runs without any delamination. 720 hours of salt spray tests were successfully completed without corrosion.

Simplicity, high performance and low costs

The cold spray process wins over other coating technologies with its simplicity, high performance and low costs. As it is a cold process, all process parameters are always constant independent of the dimensions and shape of the brake discs. There is no thermal distortion of the discs, and the layer build-up stands out with its uniformity. Thus, the coating thickness can be reduced to a minimum and the subsequent grinding costs are minimised. A standard brake disc can also be coated in a one-layer system (no intermediate layer) in less than 30 seconds. The present results show a cost-effective and resource-saving solution for the brake disc application with cold sprayed composite coatings.

Dr. Reeti Singh, Ján Kondás,
Max Meinicke and Leonhard Holzgaßner,
Impact Innovations GmbH,
Haun/Rattenkirchen, Germany
www.impact-innovations.com

Brake disc with high performance cold gas coating after coating.

Short Messages

ABB provides digital-ready solutions for modernisation of steel mill

Global technology company ABB (www.abb.com) is providing a package of metals industry-specific digital-ready solutions, including drives, controller and converter infrastructure, to enable Global Steel Wire (GSW; www.globalsteelwire.com), part of CELSA Group, to modernise operations at its steel mill in Santander/Spain. GSW manufactures and brings to market a range of steel products, including wire rod, cables and ropes. Its high-quality steel cables are used extensively in the automotive industry as well as in mattress springs. The steelmaker had been exploring the use of digital technologies to optimise its rolling wire production and will now benefit from the expertise and metals industry domain knowledge of ABB. As part of the contract, ABB will provide its medium voltage drives for high power applications, "Megadrive-LCI", together with "AC 800PEC" controllers. The demand-based medium voltage drives will result in optimised power consumption and higher process efficiency. Teams from the two companies had the chance to incorporate the use of augmented reality during the Factory Acceptance Test, with representatives at the LCI factory in Switzerland collaborating with others in Spain. It encompassed audio, video, document-sharing and live annotations. This allowed progress to continue during the Covid-19 travel limitations. The use of proven ABB technology will allow GSW to save energy and reduce its carbon emissions through increased efficiencies. The drives voltage scalability minimises harmonic influence on the supply system, and a converter efficiency of more than 99% will ensure that the system works for many years.

ABB has been appointed to provide digital-ready solutions that will help to improve efficiency, increase reliability and boost quality at Global Steel Wire's facility in Santander. (Photo: ABB)

New laboratory for industrial diagnostics and advanced robotics

Comau from Grugliasco (Turin)/Italy (www.comau.com) and the Politecnico di Bari (Poliba) have signed a five-year agreement for the joint creation of the new "Cognitive Diagnostics public-private laboratory", aimed at the development of innovative solutions for industrial diagnostics and advanced robotics. The collaboration provides for the use of a research and experimentation space where Comau, in synergy with the University, intends to launch projects related to artificial vision for non-invasive diagnostics and robot guidance. The "Cognitive Diagnostics" laboratory was created to respond to the growing demand for flexible automation that is adaptable to any production context and able to make Factory 4.0 work processes more efficient through the use of enabling technologies. In particular, the new laboratory will allow Comau to deepen the study of innovative vision systems and platforms that allow easier robot programming, thus facilitating and speeding the management and control of operators ("low code programming"). Comau will collaborate with the Politecnico's educational activities through its participation in tutoring during training and company internships. To start the lab, Comau will fund research grants, scholarships and researcher positions. The initial work team will consist of individuals contracted from the Politecnico di Bari, with the possibility to gradually increase the workforce.

Comau and the Polytechnic University of Bari will collaborate in the design of new technologies in the field of industrial diagnostics and advanced robotics. (Photo: Comau)

Atlas Copco acquires French distributor of compressors

Atlas Copco – a global industrial group, founded in 1873 in Stockholm/Sweden, with today about 40,000 employees – has acquired AEP, a French distributor of compressors and provider of service. The privately owned company has a strong market presence in Paris and the Île-de-France region. It serves a diverse group of small to medium-sized customers in industries such as manufacturing, food and beverage, and automotive. "AEP has highly qualified service technicians, and the company has for many years been a distributor of Atlas Copco", said Vagner Rego, Business Area President Compressor Technique. "By this acquisition we will reinforce our commitment to better serve our customers and strengthen our capabilities for the growing market of small- and medium-size companies." The company will become part of the Service division within the Compressor Technique Business Area.

MicroStep continues to expand: New partnership in the UK

For more than 25 years, City Plasma Services has taken care of the distribution of CNC plasma cutting systems in the United Kingdom. From now on, the family-owned company is the contact for the CNC cutting systems and automation systems from MicroStep. With MicroStep's broad portfolio, customers in the UK can now be served even more tailor-made and comprehensively. City Plasma Services has worked closely with plasma power source manufacturer Hypertherm for many years and brings this experience to its collaboration with MicroStep in the UK. In doing so, beyond plasma cutting systems, City Plasma Services also sells laser, waterjet and oxyfuel cutting machines with the MicroStep product range, as well as a variety of additional integrable options for drilling, tapping, scanning and marking. The specialist dealer is thus placing a new focus on supplying high-tech machines to a wide range of customers. Requests are served for single compact machines up to automated process lines with different cutting technologies as well as automatic loading and unloading solutions, CAPP applications and Smart Factory solutions with CAM software and ERP systems. More information is available at: www.cityplasma.co.uk.

Supertec chooses NUM technology for its latest CNC cylindrical grinding machines

Supertec Machinery Inc., one of Taiwan's leading machine tool manufacturers, has chosen to base new versions of its renowned plunge type of CNC cylindrical grinding machines on NUM's "Flexium+" CNC platform from NUM, Coventry/UK (www.num.com). Founded in 1954, Supertec Machinery Inc. specialises in precision grinding automation and produces a diverse range of centreless, cylindrical and surface grinding machines. When NUM added non-circular grinding functionality to its popular "NUMgrind" cylindrical grinding software back in June 2020, the company realised that this innovative CNC technology provided exactly what many of its customers needed on their cylindrical grinders. "NUMgrind" simplifies the creation of G code programs for CNC grinding machines through the use of a highly intuitive graphical human machine interface (HMI), and unlike conventional CAD/CAM workstation tools, it is designed specifically for use by shop floor personnel in a production environment. Supertec's plunge type of CNC cylindrical grinding machines offer a choice of six capacities, covering distances between centres from 500 to 2,000 mm. The machines can also accommodate grinding diameters from 300 up to 430 mm (3 sizes), grinding wheel speeds up to 1,390 rpm and workhead spindle speeds from 30 to 350 rpm.

Supertec's latest plunge type CNC cylindrical grinding machine is based on NUM's Flexium+ CNC platform (From left to right: Mr. Chu, General Manager of Supertec, and Adrian Kiener, CSO Asia NUM). (Photo: NUM)

thyssenkrupp Materials Services with strategic investments in growth market North America

thyssenkrupp Materials Services is significantly expanding its North American business and investing in several states in one of its core markets. The biggest mill-independent materials distributor and service provider in the western world is exploiting the market potential for expansion as well as for the implementation of new, scalable business models. "Demand for our products but especially for our services is high and has grown strongly in recent years," says Martin Stillger, Chairman of the Board of Management of Materials Services. "We now want to use our affinity for services in particular to improve our market position even further – if possible also with further acquisitions. Today we are already number 3 in America. That is not enough for us." Business in North America alone accounts for around 25% of total sales of Materials Services. With 94 service centres and more than 4,000 employees, Materials Services already has a strong, nationwide network that serves more than 55,000 customers with precision fit. These include, for example, various Fiat/Chrysler plants with around 70,000 parts a day from three "just in sequence" delivery centers.

thyssenkrupp Materials Services plans to create additional capacity to meet growing demand from the manufacturing industry at various locations across the US (Photo: thyssenkrupp Materials Services)

Products

New multiprocess welding system series

Fronius is launching the "iWave" (**Fig. 1**), an intelligent, high-end TIG series that sets new standards in quality, flexibility and connectivity, available in power categories from 190 A to 500 A. The "iWave" was developed to enable the best TIG weld quality and flawless results to be produced on different metals. The innovative option "CycleTIG" provides for maximum control over the arc and targeted heat input. Further highlights include improved ignition control and greater ease of use with intuitive operation. The new welding system proves its worth with sophisticated TIG technology and is ideally suited for manual metal arc welding – even with cellulose electrodes. The "Multiprocess PRO" option gives the user unlimited access to all MIG/MAG processes in power categories from 300 A. Customers can choose the specific features they actually need and have the assurance that they can add to the range of functions as and when needed. Starting with standard TIG or MIG/MAG applications, the "iWave" enables upgrades to the full Fronius range, including the Cold Metal Transfer (CMT), Pulse Multi Control (PMC) and Low Spatter Control (LSC). Modern wireless connections give welders freedom and security. Peripheral devices, such as a remote control or the "Vizor Connect" welding helmet, can be wirelessly connected via Bluetooth. WiFi enables communication with other devices in the same network so the user can enjoy a whole host of digital advantages, such as central user management, real-time data transfer and rapid updates. (Fronius International GmbH, Froniusplatz 1, 4600 Wels/Austria; www.fronius.com2

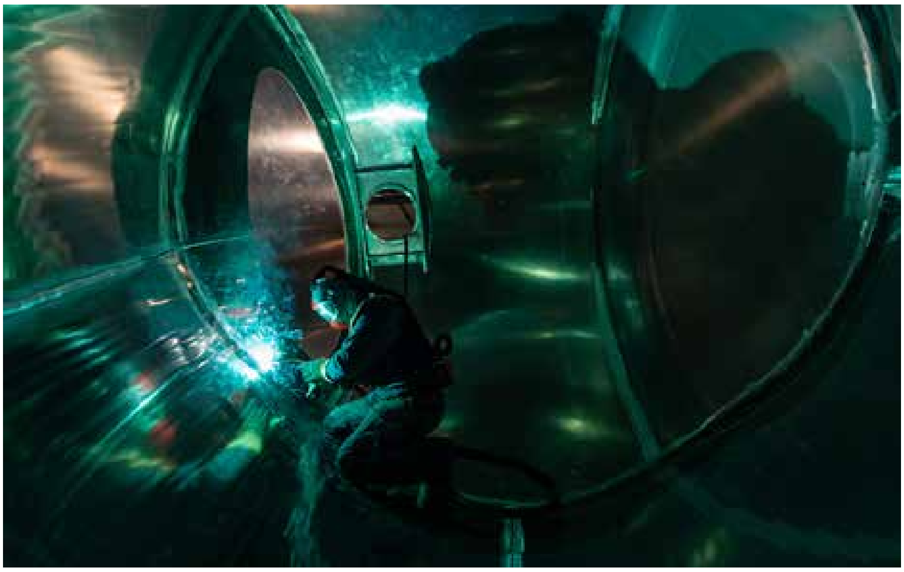


Fig. 1

Compact welding cells with pre-assembled welding equipment

To make it easier for small and medium-sized enterprises to get started with automation, Kuka and Abicor Binzel are intensifying their cooperation: With "Kuka cell4_arc powered by Abicor Binzel", the two companies offer cost-effective complete welding cells that are easy to use (**Fig. 2**, from left: Jörg Lehnhäuser, Director Sales Western Europe from Abicor Binzel and Sascha Liese, Head of Business Unit Arc Welding & Laser Applications KIO from Kuka). Neither a high level of expertise in automation technology and programming is necessary, nor a special operating system. Areas of application can be found in the production of small assemblies made of steel or aluminium, small to medium-sized production volumes and generally in applications with the MIG/MAG welding process. Of course, customer-specific adjustments and additional options are possible with the robot welding cell. It is ideally suited for the automated welding of smaller components up to 800 mm × 1,200 mm, which can be loaded/unloaded and welded at the same time. Additional devices such as tools can easily be integrated. The possibility of constant process monitoring and documentation reduces production errors and ensures process quality. Appropriate protocols are created for quality assurance. As a high-performance unit mounted on a base frame, this compact, space-saving welding cell can also be easily transported to the respective destination using a forklift and be repositioned again and again individually. (Alexander Binzel Schweisstechnik GmbH & Co. KG, Kiesacker 7-9, 35418 Buseck/Germany; www.binzel-abicor.com and Kuka AG, Zugspitzstraße 140, 86165 Augsburg/Germany; www.kuka.com)

Fig. 2

Modular MIG/MAG welding machines

With the modular versions of the "Phoenix XQ puls", "Taurus XQ Synergic" and "Taurus XQ Basic" MIG/MAG welding machines (**Fig. 3**), it's all about user customisation. While the power source remains at the heart of the machine, other parts of the welding machine are not permanently installed and can be freely configured. This means users can pick and choose which wire feeder or what cooling they prefer to use for their daily tasks. Customers can also retrofit their machines as needed, gradually completing their set-up with new modules. The wide range of user-oriented accessories – including a toolbox and cover lens for the control – also gives users the freedom to adapt their modular "XQ" series machines to any working area. The machines are also space-saving and lightweight, offering more mobility and flexibility. They are compatible with the ewm "Xnet" welding management software. This software solution supports, documents and analyses the entire production process, from work preparation to final costing, all completely paperless. This makes quality assurance even easier and allows users to extensively evaluate any welding parameters used for a job after the fact. (EWM AG, Dr. Günter-Henle-Str. 8, 56271 Mündersbach/Germany; www.ewm-group.com/en)

Fig. 3

Desktop resistance weld checker

With the "MM-400A" desktop resistance weld checker (**Fig. 4**), operators can easily monitor and manage key welding variables that result in changes in weld heat, including current, voltage, time, force and displacement. The compact unit supports AC/DC inverter, AC inverter, transistor and capacitive discharge resistance welding technologies. The "MM-400A" is ideal for use in process development, where it can be used to correlate waveform and numeric data with process results and provide detailed weld data for process optimisation and validation. In a production environment, it reduces scrap by detecting drifts in the weld process and alerting operators before process failure. The device also reduces the frequency of destructive testing and provides an independent way of monitoring the welding power supply. It features a simple and intuitive user interface and colour touch panel display. An envelope function allows the operator to set upper and lower segmented or continuous limits around the entire waveform. The unique seam welding mode monitors AC current and voltage or DC voltage for up to 5 min. The unit provides ISO17657-compliant measurement for current (when used with available ISO-compliant toroidal coil) and offers Ethernet (TCP/IP), and RS-232/485 communication. Pre-weld displacement measures workpiece thickness prior to welding. Multi-language support includes English, Spanish, Japanese, Chinese, Korean, German and French. (Amada Weld Tech GmbH, Lindberghstr. 1, 82178 Puchheim/Germany; www.amadaweldtech.eu)

Fig. 4

Compact spark-OES metals analyser

Fig. 5

"Q4 Polo" (**Fig. 5**) is a compact Spark Optical Emission Spectrometer (OES) with superior analytical performance for multiple applications across the metals industry. It extends Bruker's line of benchtop OES systems, combining high precision elemental analysis capabilities with low cost of ownership and small footprint. In addition to excellent analytical performance for the large element range from lithium (Li) to bismuth (Bi), the "Q4 Polo" enables applications previously not addressable by such compact instruments:

- Outstanding precision, particularly on light elements,
- Excellent results in the challenging analysis of cast iron,

- Reliable analysis of nitrogen at low ppm levels in low alloyed steels,
- Analysis of oxygen in copper.

The "Q4 Polo" has very good long-term stability. The absence of thermal- and contamination-based drifts reduces the need for cleaning and recalibrations. Bruker's patented "Automatic Ambient Compensation" (AAC) ensures that the optical system keeps its focus by eliminating thermal drift. The new "ArgonShield" prevents contamination of the optical window during measurements. The active sensing digital "SmartSpark" source further improves analytical precision and long-term stability, enabling shorter measurement times. The coverage of the full elemental range is achieved by a unique electromagnetic light junction as core component of the "MultiVision" optics. (Bruker Corporation, 40 Manning Road, Billerica, MA 01821/USA; www.bruker.com/q4polo)

MIG/MAG welding machine with integrated wire drive for manual welding

Fig. 6

The MIG/MAG welding power source "Qineo StarT" (**Fig. 6**) offers an easy entry into the world of modern welding technology. Due to the excellent price-performance ratio, users can weld any workpiece at economic conditions. The heart of the machine is an inverter power unit developed by Cloos which clocks with a high frequency. This allows an even better arc control for excellent results. The configuration possibilities are as flexible as the welding applications are versatile. This is guaranteed by the modular product concept. From the capacity class to the wire tip, each "Qineo StarT" is customised. The easy, quick and intuitive operation is a convincing feature of the welding machine. Users benefit from the comfortable operating concept that they can adapt to their individual requirements. The "Qineo StarT" is characterised by high-quality components with numerous optional functions. (Carl Cloos Schweisstechnik GmbH, Carl-Cloos-Str. 1, 35708 Haiger/Germany; www.cloos.de/de-en)

New web-based module for CAD/CAM nesting software

Hypertherm released "Production Manager", an optional module for its "ProNest" CAD/CAM nesting software (**Fig. 7**). This web-based module is designed to improve productivity, maximise machine up-time, boost on-time delivery and increase material utilisation. It seamlessly integrates with Hypertherm's "Edge Connect" CNC, to automatically capture machine data without the need for operator intervention. In addition, it displays real-time production data so team members across an organisation can track the status of job orders, the production schedule and pending inventory requirements. Additional features include:

- An intuitive dashboard view provides production stats and trends in one view. Colour-coded status alerts help users quickly understand the on-screen information while an interactive display allows users to drill down for additional insight.
- Real-time machine data from the CNC is transferred to "Production Manager". This enables users to track job progress from pending, to in-production, to actual completion time making it easier to respond to customer inquiries and forecast the production schedule.
- Orders can be canceled or held to add or remove parts based on last-minute changes. Users can view machine backlogs and ensure loads are evenly distributed across cutting machines in a way that optimises the production schedule.
- Remote access makes it easy for users to access "Production Manager" via a computer, mobile phone or tablet anytime and anywhere they have a secured network or VPN connection.

(Hypertherm Europe B.V., Vaartveld 9, 4704 SE Roosendaal/The Netherlands; www.hypertherm.com)

Fig. 7

Control system to handle multiple thermal spray processes

Lincotek Equipment – turn-key equipment provider for thermal spray coating solutions, diffusion coatings and related processes – has announced the launch of a new equipment control system (**Fig. 8**). Combined with next-generation proprietary software and a newly designed HMI console, it is designed to improve efficiency, flexibility and usability, while still delivering the same high standards of reliability and repeatability. The concept is to provide a tailor-made platform which handles multiple thermal spray processes, different spray guns and unlimited handling options. Only one ergonomic console is required, featuring a single touch-screen monitor for process control, three short-cuts for key functions, USB connection for data storage, as well as ethernet connections to allow direct dialogue with equipment and factory LANs. Interfaces can be tailor-made with innovative communication protocols. The HMI software allows for unlimited versatility and equipment control over process parameters, powder feeders, handling system, doors, cooling and filtering systems. It also provides unlimited storage of recipes, parameters and data logs. The coating process has Industry 4.0 and IoT features that provide real-time monitoring, equipment health checks and the recording of critical parameters. Safety is provided by an automatic stop on all equipment in the event of any critical situation. (Lincotek Surface Solutions, Via Mistrali 7, 43046 Rubbiano, PR/Italy; www.lincoteksurfacesolutions.com)

Fig. 8

Compact welding cells as easy gateway into automation

With a portfolio of new, turn-key compact welding cells, Lorch Schweißtechnik and Yaskawa enable small and medium-sized enterprises to easily enter robot-automated welding to produce small assemblies with great efficiency and at high quality (**Fig. 9**). These space-saving and efficient welding cells take just a few minutes to be ready for operation. Their compact build keeps their footprint small and makes them easy to relocate later. The special cell construction maximises freedom of movement for the robot and permits complete integration of the welding power source in spite of its small size. The welding cells are available as the "ArcWorld HS Micro", with a footprint of 1.3 m2 and the "ArcWorld RS Mini" with a footprint of 2.3 m2. A maxi version with the "ArcWorld CS" is also available for larger parts or customer-specific requirements. The platform and housings are equipped with a blue polycarbonate glare protection and use the "Motoman AR900" robot by Yaskawa. The "S3"- and "S3-RoboMIG XT" with their complete Lorch Speed welding processes are available as welding power sources (MIG/MAG). The combined Lorch and Yaskawa solution is made special by integrating the control in a single operating panel. The Universal Welding Interface (UWI) is used to program robots, to set and select the welding processes. The optimal adjustment of the components makes operation of the welding system much easier. (Lorch Schweißtechnik GmbH, Im Anwänder 24-26, 71549 Auenwald/Germany; www.lorch.eu/en; Yaskawa Europe GmbH, Hauptstr. 185, 6560 Eschborn/Germany; www.yaskawa.eu.com)

Fig. 9

Analysis of brazing imperfections by metallographic investigation / optical microscopy – Part 1

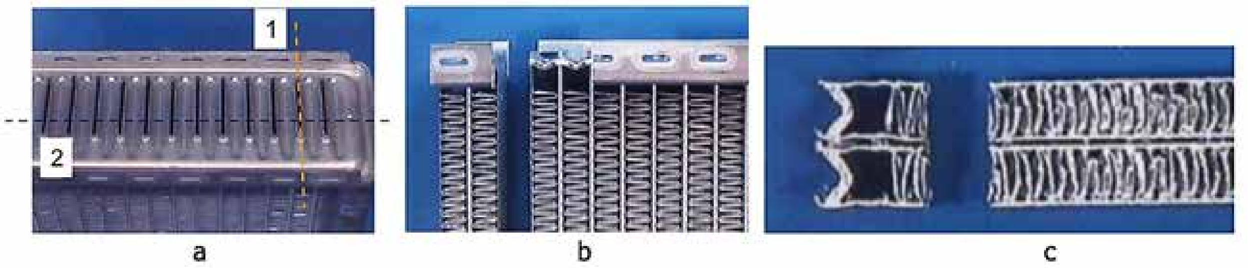


Fig. 1 • Cutting of a radiator for examination of the joint quality; a) brazed part with marked cutting lines, b) part after cutting along line 1, c) part after cutting along line 2.

In everyday practice we can encounter problems connected with brazing imperfections – often manifested as leaking. To identify the failure root causes, usually a detailed examination needs to be performed. Optical metallography is one of the most important tools for such an analysis.

The purpose of this article is to present the basic principles for performing analysis of brazing joints, and to show what information can be obtained from the investigation.

Before starting to work with an optical microscope, the part to be examined must be prepared appropriately. There are several steps in this procedure:

- Cutting out smaller pieces to about 30 mm to 40 mm with a band saw.
- Embedding the cut sections in epoxy resin.
- Step grinding with sandpaper (220 grit, 500 grit, 1000 grit).
- Polishing with diamond suspension (6 µm and 3 µm) and with oxide polishing suspensions (OP-S).
- Microscopic observation in non-etched conditions – mainly to determine if the quality of polishing is sufficient.
- Microscopic observation after etching – most common etchant: 0.5% hydrofluoric acid, (10 – 15 seconds immersion).

There are usually two steps in a metallographic examination.

The first one is to evaluate the brazing quality. It is usually performed when introducing a new product. In such case the manufacturer should define the way the sample is cut for microscope observations. In most cases the tube to header and the fin to tube joints are examined. Such exemplary cutting is shown in **Fig. 1**.

The second step is connected with the actual examination of the parts – looking for root causes of not brazed parts.

It is of primary importance to choose properly the observation plain. In most cases it runs across the examined defect. This will be seen case by case in the following industrial cases examples.

However, before we go into fault analysis, we should understand what can be seen in an optical microscope metallographic picture. **Fig. 2** represents the metallurgical structure of a tube to header joint of a brazed aluminium radiator.

Apart from the intrinsic features of the brazed structure quite often we can observe another phenomenon strictly connected with the brazing process. An example of such phenomenon is shown in **Fig. 3**.

Silicon diffusion is a phenomenon where silicon diffuses from static liquid filler into the base metal and aluminium diffuses into the liquid filler – resulting in partial melting of the base metal at brazing temperature. The extent of this phenomenon is enhanced by too high brazing temperature and/or too long time at brazing temperature.

The phenomenon of diffusion sometimes can develop into so-called erosion. In such cases the liquid part of the base metal had flown away – leaving a gutter behind. That can potentially happen at the end of a brazing cycle, when significant temperature gradients develop during cooling. It should be noticed that this phenomenon, which results in thinning out of for example the tube wall cross section, is very dangerous for part performance, because the thinner tube wall could be a potential place for fatigue and/or corrosion failure.

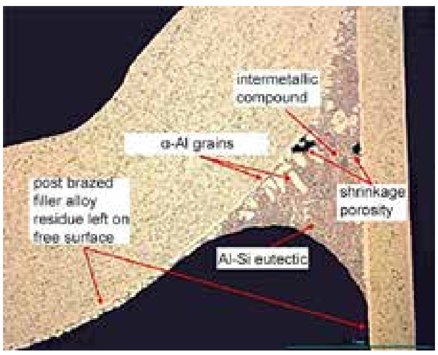


Fig. 2 • Metallographic structure of a tube to header joint – etched with hydrofluoric acid (HF).

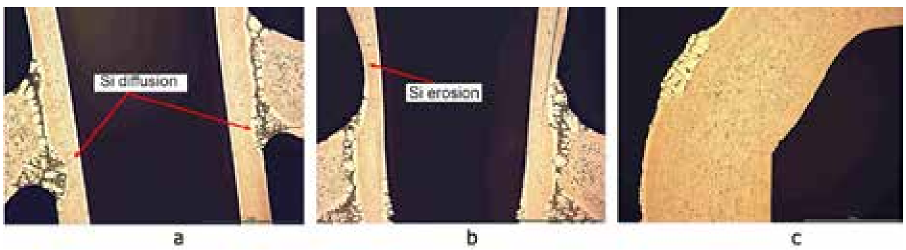


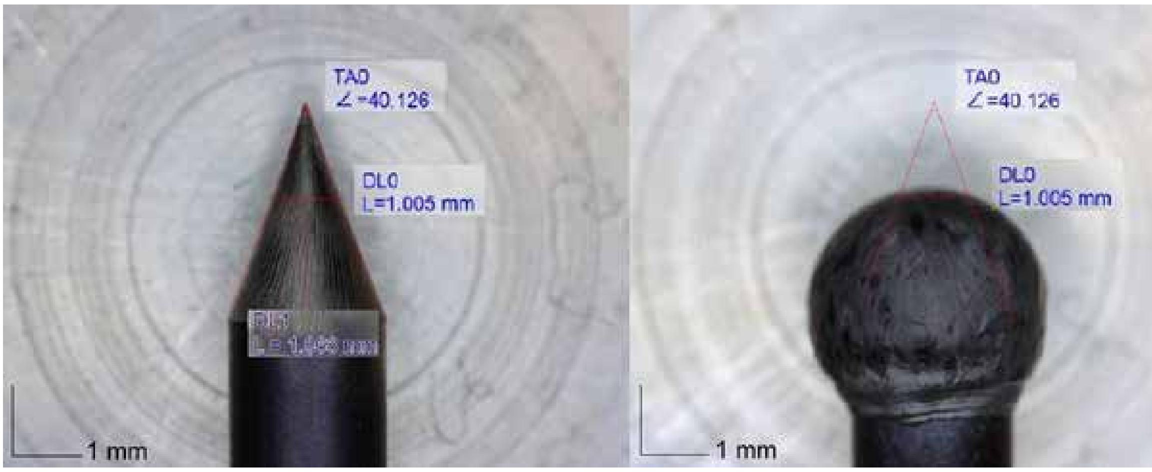
Fig. 3 • Examples of structural brazing phenomena; a) silicon diffusion, b) erosion, c) liquid film migration.

The liquid film migration (LFM) physically is an entirely different phenomenon than the two ones discussed above. During brazing, there are always some interactions between the filler alloy and the base alloy. They take place before and after melting of the filler alloy. However, in some situations they have a very specific character. It is a phenomenon of rapid silicon diffusion into the matrix alloy. It starts at temperatures below the brazing window. During that process a moving liquid interface is created, which sweeps from the clad/core interface into the core of the material.

The degree of LFM depends on cold deformation induced to the base metal before brazing and also strongly depends on the alloy type of the part. Since this process diminishes the amount of liquid available to form joints – and it can also destroy a sacrificial layer in the base alloy (e.g. used for corrosion protection) – it should be avoided in the brazing practice. It is worthwhile pointing out that minimisation of LFM can be achieved by proper choice of the base material and its temper, thus for a given part it must be done at designing stage.

(According to press information from NOCOLOK)

When and why truncate the tip of the electrode?



A ground electrode before welding (left) and after AC welding (right) with incorrect settings on the welding machine (Diameter Ø 2,4 mm, grinding angle 20° = tip angle 40°).

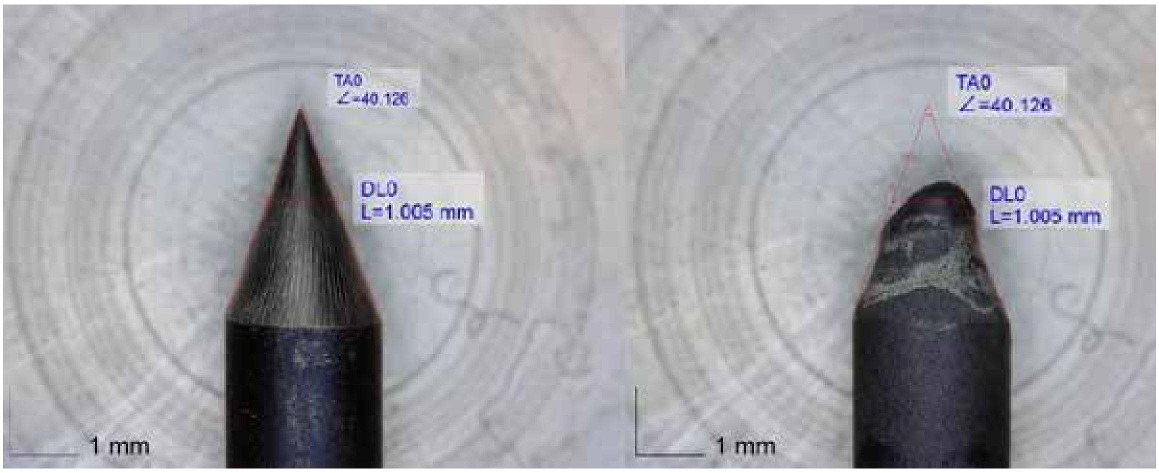
There are two situations, when TIG welding, that really stress your tungsten electrode:

1. High amperage welding
2. AC welding aluminium.

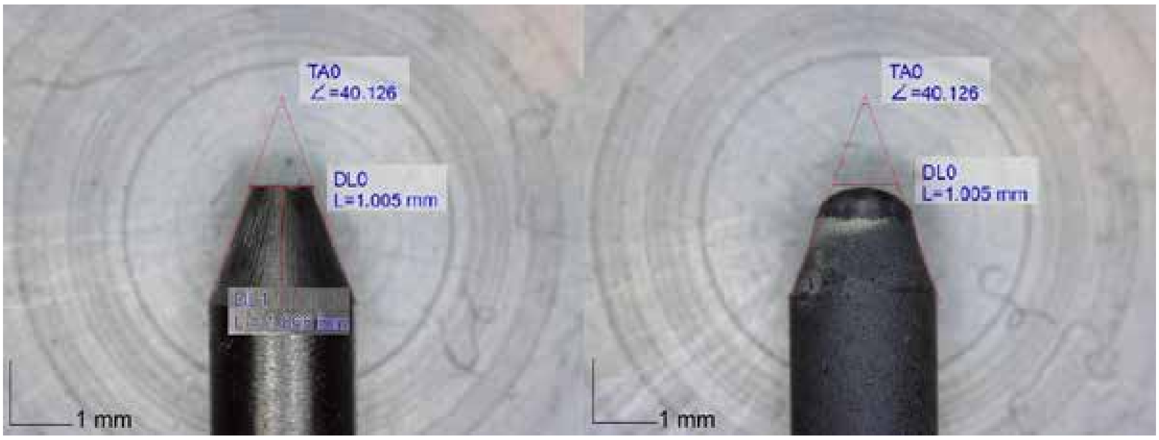
The first situation is stressful on the tungsten electrode, because the arc is creating a lot of heat. Although tungsten has a melting temperature of 3.422°C, it is just as affected by heat as any other metal. Meaning that the smaller the material, the less heat it can carry. A ground electrode cannot carry the same amount of heat at the point as further up the electrode. Therefore, welding at high amperage and creating a lot of heat wears down your tungsten. The worst-case scenario is the point of your tungsten electrode melting off and falling into your weld pool and thereby polluting the weld.

The second situation, welding aluminium, is stressful on the electrode because of the alternating current. When alternating current is applied, the heat is alternately focused on the electrode and the base material. Causing the electrode tip to melt and "ball up". With incorrect settings, ground or not, the electrode will "ball up" tremendously, causing an unstable and wandering arc, a wide weld pool and a poor-quality weld.

However, with the correct settings (frequency, AC-T and AC-I balance and electrode preheat) you can somewhat maintain the point of your ground electrode. If the electrode is too pointy, the tip will melt off, because of the heat applied on the



A ground electrode before welding (left) and after AC welding (right) with correct settings on the welding machine (Diameter Ø 2,4 mm, grinding angle 20° = tip angle 40°). Where did the tip go?



A ground and truncated electrode before welding (left) and after AC welding (right) with correct settings on the welding machine (Diameter Ø 2,4 mm, grinding angle 20° = tip angle 40°).

electrode. In this case, your tip might fall into your weld pool and pollute the weld.

In both situations you can diminish the risk of melting of the tip by truncating your tungsten electrode. Research has shown, that truncating the tip prevents the tip from melting off, preserves the tip and a stable arc, and extends the amount of time between regrinds.

Conclusion

Truncate the tip of the electrode if welding with high current or if AC welding!

Because it provides:

- Better welding quality
- More stable arc
- Less wear on the electrode.

(According to press information from Inelco Grinders)

The ABC of Joining - International Industry Guide

business partners Market overview manufacturers
Suppliers service providers German English
DER PRAKTIKER SCHWEISSEN UND SCHNEIDEN 6 main groups
830 keywords WELDING AND CUTTING 46 categories

www.abc-der-fuegetechnik.de/en/

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DVS launches website in English

The English-language version of the website www.dvs-home.de/en has been online since January 2022: International users can now find out about DVS and its range of services quickly and easily. The English-language site now gives users an initial insight into the association's far-reaching network, the diverse career paths in welding technology and DVS's international events.

The new DVS website was launched only last year: The online presence, which is optimised for all devices, provides all the necessary information about education, technology, research and the events of the DVS in a clear and concise manner, in addition to intuitive navigation. Talent promotion at DVS has found its own home under "Next Generation" at dvs-home.de.

"For years, we have been a strong partner all over the world when it comes to standards and norms in technology and in education and training," says Dr.-Ing. Roland Boecking, DVS Managing Director. "With the International Institute of Welding (IIW) and the EWF – European Federation for Welding, Joining and Cutting, we share more than a passion for technology. We are pleased that this is now also visible to visitors to our website."

In addition, the extensive DVS education system and the English-language DVS rules and regulations are of particular interest to international users, he said. "We experience this frequently through email enquiries or at trade fairs abroad," confirms Roland Boecking. "It is precisely here that we are now offering users an initial introduction to the world of joining, cutting and coating and making them curious about the extensive network of DVS educational institutions."

DVS student groups: Staying in touch during the pandemic

For many students, the past two years have been a difficult time: hardly any personal contact with other students, no lectures or seminars at the university or college, and sometimes technical challenges to study online. The DVS student groups felt this, too. Therefore, they changed to other formats to keep in touch with each other. One example is the group from TU Braunschweig.

Practice room with closed doors

At the Institute for Joining and Welding Technology at the Technische Universität Braunschweig, the consequences of the Coronavirus pandemic were clearly felt. Particularly painful for the students were the closed doors of the practice room in the institute basement. The welding machines were turned off. "Usually, we get together with our student group every two weeks in the evenings after the lecture and show the beginners various welding techniques," explains Paul Diekhoff, chairman of the group. The students were also unable to carry out their own projects, such as the design and manufacture of a barbecue a few years ago.

Normally, the meetings offer a lot more besides improving practical skills and learning different welding processes. The get-together is mainly for networking purposes. "The personal contact with the students as well as the relaxed socialising are missing and make it difficult to maintain the student group's network," says Diekhoff.

Social media channels

To stay in touch, the student group increasingly used social media channels. The exchange of information between the 45 participants is currently taking place in a separate WhatsApp group. With Instagram, another digital offer was created to inform the followers about the events of the DVS student group Braunschweig, @dvs.tu.braunschweig. Under the hashtags #WeldingWednesday and #HappyWelding, they regularly post pictures or they exchange ideas with each other in the chat group. There, many questions about welding are discussed and answered.

The two chairpersons of the DVS student group Braunschweig, Paul Diekhoff (left) and Tamás Tóth, kept in touch with their students digitally during the pandemic. Now they are looking forward to welding in the group again as well as to the personal exchange. (Photo: Paul Diekhoff, TU Braunschweig)

Since the winter semester of 2021, "the basement" has been open again and participants of the student group Braunschweig have returned there to weld and discuss with each other. "We hope that we can now keep the meetings going," says Diekhoff. Perhaps a new project will be started this year. Instagram and WhatsApp will continue to be used for exchanges, however. Interested parties are cordially invited to drop by there.

There are currently 15 student groups in DVS, which are supported by their respective district branch. If you would like to join a group or found a new one, you can get more information from Simone Weinreich at the DVS head office, phone +49 211 1591-302, email simone.weinreich@dvs-hg.de.

50 years of Tallinna Lasnamäe Mehaanikakool

Director Vladimir L. Beloi in his office in the 1990s.

View into the welding workshop of Tallinna Lasnamäe Mehaanikakool.

In September, the training years for school leavers in Estonia begin at vocational schools. In 2021, it was a special event for DVS's partner institution, Tallinna Lasnamäe Mahaanikakool (TLMK). The state-recognised educational institution could look back on 50 years of vocational education in Estonia. The last 30 years were marked by the gateway to Europe being opened. DVS, DVS PersZert, DVS ZERT, the Welding Training and Research Institute Mecklenburg-Western Pomerania and the DVS Mecklenburg-Western Pomerania Federal State Branch have maintained a partnership with this institution for about 25 years.

The then director Vladimir L. Beloi, with the support of the Ministry of Economics of Mecklenburg-Western Pomerania, laid the foundation for the establishment and development of the first DVS-recognised welding education institution in the Baltic States in Estonia. Estonian colleagues from the shipbuilding, steel construction and education sectors and colleagues from Mecklenburg-Western Pomerania, represented by Prof. Peter Seyffarth and Dr. Hans-Georg Groß, concluded a framework agreement for the establishment of a welding training centre according to DVS/EWF/IIW regulations.

The DVS Baltic Regional Branch and the DVS Mecklenburg-Western Pomerania Federal State Branch (LV) successfully worked towards national and international awareness. They succeeded in establishing a network with the German Embassy in Estonia, welding associations from Lithuania and Latvia came for consultations, the European Welding Federation (EWF), the International Institute of Welding (IIW) as well as the main certification committee of DVS use the educational institution for their meetings, seminars and courses.

One of the highlights of the events in the Baltic region was the "International Baltic DVS & GSI Forum" 2018 with the theme "Lifelong Learning & Industry 4.0", which helped the TLMK to gain further recognition. The cooperation made it possible to conduct qualifications for welding technical and management personnel as well as inspectors for visual, dye penetrant or magnetic particle inspection according to ISO 9712.

Today, the Welding Education Centre of Tallinna Lasnamäe Mehaanikakool operates as an accredited BE2 PS2 course centre of DVS PersZert. LV Mecklenburg-Western Pomerania continues to support the DVS Examination and Certification Committee and the DVS Baltic Regional ABranch in their cooperation in the interest of the Estonian and German economy.

More information is available from Dr. Hans-Georg Groß, email h.-g.gross@dvs-mv.de, and Vladimir L. Beloi, email vladimir.beloi@mehaanikakool.ee.

A lot to discover at the ITSC 2022 in Vienna, Austria

The ITSC 2022 in Vienna will offer a full spectrum of coating solutions. (Picture: DVS)

Access to the ITSC has never been so easy: First, this year's ITSC – International Thermal Spray Conference & Exposition will take place on 4 to 6 May in Vienna, right in the middle of Europe. In addition, two free-entrance events within the ITSC framework are aimed at parties interested in new coating solutions that want to learn without obligation about the practical possibilities of using various surface treatment technologies.

Not only thermal spraying techniques are part of ITSC 2022, but also cladding, soldering and additive manufacturing processes. The ITSC in Vienna offers attractive opportunities to learn about the various application possibilities of different coating processes:

- The "Industry Forum" presents application-related products, services and solutions from the industry – from practical experience for practical application.
- The forum "Thermal Spray in a Nutshell" is new at the ITSC. It examines the main application areas of thermal spraying in a clear and concise manner. Short, focused presentations provide information on the importance and practical application of processes across various industries.

Furthermore, a visit to ITSC is always worthwhile because of the high-calibre technical papers, discussions and the exhibition ("3-Days-Exposition"). The ITSC – International Thermal Spray Conference & Exposition takes place at the Austria Center Vienna (ACV). It is organised by DVS – Deutscher Verband für Schweißen und verwandte Verfahren e. V. (German Welding Society) in cooperation with the ASM International and the International Institute of Welding (IIW).

More information and the complete conference program is available online at www.dvs-ev.de/itsc2022/.

Isabel Nocker M. A.,
DVS Media, Düsseldorf/Germany

Call for abstracts: 24th IAS Steel Conference in October in Rosario, Argentina

The Instituto Argentino de Siderurgia (www.siderurgia.org.ar/home-e.php) will organise the 24th IAS Steel Conference with exhibition in Rosario, Santa Fe/Argentina on 25 to 27 October 2022. It will include topics ranging from raw materials to end-products, including sessions on safety and environment and with a special emphasis on "Steel Industry 4.0". The event will provide a good opportunity for researchers, manufacturers, suppliers and users in the steel industry around the world to review the progress in recent years, to assess new developments in steel research, production and application and to promote further international exchange and collaboration.

The Conference 2022 is the place for speakers to share ideas, experiences and knowledge of the industry. Thus, the organisers invite interested parties to submit their abstracts for consideration by 8 April 2022 on the following topics:

- Ironmaking,
- Steelmaking,
- Rolling,
- Processing, Products and Applications,
- Maintenance and Automation,
- Safety and Environmental Issues,
- Industry 4.0.

Abstracts may be submitted online at https://events.siderurgia.org.ar/24th-ias-steel-conference/ by 8 April 2022. The abstract must be written in English and it should provide sufficient information for a fair assessment including the objective of the paper, the methodology used and the conclusions or results of the work.

The Conference will be enhanced with the "Expo IAS 2022" to the steel industry at which companies will have the opportunity to share their latest developments and products. The exhibit area will be a key point of the conference. The exhibition will run throughout the event.

International trade fairs “wire” and “Tube” in Düsseldorf postponed to early summer 2022

Messe Düsseldorf postpones the international trade fairs “wire” (www.wire-tradefair.com) and “Tube” (www.tube-tradefair.com) in consultation with the partners and associations involved to 20 to 24 June 2022. The currently very dynamic infection patterns and rapidly spreading Omicron variant have resulted in adjustments in the Düsseldorf trade fair calendar that require re-scheduling the events originally planned for 9 to 13 May.

The new period offers more planning security and added value due to “Metav” (www.metav.com) held concurrently in part. This leading trade fair for metal-working technologies was already postponed by the organiser VDW (German Machine Tool Builders’ Association) to 21 to 24 June.

Wolfram N. Diener, CEO of Messe Düsseldorf, emphasises the backing for the new trade fair dates: “The tenor among our exhibitors is: We want and need ‘wire’ and ‘Tube’ – but at a point in time that promises the biggest prospects of success. Together with the partners and associations involved we regard early summer as the ideal period for this. We not only expect infection patterns to calm down but also more people to be able to enter the country and take part. This means exhibiting companies as well as visitors can do their business in an environment that is clearly less affected by Covid-19.”

As the No.1 international trade fairs for their industries, “wire” and “Tube” have global appeal and require particularly long lead times. Traditionally, two thirds of all exhibiting companies travel to Germany from abroad every two years. Trade visitors from over 80 countries meet at the Düsseldorf Fairgrounds at peak times. The new fair date from 20 to 24 June 2022 therefore now provides these industries with clear planning security.

Exhibitors at wire will present their technological highlights in exhibition halls 9 to 15, while Tube exhibitors will be in halls 1 to 7a. The guest event “Metav”, international trade fair for metal-working technologies, will be held from 21 to 24 June 2022 in exhibition halls 16 and 17. (According to press information from Messe Düsseldorf; www.messe-duesseldorf.com)

Development of a micro-habitat hyperbaric welding system – Part 2

Part 1 of this article was published in issue 4/2021 of WELDING AND CUTTING.

4 Diver safety

4.1 Regulatory measures

Compliance with the statutory requirements specified in (Health & Safety at Work Act 1974, 2019) concerning the management of major accident hazards (MAH) on offshore installations, is determined through various industry regulations, namely 'The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015' (UK Legislation, 2015). These regulations combine to determine an MAH (major accident hazard) by the definition given within the Approved Code of Practice (Health and Safety Commission, 2014). Not all are listed here, but the definition most applicable to the discussion is as follows: "The failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations."

The differentiating factor between a modular habitat and the "µ-Habitat" is that the former requires divers to remove their diving suits, making them more vulnerable in an emergency. In a scenario where the divers cannot return to their diving support vessel (DSV), they must enter a temporary refuge in the habitat. With the "µ-Habitat", the diver remains fully dressed in their personal protective equipment. Therefore, emergency scenarios are no different from any other diving operation, whereby the diver makes their way back to the safety of the diving-bell and DSV.

Fig. 7 • Framework risk assessment model.

Modular habitat systems have been and will continue to be operated safely from offshore installations with no other viable means of repair. The primary aim of 'The Offshore Installations (Offshore Safety Directive) (Safety Case Etc.) Regulations 2015' is to reduce the risk from MAH to workforce personnel (UK Legislation, 2015). In line with the Health and Safety at Work Act, this constitutes a continual demonstration that MAH risks are ALARP (as low as reasonably practicable). In other words, operators should only consider a modular habitat if the "µ-Habitat" is not a viable option, as in the case of a severed brace, for example.

The "µ-Habitat" significantly reduces risk to divers, and in certain instances, it eliminates some of the hazards associated with the use of a modular habitat. Remarkably, this technology innovation reduces risk and business costs, which is in contrast with the traditional model shown in **Fig. 7**, where the cost associated with risk reduction efforts is often grossly disproportionate to the achieved risk reduction.

4.2. Step change in safety

The development of the "µ-Habitat" marks a significant step forward in diver safety. Some of the main advantages are as follows:

- no requirement for a life support package (LSP),
- no requirement for diver safety module (DSM)/escape refuge,
- no working in a confined space, and
- no explosive environment.

The most notable feature is that the diver can remain fully dressed in their diving suit, supported by an umbilical line from their DSV, as per any standard diving operation, avoiding the requirement for a topside LSP. In an emergency, the diver returns to the bell instead of being forced to seek refuge in a DSM. Another significant improvement

Hazard description	Modular habitat	*µ-Habitat*
Fire generated within the habitat system due to hot works	Risk mitigation required	Not applicable
Fire adjacent to or impinging on the habitat (Riser Fires)	Risk mitigation required	Risk mitigation required
Drowning due to water ingress	Risk mitigation required	Not applicable
Toxication due to smoke within the habitat system	Risk mitigation required	Not applicable
Structural collapse due to adverse weather	Risk mitigation required	Not applicable
Evacuation from the habitat to the TR is possible in every hang off position regardless of a hydrocarbon fire event at or adjacent to the habitat entrance	Risk mitigation required	Not applicable
Standard means of evacuation (Escape Route, TEMPSC, Life raft, Donut) would not impede the exit of the habitat in any of its hang-off positions.	Risk mitigation required Location-specific	Not applicable

Table 1 • Comparison of prevention of fire and explosion and emergency response regulations (PFEER) requirements between modular and "µ-Habitat" systems.

is eliminating the confined space working environment, negating the need for a breathing gas regeneration system and extraction of welding fumes and gases.

The "μ-Habitat" significantly reduces the time required to complete a repair compared to a modular habitat. The reduction in offshore dive time alone results in a risk reduction as there is less hazard potential, **Table 1**.

Aside from the commercial advantages that the "μ-Habitat" offers, one can easily see that operators should aim to adopt the "μ-Habitat" as the base-case repair technology in all compatible scenarios. In doing so, they would meet the ALARP criteria.

5 "μ-Habitat" concept design and selection

The "μ-Habitat" concept originated because of a distinct technological gap in current subsea repair methodologies. Subsea structural repairs have typically relied on purpose-built bespoke welding habitats that require long lead times and significant upfront costs. More recent techniques use modular habitat systems, which are more flexible in that a single habitat can fit multiple weld locations rather than a single location (Mann et al., 2013). Although an improvement on earlier designs, the modular habitat system is not without drawbacks, such as a significant amount of topside support being required and long installation times, ultimately leading to costly high-risk repairs.

The solution, whatever it may be, must be safer, more efficient, and more cost-effective while remaining flexible. Employing a combination of design techniques, such as design thinking, first principles, and minimum viable product (MVP), to design and engineer a practical and effective repair solution was highly effective.

5.1 Design thinking

Design thinking has been around for many years but not widely used outside of the design community until about ten years ago. The process can be very effective in developing new products, services or formulating innovative solutions to a wide range of problems (Brown 2019).

Design thinking sets out to simplify the design process by breaking it down into simple steps (Dam & Teo 2019):

1. Empathy:
   Understand the problem from every point of view.
2. Exploration:
   Explore every possible solution, i.e. even the radical.
3. Iteration:
   Engage rapid iterative prototyping.
4. Validation:
   Function testing in a real-world application, i.e. mock-ups.

The process is not without its criticism – an oversimplification of the design process and diminishing technical importance are common complaints (Brown 2019). However, a modified version of design thinking in conjunction with first principles, MVP and AGILE, were highly effective process facilitators for the development of the "μ-Habitat" from concept to final delivery (offshore execution), **Fig. 8**.

5.2 First principle thinking

Applying first principle thinking – focusing on function and not form, allowed us to break free from current narrow constructs to find a new and innovative solution. When tackling complex problems and developing cutting-edge ideas or radical innovations, it is often very effective to break down the problem or solution into their fundamental parts, we know to be true, using first principles (Anderson 2012), **Fig. 9**.

5.3 Front end engineering design (FEED)

Conducting a FEED study and producing a basic design report is necessary before fabrication and full-scale production of the "μ-Habitat". Thus allowing an investigation into the system feasibility and likelihood of making surface quality welds in a "μ-Habitat".

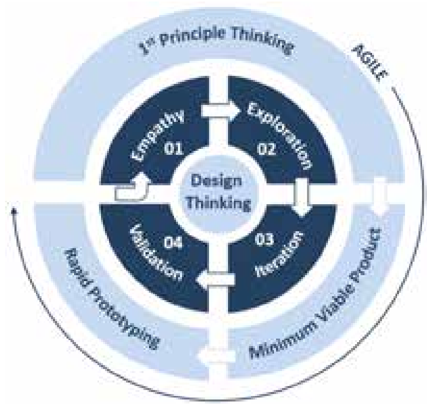

Fig. 8 • "μ-Habitat" development process framework.

5.4 Design drivers

The primary and overarching design driver for the "μ-Habitat" was diver safety, risk reduction and restoration of the platform jacket integrity. The secondary design driver was cost reduction in both (CAPEX), and project operating (OPEX) costs. This results in the following strategies:

- Reduce or eliminate project safety hazards and risks.
- Reduce fabrication and construction costs by reducing the habitat size, with standardised components compatible with all "μ-Habitats".
- Reduce topside support services as much as practicable.
- Reduce installation cost by reducing the "μ-Habitat" footprint and improving the sealing efficiency.
- Reduce repair execution cost via extensive mock-up testing to ensure operational efficiency.

The evolution of the "μ-Habitat" design resulted in a significant increase in the maximum number of weld configurations

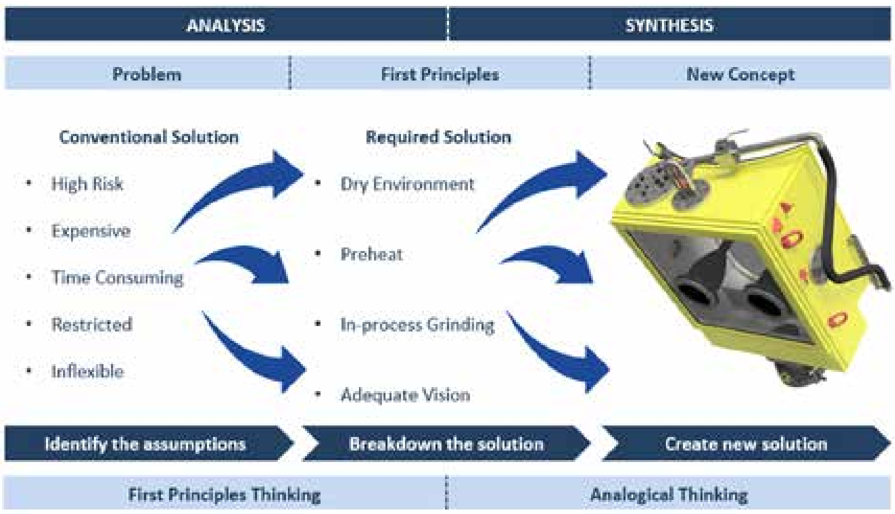

Fig. 9 • "μ-Habitat" concept development using first principle thinking.

Fig. 10 • "µ-Habitat" concept evolution.

and locations accessible via this radical new approach, **Fig. 10**. The key to this achievement was a collaborative effort between the contractor and asset owner. Extensive prototyping and factory acceptance testing of completed "µ-Habitats", prior to use, provides the necessary validation and learning, facilitating continuous improvement.

5.5 "µ-Habitat" key criteria

The "µ-Habitat" key requirements are as follows:

- The habitat design and selection of hardware/tooling shall minimise Non-Productive Time (NPT) during offshore operations.
- The habitat shall be capable of performing a complete through-thickness repair at any radial position on either vertical, horizontal or diagonal members.
- The habitat shall be capable of achieving and maintaining a positive pressure differential.
- The habitat shall provide the diver with a clear, unobscured view of the repair site.
- The habitat shall permit the use of preheat.
- The habitat shall permit the use of a portable arc monitoring system (PAMS).
- The habitat shall permit the use of grinding or power wire brushing.
- The habitat shall be capable of allowing non-destructive testing (NDT) of the repaired weld.
- Multiple welding processes must be able to be used inside the habitat.
- The option to supply the habitat with welding gas/electrical/air from DSV or topsides.
- The habitat shall ensure that the health and safety risk of all activities is as low as reasonably practicable.

5.6 Detailed design, fabrication & assembly

Using a product development methodology such as AGILE or SCRUM (commonly used in software development) for producing, implementing, and advancing emergent technologies reduces the preparation time, making the system exceptionally responsive yet flexible. Additionally, employing a dedicated, small, and cross-functional team in combination with a standardised product further reduces the response time required to execute a subsea repair.

The approach outlined below resulted in the delivery of four "µ-Habitats" in the first six months of production. With each habitat gaining in sophistication and addressing specific requirements, yet the design, fabrication and testing, **Fig. 11,** took less time than the previous version demonstrating the value and need for a product development/process improvement framework to be in place.

Similar to design thinking, process improvement methods break product development into small increments that decrease the time required for planning and design. Short, iterative and incremental development cycles stimulate the creative product evolution. In the interval between each of the production cycles, it was possible to produce a working unit. The lessons learned from the previous phase are applied in the subsequent production cycle, resulting in continuous improvement, **Fig. 12**. The phased approach minimises risk and allows the "µ-Habitat" system to adapt to new requirements or specifications.

5.7 Design verification

Acceptance testing is conducted on each unit after production to determine if

System Component / Function	Test	Result	Acc/Rej
De-watering	Time to De-water	< 5min	✓
Sealing / leak test	Pressure loss after 24hr hold	<0.1bar	✓
Maintain constant internal pressure	Monitor internal pressure	± 1 %	✓
Exhaust welding fumes/smoke	Gas purge	Fumes exhausted	✓
Adequate vision	Constant gas purge	>0.5 m	✓
Inserting / removal of hands in gloves	Insert/remove @ Δ P_{bar}	< 1 min	✓
Parameter Arc Monitoring System (PAMS)	Verify amps & volts	± 1 %	✓
Pre-Heat system	Time to temperature	< 1 hr	✓
Thermocouples	Temperature Verification	± 1 %	✓
Internal lighting	Night simulation (dark pool)	> 1.0m	✓
Internal cameras	Function test (wet/dry)	Good picture	✓
Internal / external pressure sensors	Function test (wet/dry)	± 1 %	✓
GTAW / SMAW welding tests	Full weld simulation	NDT/Mech test	✓

Table 2 • Factory acceptance testing summary.

the specifications' requirements have been met. As a minimum acceptance testing of the "µ-Habitat" consists of the physical and performance tests showing in **Table 2.**

6 Conclusion / Summary

Many North Sea platforms are projected to achieve sustained production for more than 20 years. The capability to effectively repair structural defects is fundamental to meeting these targets, particularly in the context of mature fields. According to Ikeda (Ikeda, 2015):

"As production curves decline and the production infrastructure ages, these fields become technically, operationally and economically challenging." … "Contrary to the notion that the life of a producing asset ends when production runs out, the reality is that the life of the asset ends when profit runs out. This situation presents a conundrum for many operators."

The "µ-Habitat" can help shift the economics in mature fields by offering operators a cost-effective means of meeting this challenge. As a result of these savings, the "µ-Habitat" can go a long way in maintaining the economic viability of mature assets.

The "µ-Habitat" creates a step-change for future repair projects and facilitates the ongoing effort to reduce asset integrity costs as follows:

A step-change in diver safety

- divers remain within their suits at all times,
- no requirement for temporary refuge,
- no reliance on a topside life support facility, and
- reduction in offshore execution time, reducing the risk to divers.

A step-change in weld repair technology

- significant cost savings due to faster repair times (reduced vessel days), reduced weather dependency, and minimal topside spread,

Fig. 11 • "µ-Habitat" factory acceptance test (FAT) / mock-up trials.

- significant cost savings owing to the ability to qualify welders in a test tank rather than the hyperbaric centre,
- reduced project risk profile from the knowledge that further divers can be rapidly qualified and sent offshore,
- offers a rapid response solution in < 2 months from defect discovery,
- ability to access all subsea welds without depth restriction (within SAT diving ranges),
- ability to access congested areas,
- minimal disruption to topside asset.

The "µ-Habitat" is regarded as a relatively radical approach, so much that when the concept was initially conceived, it was met with significant scepticism. Gaining confidence in the idea and the backing of management were the first challenges to overcome.

The following approaches were adopted to convince critics and gain sanctioning for the project:

- Phased approach with predefined gate criteria to limit exposure/control cost.
- Minimum capital expenditure through the use of existing parts/equipment/facilities.
- Capital expenditure minimised during product development until the concept was proven.
- Standardisation was applied where possible.
- All parts/components were standardised and interchangeable, reducing cost while simplifying the solution.
- Early prototyping/testing of the "µ-Habitat" validated assumptions while providing proof of concept resulted in management buy-in.

Of course, the "µ-Habitat" has its limitations, which appear in the form of brace severances. The central underlying premise of any integrity strategy should be a conscious effort to minimise the risk of brace severance. However, by harnessing the flexibility of the "µ-Habitat", it offers operators the best chance of avoiding a severance scenario and ensuring structural integrity compliance.

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Fig. 12 • "µ-Habitat" product manufacture process framework.

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Friction stir welding of steel for shipbuilding and marine applications

1 Executive summary

Friction stir welding is a solid-state joining process invented by TWI and originally used for making strong, lightweight, fatigue resistant, aluminium fabrications. Its success in that application has spurred demand for the process to be developed for joining steel, particularly for the European shipbuilding industry, and project RESURGAM was set up to achieve that. RESURGAM is a three year, EU funded, multi-national research initiative managed by the European Welding Federation (EWF) to develop the equipment, processes and qualification routes needed for fabricating ships and conducting underwater repairs of steel structures using FSW. This Technical Bulletin summarises progress made during the first six months of the project, specifically regarding the technical achievements in developing the FSW tools and welding techniques that provide the underlying process technology.

The objectives of the process development that forms Work Package 1 of the RESURGAM project are to:

- develop FSW tools suitable for welding marine grade steels in air and liquids;
- establish the performance (longevity and reliability) of FSW tools for steel used in air and water;
- establish the FSW process envelope for specific tool sizes in air and water;
- determine the weld properties of marine grade steels welded by FSW in air and water;
- develop a route map that will enable guidelines to be drawn up to allow the use of steel FSW for marine applications.

Work performed on the fundamental friction stir welding technology that underpins RESURGAM during the first six months of the project has shown that:

- Steel up to 12 mm thick can be friction stir welded by the tools developed by Element Six (UK) Ltd.;
- Butt welds in the grades of steel being targeted can be made whose strength is at least equal to that of the parent metal;

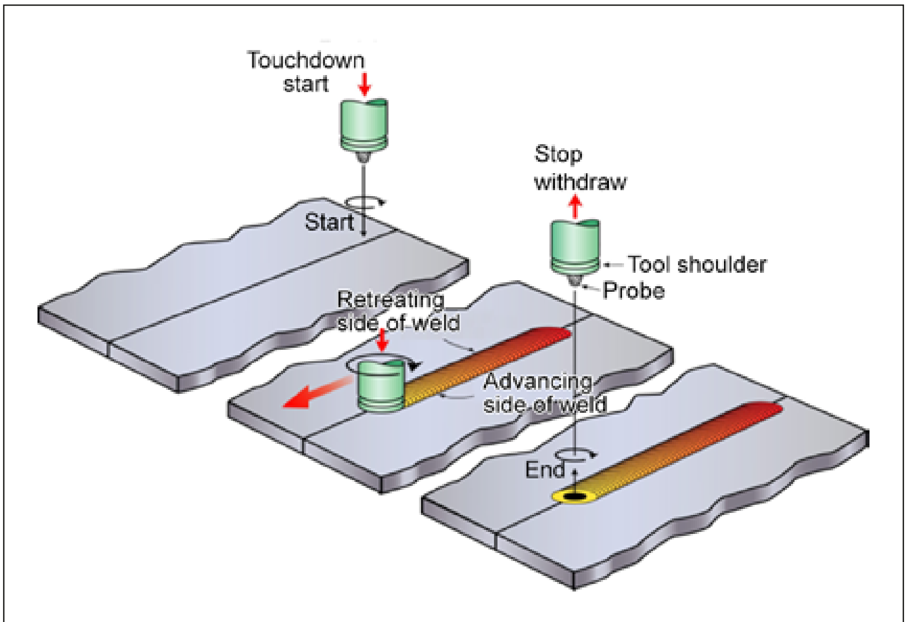

Fig. 1 • The basic principle of friction stir welding.

- Two-dimensional lap welds suitable for making fully sealed patch repairs can be made through 6 mm thick steel plate;
- An integrally stiffened panel (ISP) can be made from rolled T sections and flat plate, reducing the number of welds required by half when compared with conventional welding techniques.

2 Introduction and the need for steel FSW

Friction stir welding is a solid-state welding process invented by TWI in 1991 and subsequently widely used for the fabrication of structures requiring high strength, lightweight, fatigue resistant joints. The process was originally developed for joining aluminium, as this is considered a difficult material to weld, and was subsequently developed for other hard to weld metals such as magnesium and copper. The process of friction stir welding, illustrated schematically in **Fig. 1**, is very simple:

- A rotating tool is used to generate frictional heating which softens the material to be welded;
- The tool is then traversed along the joint line, mechanically stirring the two components together.

FSW was quickly adopted as a fabrication technique for spacecraft, trains, shipping and automotive components, as well as electronics assemblies and consumer goods, all applications where aluminium joints needed to be made that were strong, tough, fatigue resistant and lightweight. Once the good mechanical properties of FSW joints were recognised, along with the benefits of the potentially low cost and automated means of creating them, users began to request that the process be developed for steel too.

An area where FSW in steel is likely to see early use is in shipbuilding and ship repair, for which the technology is being developed as part of the RESURGAM project. This is a three-year, EU funded, multi-national research initiative to develop the equipment, processes and qualification routes needed for fabricating ships and conducting underwater repairs of steel structures using FSW.

3 Tool development

The development of tools sufficiently strong to stir steel, and to be chemically inert to the steel itself at the high temperatures required to soften it, means that introducing FSW to steel is a challenging undertaking. Steel does not soften and flow sufficiently for friction stir welding until almost twice the temperatures experienced with aluminium, typically around 900 to 1,000°C. Few materials retain adequate strength, toughness and abrasion resistance to stir steel at such temperatures and of those that do, the problems of steel's high chemical reactivity results in rapid tool wear as the hot steel effectively alloys with and dissolves the tool.

Fig. 2 • Element Six FSW tools for welding 6 mm and 12 mm thick steel.

Consortium member Element Six is a world leader in the development of materials for use in extreme environments, particularly at high temperatures and under extremely abrasive conditions. Using that expertise, Element Six developed a Polycrystalline Cubic Boron Nitride (PCBN) based tool for welding steel of 6 mm and 12 mm thickness. Examples of the tools are shown in **Fig. 2.**

Work is ongoing to refine the design of the tools and the materials used to manufacture them, the intent being to:

- enhance tool life;
- reduce tool cost;
- increase the thickness of steel that can be welded.

4 Process development for steel FSW

4.1 Preliminary tool evaluation

The prototype tools developed by Element Six for welding 6 mm thick steel have been tested at TWI and shown to be consistent from batch to batch, and capable of producing defect free welds in carbon steel under several different testing conditions described below:

Regimen 1: Multiple 2 m welds

- Multiple tool plunges into cold, hard steel;
- Tool operating several minutes at elevated temperatures;
- Typical of pipeline welding, repair welds, assembly work.

Regimen 2: Multiple 5 m welds

- Fewer tool plunges into cold, hard steel;
- Tool operating typically 20 minutes at elevated temperature;
- Typical of modular construction, pressure vessels.

Regimen 3: Fewer, but longer, 20 m welds

- Two or three tool plunges into cold, hard steel;
- Tool operating at elevated temperature for an hour or more;
- Typical of panel production for ships.

The welds were made at a welding speed of 300 mm/min in S355J2+N steel. Under all service conditions, the tools were capable of producing consistent, defect free welds. All tools tested reached an accumulated weld length of 40 m, with no failures experienced during the trials. Testing is still ongoing to determine the ultimate longevity of the tools.

4.2 FSW objectives in project RESURGAM

A second series of tools, designed for welding steel 12 mm thick, was then developed by Element Six and provided for further development of the FSW process at TWI. The objectives of the process development that forms Work Package 1 of the RESURGAM project are to:

Fig. 3 • Surface detail of a friction stir weld in 12 mm thick S460 steel.

Fig. 4 • Image of a DH36 steel 'patch' lap welded to a 12 mm thick S460 'hull' plate.

- develop FSW tools suitable for welding marine grade steels in air and liquids;
- establish the performance (longevity and reliability) of FSW tools for steel used in air and water;
- establish the FSW process envelope for specific tool sizes in air and water;
- determine the weld properties of marine grade steels welded by FSW in air and water;
- develop a route map that will enable guidelines to be developed to allow the use of steel FSW for marine applications.

4.3 FSW parameter and process envelope development

As part of RESURGAM, process control parameters will be developed for steel that will allow good welds to be made in S355, S460 and DH36 steel, in both air and water, in thicknesses up to 12 mm. These parameters will need to be suitable for the two application cases being considered under RESURGAM:

1. The fabrication of modular assemblies, e.g. stiffened panels, using a converted milling machine, for dockyard construction;
2. The welding of a repair patch, under water, to a representative section of damaged ship's hull.

4.3.1 Primary and secondary process control parameters

Parameters exist that, by varying them, allow control to be exerted over the FSW process. These may be termed Primary or Control parameters and include:

- Tool rotation speed;
- Welding speed;
- Tool plunge depth;
- Tool tilt angle.
- Tool down force (FZ).

During the weld, other parameters can be measured to give some degree of feedback as to how the FSW operation is proceeding. These are the Secondary parameters and include:

- Spindle torque;
- Traverse force (FX);
- Lateral force (FY);
- Tool temperature;
- Workpiece temperature.

4.4. Operational constraints

Different constraints will apply to the two applications cases. It is envisaged that the force and torque requirements in particular will place limitations upon the thickness of steel that can be friction stir welded by a retro-fit head on a converted milling machine. Previous experience has shown that it is possible to friction stir weld 6 mm thick carbon steels at industrially useful speeds (around 300 mm/min) using axial forces of around 60 kN, and it is the aim within RESURGAM to try and develop tool designs and process parameters that will bring this force requirement down to around 40 kN for similar thicknesses of steel. Consideration will also be given to developing parameters that minimise heat transfer into the welding machine.

The FSW machine that is required to work under water will need to be marinised, and be capable of remote operation. These particular attributes will be addressed by consortium partner Forth Engineering, who have considerable experience in this type of work. It is likely that the machine will need to be hydraulically rather than electrically actuated, and the marine environment may present problems with control systems that rely on vision. The machine can probably be reasonably large, thus space is not likely to be a constraint, and cooling of the tool

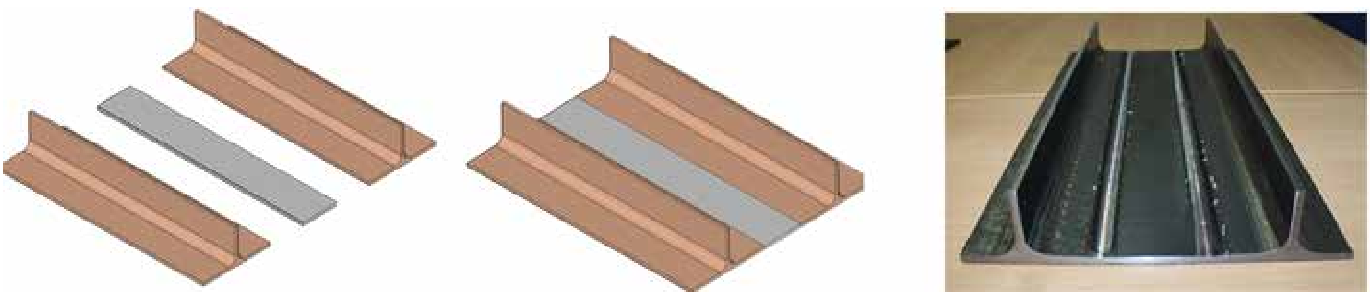

Fig. 5 • Concept of stiffened panel construction from rolled T sections spaced apart with rolled plate (left); integrally stiffened plate demonstration piece fabricated by friction stir butt welding two rolled T sections to a steel plate.

holder may not be a critical factor either as the marine environment will provide a large and effective heat sink.

5 Proof of concept demonstrations

5.1 Butt welds

The simplest weld geometry is a square butt weld where the two plates to be joined are laid edge to edge and joined by making a single pass with the FSW tool along the joint line. This has been demonstrated for DH36, S355 and S460 steel in two thicknesses, 6 mm and 12 mm. **Fig. 3** shows just such a weld made between two plates of 12 mm thick S460 steel.

To represent a real world rather than a laboratory welding scenario, the plates to be welded were not cleaned and degreased, nor were the mating edges prepared. Despite being made through a layer of surface rust, the weld was smooth and regular with no toe flash or surface imperfections.

A macro-section through the weld showed there to be no internal defects and, under tensile testing, the cross weld test piece failed in a ductile manner in the parent metal outside the weld and heat affected zone. Test pieces cut from the weld at the weld start, middle and end all passed face and root bend tests.

More detailed mechanical testing of the welds, including hardness, toughness and fatigue testing will be undertaken by consortium member TUD (Technical University of Delft) at a later stage in project RESURGAM.

5.2 Lap welds

A second application of friction stir welding being developed in RESURGAM makes use of the ability of FSW to make good welds under water – or even other fluids such as oil. Consortium member Forth Engineering Ltd is developing a robotic system that will be capable of being deployed underwater to weld a repair patch over a damaged structure, such as a ship's hull, to effect a temporary or even permanent repair without the need for either dry docking the vessel or using a hyperbaric welding chamber and conventional welding techniques.

Such a weld is most easily achieved by making a lap weld through a steel patch placed over the damaged region of the ship's hull, and the feasibility of this has been demonstrated at TWI. **Fig. 4** shows a 4 mm thick DH36 steel patch lap welded to a 12 mm thick S460 steel hull plate using a 2D weld. The weld was made using a 12 mm tool, so penetrating 8 mm into the hull plate to provide a watertight seal. The weld was made through the primer coat of the patch, and the underlying hull plate was not cleaned or degreased prior to welding.

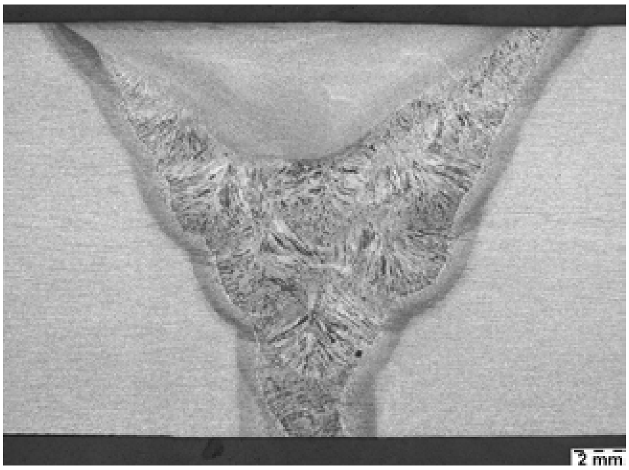

Fig. 6 • A metallographic section through a multi-pass arc weld in 20 mm thick carbon steel, with the weld cap re-processed by FSW to show the difference in weld microstructure. The FSW has a fine microstructure close to that of the parent metal, whereas the arc weld has a coarse, cast microstructure.

5.3 Integrally stiffened panels

Many ships (and civil engineering structures) are built in a modular fashion from assemblies of stiffened panels. Traditionally, these stiffened panels are made by welding ribs onto a flat steel plate, usually by making a fillet weld along both sides of the rib. Complex welding procedures are necessary to minimise distortion arising from the heat input to the weld zone and so allow good fit up of the panels produced. An alternative technique, maximising the benefits of friction stir welding, replaces the two fillet welds with a single butt weld to join a wrought plate spacer to a rolled T section, **Fig. 5**. This results in a fully forged structure that is potentially stronger, more fatigue resistant and less distorted than an arc welded equivalent.

6 Metallurgical considerations

The fine grained microstructure seen in friction stir welds generally provides them with tensile strength properties closer to the parent metal than is typically the case with conventional fusion welding, **Fig. 6**. With steel, this benefit is further enhanced by the fact that welding takes place in the transformation temperature range and careful selection of the welding parameters can exert a useful degree of control over the phase transformations that take place during the welding process. It is possible, for example to make welds optimised for strength or for toughness, or a combination of both, depending upon the service requirement. It is generally the case that friction stir welds in steel are found to be stronger than the parent metal in which they were made. Where friction stir welds are made between dissimilar grades of steel, for example a carbon steel and a stainless steel, the failure tends to occur in the weaker of the two parent metals and away from the weld zone.

During RESURGAM, TUD will investigate the microstructures generated in steel FSW and assess how they influence the mechanical properties of the welds made.

7 Conclusions

Work performed on the fundamental friction stir welding technology that underpins RESURGAM during the first six months of the project has shown that:

- Steel up to 12 mm thick can be friction stir welded by the tools developed by Element Six;
- Butt welds in the grades of steel being targeted can be made whose strength is at least equal to that of the parent metal;
- Two-dimensional lap welds suitable for making fully sealed patch repairs can be made through 6 mm thick steel plate;
- An integrally stiffened panel (ISP) can be made from rolled T sections and flat plate, reducing the number of welds required by half when compared with conventional welding echniques.

(According to press information from © TWI Ltd and Element Six (UK) Ltd)

INFO

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Weld overlay cladding offers enhanced performance

Fig. 1 • TIG welding overlay cladding with reclining lance.

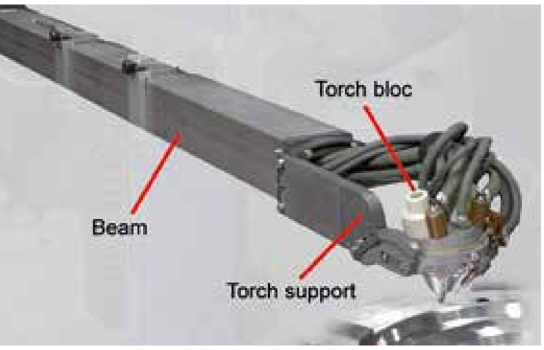

Fig. 2 • Reclining welding lance for the TIG^er process.

Since many years the French company Polysoude enjoys excellent reputation in the area of weld overlay cladding. Process controller, power source, mechanical system components, cladding lances are the result of continous improvement and close cooperation with end users. In 2013 Polysoude has introduced the unique TIG^er technology, a modified TIG hot wire process. The two TIG arcs released by the bi-cathodic torch are controlled and transformed to one single arc with characteristics which differ significantly from an ordinary TIG arc **(Fig. 1)**. The enhanced energy concentration allows remarkably improved melting rates whereas low dilution between layer and base metal helps to meet the strict requirements of today's cladding standards and guidelines.

Originally, the TIG^er cladding lances have been made for circular or longitudinal cladding of the inside or outside of cylindrical bodies. However, the outstanding performance of the TIG^er process especially if mounted on a CNC machine, has created the demand to handle more complex workpiece geometries.

For the design of a cladding lance a lot of technical marginal conditions have to be taken into consideration, e.g. the welding position which depends on the orientation of the workpiece, the shape and size of the surface which has to be cladded, the characteristics of the machines which hold and lead the lances on their trajectories (column and boom equipment, longitudinal seam welders, gantry devices, etc.). Based on a comprehensive analysis of the related problems Polysoude has developed a torch which can be configured to meet most of the technical requirements.

Reclining welding lance for the TIG^er process

The reclining welding lance is composed of a beam which allows mounting the cladding lance at its right or left side, an adjustable, modular and symmetric torch bloc **(Fig. 2)**. A bore diameter of only 150 mm is sufficient to introduce the lance, the length of the cladded area can be up to 1 m.

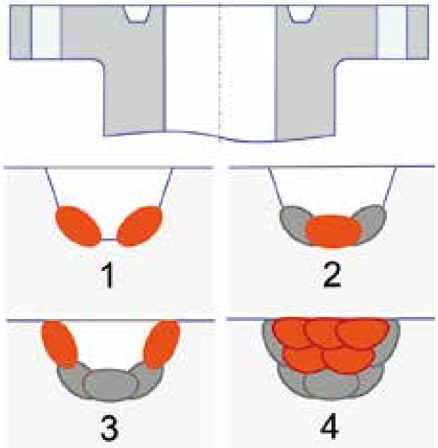

Fig. 4 • Scheme of a flange to be sealed with a metallic joint and schematic drawing illustrating the principle of groove filling.

The torch bloc is adjustable in whatever axis by means of an Allen key, the two torches can be reclined independently of one another so that the optimum configuration for each particular cladding task becomes possible.

Within the duty cycle of the torch two welding currents, one per electrode with an intensity of up to 2 × 300 A can be applied, complemented by a hot wire current of up to 140 A.

For easy set-up of the lance the so-called preferred positions P1, P2 and P3 **(Fig. 3)** are indicated on the different components. To fit the desired application, the indicated reference points on the torch bloc and the used sector have to be aligned.

In the same manner the wire guide is mounted on a setting ring to ease the finding of the best position for correct wire impact **(Fig. 3)**.

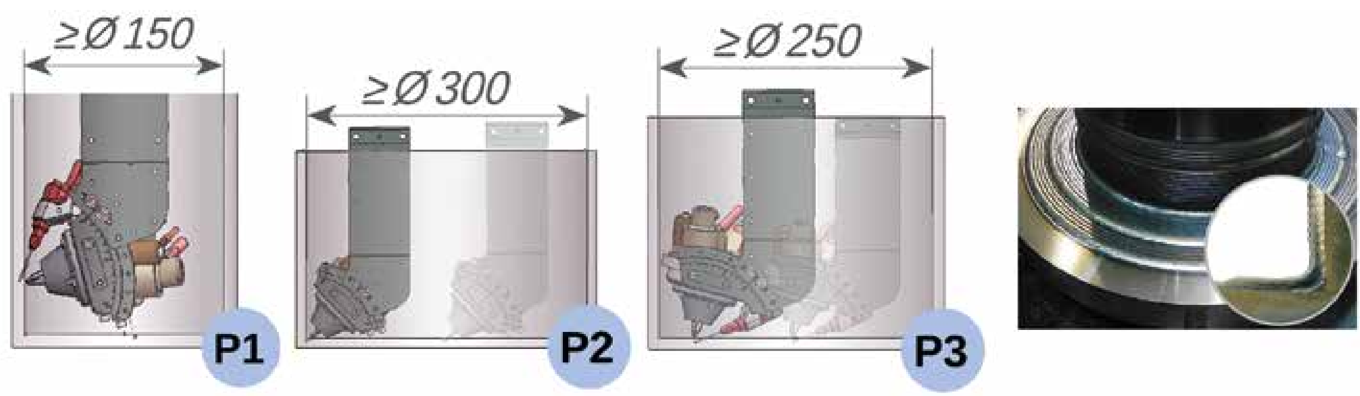

Fig. 3 • Preferred positions P1, P2 and P3: position P1 has to be taken if a cylindrical body has to be cladded at the inside; position P2 is chosen if the wire impact shall be suitable for cladding of a corner; position P3 is selected if the bottom of a workpiece shall be cladded (left). Example of a workpiece where the three preferred torch positions are used (right).

Fig. 5 • Adjustment of electrodes and wire for the cladding of the flange surface and example of a cladded specimen.

Fig. 6 • Example of an area where the "Patch" function becomes indispensable.

The modular design of the reclining TIG^{er} torch is perfect for cladding in tilted position, the orientation of electrodes and wire impact can be different so cladding in reverse directions becomes possible.

Components for high temperatures or high pressure are often equipped with flanges which are to be sealed with circular metallic joints. The grooves in the flanges are filled by weld overlay cladding, after this the entire surface is cladded with corrosion-resistant alloy. The final geometry and surface quality are obtained by machining.

The cladding operation is executed in two phases: during the first one the groove is filled, the second one consists of depositing a coating on the entire surface of the flange.

The filling of the groove starts at the corners, matching welding speed and proper filler wire setting. The TIG^{er} torch is tilted, the wire impact is adjusted in front of the arc **(Fig. 4)**.

Several filler passes are afterwards laid with the TIG^{er} torch perpendicular to the surface of the groove bottom, the two electrodes are set in line and the wire impact occurs behind the arc.

During the second phase of the procedure the surface of the flange is cladded with two layers; the TIG^{er} torch is positioned perpendicular to the surface of the flange and the two electrodes, and the wire are set in the classic TIG^{er} configuration **(Fig. 5)**.

As further innovation: a software-based solution

For cladding equipment with CNC machines, i.e. of the type Polyclad CN, Polysoude has introduced a function named "Patch" which is quite useful for areas which cannot be described easily in geometric terms (**Fig. 6**). The function is based on torch trajectory control and may be applied for the cold and hot wire TIG process as well as for the TIG^{er} technology. The choice of "Teaching" simplifies the specification of the zone to be cladded.

The indicated surface is cladded by means of a cladding cycle where the torch is moving back and forth (with indexed feed and inversion of the welding direction).

The "Patch" function is part of the menu "Cylinder" within the process controller software of the CNC machine. The shape of each surface has to be specified by the coordinates of 4 points which can be memorised either by teaching or by direct input of their position. In cladding direction, the points are memorised in pairs marking the limits of the surface to be cladded. The turning points of the direction are interpolated by the software, due to the particular radius of gyration an additional correction of the welding speed can be carried out (**Fig. 7**).

Within the "Patch" mode the reverse function can be activated; the automatic reversion of the cladding direction serves to avoid multiple stops and starts during the cladding cycle (**Fig. 8**).

The combination of a reclining TIG^{er} lance with the "Patch" mode simplifies considerably the programming of complex workpiece geometries, often the areas which have been accessible in the past only by manually can now be cladded automatically.

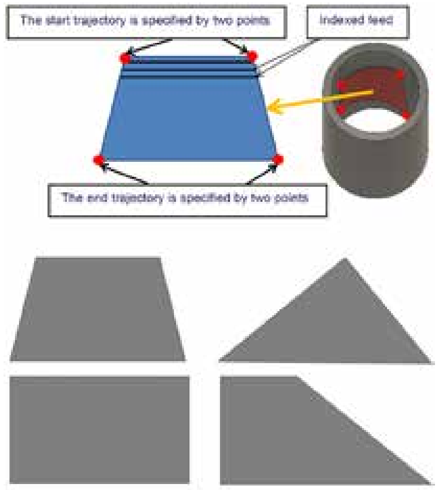

Fig. 7 • Examples of a surface defined by memorising four reference points (above) and of surfaces which can be specified with the software.

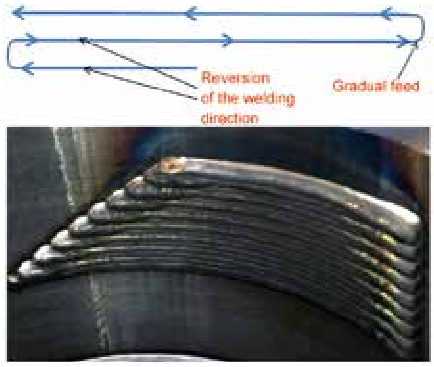

Fig. 8 • Cladded surface obtained by the "Patch" mode including reversion and welding speed correction.

The entire equipment for improved weld overlay cladding operations is now available: besides the unrivalled quality as result of the TIG hot wire process the TIG^{er} technology can be used to obtain increased deposit rates whereas a reclining welding lance together with related software stand for higher productivity. Virtually all workpiece geometries from simple cylinder bodies up to complex penetrations can thus be programmed and cladded easily.

(According to press information from Polysoude, www.polysoude.com)

Flexible bonding of flexible hybrid plastic bipolar plates

The production of graphitic bipolar plates by building them up layer by layer from individual flexible foils, instead of preformed halves, represents a new manufacturing approach. Five layers of a special compound foil were individually cut with a CO_2 laser according to a previously constructed cell design and joined into a bipolar plate with the help of adhesives. Selected epoxy resin adhesives, acrylate pressure-sensitive adhesive tapes and polyolefin hotmelts were tested for their suitability in the fuel cell environment with regard to electrical conductivity, chemical resistance and hydrogen impermeability. The bonded, foil-based bipolar plate showed significantly higher electrical contact resistances than the injection-moulded reference. In the test rig, such a bipolar plate was successfully operated for 379 h under fuel cell operating conditions without any leaks occurring.

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KEYWORDS

adhesive bonding, material questions, fuel cell, bipolar plate

1 Introduction

Due to the Paris Climate Agreement and the uncertain long-term availability of fossil fuels, alternatives to the combustion of fossil raw materials are being sought for the propulsion of vehicles, or for the provision of electrical energy. For this reason, the purchase of electric cars is already being subsidised in Europe and the registration of new petrol and diesel vehicles will be restricted or even completely banned in the coming decades [1]. Alternatives to the petrol and diesel engines are battery-powered or fuel cell-equipped vehicles and systems. The combination of battery-powered drive and on-board power supply via a fuel cell also represents a possible alternative for energy-intensive luxury and commercial vehicles (e.g. refrigerated transport) [2].

Hydrogen fuel cells (FC) are an efficient solution for providing electrical energy for several applications. With up to 65%, the fuel cell has a considerably higher efficiency than heat-power machines [3]. Compared to batteries, power and capacity of the fuel cell can be scaled independently by increasing the active area (flow field) of a bipolar plate (BPP) or the size of the hydrogen tank [4]. The Toyota Mirai has a ready-to-use fuel cell stack, which consists of 330 individual fuel cells or bipolar plates. These components are by far the most important repeating elements in a fuel cell.

2 State of the art

2.1 Materials for bipolar plates

The basic design of a bipolar plate can be divided into three functional areas:

1. The flow field, which is responsible for the gas distribution of the process media and the electrical contacting of the bipolar plate to the membrane and can be found on both the front and the back of a bipolar plate.
2. Inside of the hollow bipolar plate is the cooling structure. It contains channels where a cooling liquid can pass.

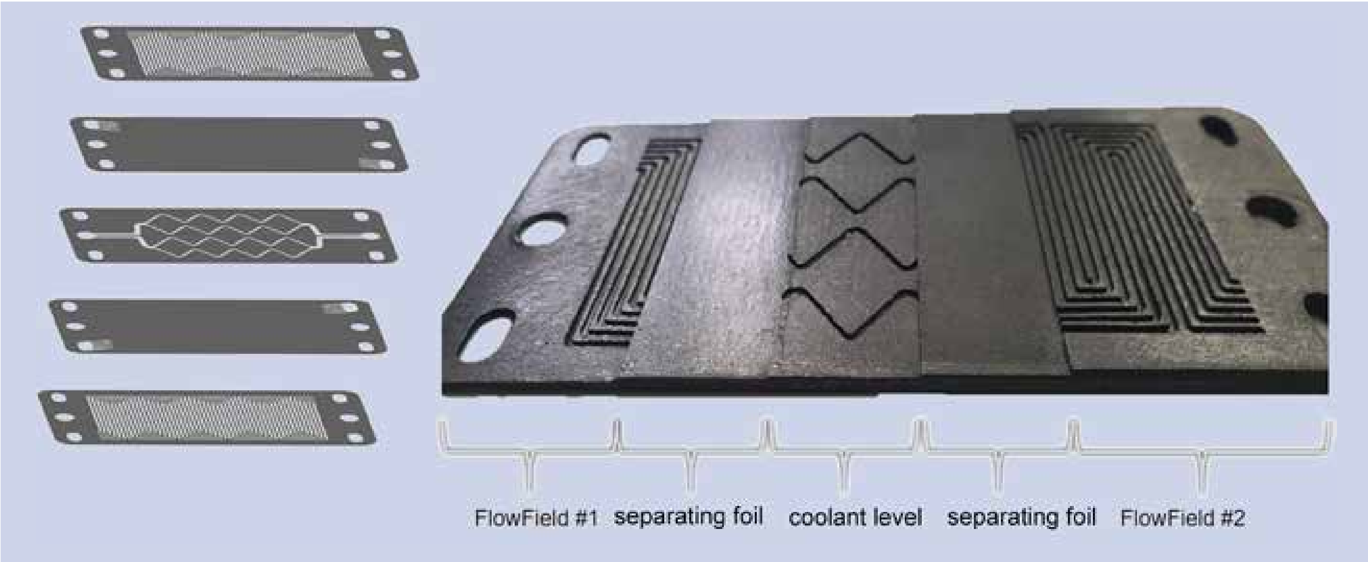

Fig. 1 • Structure of a foil-based bipolar plate as an exploded view (left) and as a step model (right). (Source: ZBT GmbH)

3. The separating layer, which separates the flow field from the cooling structure. This prevents the different media from mixing. The individual layers are shown in **Fig. 1.**

All previous production methods for metallic or graphite bipolar plates had the same difficulty: the geometric dimensions of the BPP, as well as the flow field and the cooling area must be defined in advance and a corresponding tool must be manufactured [5], whether using conventional toolmaking or modern additive manufacturing techniques such as material extrusion (MEX). As a result, these manufacturing processes can only be used economically in large quantities. They do not provide any flexibility as it is required for prototype construction. In addition, high investment costs are incurred for equipment, such as forming machines, injection moulding machines or CNC milling machines. That takes the R&D section of fuel cells on a cost-intensive level. Because of that and due to the currently unpredictable market situation of fuel cells, SME companies have a challenging entry into this market in several ways.

3 Material and methods

The approach of the research project FC Flex² is a layered structure of the bipolar plate, whereby single, individually cut layers of e.g. graphite or metallic sheets are placed on top of each other and finally are joined, to produce a fully functional bipolar plate [6]. Variations in design and the challenges to the joining technique are described below.

3.1 Materials

3.1.1 Foil substrate

A compound foil, developed at the hydrogen and fuel cell center ZBT GmbH, was used as base material. It was cut with the help of a CO_2 laser according to a specified CAD model. The foil had a thickness of 480 µm. The compound matrix was polypropylene and a mixture of graphite and carbon black particles (G+R) was used as filler. The fraction of this filler is 77 wt %.

The compound material used, was a product under development, whose thermal properties did not yet correspond to the continuous operating temperatures of the fuel cell. Optimisation of these properties was possible at the end of the project.

3.1.2 Adhesives

To join these individual layers, acrylate adhesives, polyolefin hotmelts and specially formulated epoxy resin adhesives were tested at the Institute of Joining and Welding (ifs). The aim was to get a structural rigidity, electrically conductive and hydrogen impermeable bond, according to the local requirements. At the circumferential border area of the BPP, the bond must act as a sealant against hydrogen and coolant. In the active area (flow field), electrical conductivity between the individual layers through the entire bipolar plate is necessary. **Fig. 2** shows the individual bonds and their necessary properties.

The used adhesive formulations, described as 2k_x, are based on a two-component epoxy adhesive, which cures at room temperature. The formulation 1k_29, as well as a commercial electrically conductive adhesive, are both hot curing systems at 100°C.

To create electrical conductivity throughout the joint, the same particles used for the foil production were used as fillers for the adhesives. Different mass fractions of G+R were added to the epoxy resin base, which are listed as an index (e.g. 2k_33 corresponds to 33% mass fraction of graphite and carbon black). The commercial adhesive named KK, is based on a heat-curing epoxy resin adhesive, with silver flakes.

The adhesives were each applied to the compound foil by roller application. In addition to these multifunctional adhesives, a commercially available pressure-sensitive adhesive (PSA) tape based on a modified acrylate pressure-sensitive adhesive was investigated.

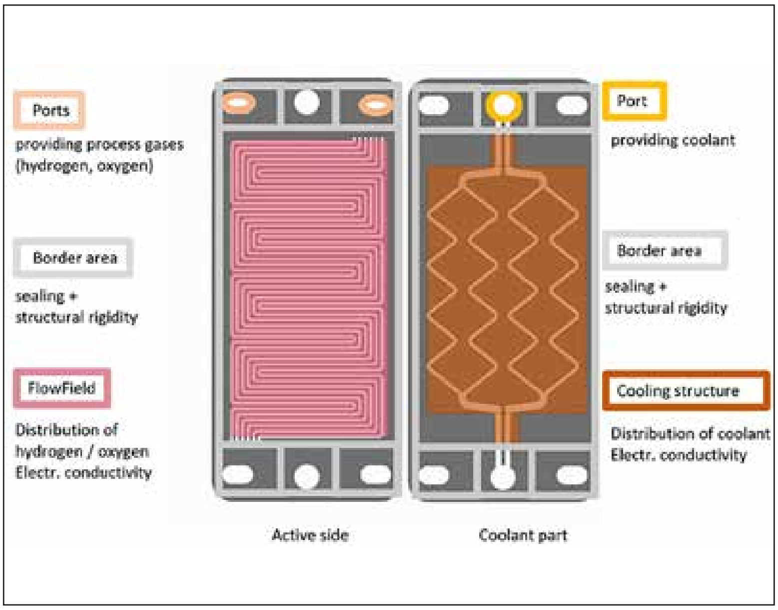

Fig. 2 • Locally resolved functional requirements for the bonding points on the active or cooling side of a bipolar panel. (Source: ZBT GmbH)

3.1.3 Testing methods

The tensile strength of the compound film was tested in a tensile test according to ISO 527. For this purpose, type 5a tensile bars were punched out longitudinally from the compound film and pulled at a test speed of 100 mm/min.

To characterise the joint, tensile shear specimens with the dimensions 100 × 25 mm and an overlap length of 12.5 mm were produced according to EN 1465. To reinforce the foil, it was structurally bonded to an aluminium substrate (2 mm) beforehand. The test was carried out at room temperature (RT) at a test speed of 1 mm/min.

Peel specimens of the compound foil and the PSA tape were prepared according to EN 1464 with a length of 125 mm and a width of 25 mm. They were tested with a test speed of 100 mm/min at RT.

The substrate was primarily cleaned with isopropanol and then treated with an 800 W atmospheric pressure plasma prior to the adhesive application, to increase the surface energy and polar fractions. The evaluation of the surface tension was carried out via contact angle measurements (goniometer OCA 30) and the implemented software via the parameterisation according to Owens, Wendt, Rabel and Kaelble (OWRK model).

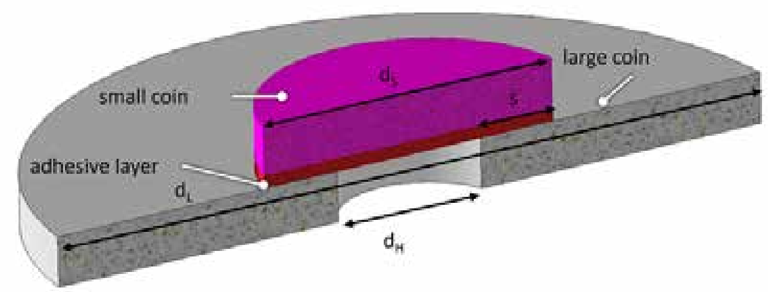

Fig. 3 • Sectional view of a coin specimen for measuring hydrogen tightness. (Source: ifs TU Braunschweig)

3.2 Measuring method – electrical resistance

To determine the electrical resistances, a measuring setup was used at the ZBT, where both the total resistance of a substrate and the individual partial resistances (contact, material) can be determined separately. The measuring setup consisted of a pneumatic press with two measuring tips punches and centred measuring needles. There was a gas diffusion layer (GDL) between the sample and the measuring plunger to obtain a situation that was as close to reality as possible. Within a series of measurements, the specimens were measured at increasing contact pressure (standard: 5 bar, 10 bar, 20 bar, 30 bar) and increasing currents were applied (standard: 500 mA, 1000 mA, 1500 mA, 2000 mA). The resulting voltages were used to determine the resistances.

The total resistance R_{total} resulting from the measured values is composed as follows, **Formula 1**.

$$R_{total} = 2 \times R_{GDL} + 2 \times R_{contact} + R_{bulk} \tag{1}$$

This consists of the GDL resistance R_{GDL}, the contact resistance $R_{contact}$ and the material resistance R_{bulk}. R_{GDL} was determined in an initial series of measurements and then taken as given. R_{bulk} resulted from the measurement via the measuring needles. $R_{contact}$ can be determined by calculation. In the following, we will primarily refer to the area-specific volume resistance $R_{forward}$, which is determined according to **Formula 2**.

$$R_{forward} = R_{total} - 2 \times R_{GDL} \tag{2}$$

For the investigation of the electrical contact between two compound foils, so called sandwich specimens were prepared. For this purpose, the compound foil was cut into pieces of 4 cm × 4 cm size, cleaned with isopropanol and pretreated with atmospheric plasma. Subsequently, two compound sheets with an adhesive layer in between were produced to form a sandwich specimen. Curing was performed at two different contact pressures (1.8 MPa and 0.625 MPa). In addition, the adhesives were cured at 60°C and 100°C, respectively.

As a reference, two sheets of the compound material were placed on top of each other and measured for electrical contact resistance without any bonding process.

3.3 Measuring method – hydrogen permeability

The hydrogen impermeability of the composite is an elementary property for fuel cell operation. It is necessary, that the adhesive layers are as impermeable against hydrogen as possible. The setup to measure the hydrogen leakage consists of a cylindrical chamber, which is sealed against the environment. A specimen is placed in the centre of this chamber; doing so it divides the chamber into an upper and a lower area. While one area of the chamber is flooded with hydrogen at 1 bar, the amount of hydrogen in the other chamber is detected cyclically by suitable sensors over a period of one hour. The leaked hydrogen can be measured as a leakage rate.

To be able to determine an adhesive layer with regard to its hydrogen leakage, coin specimens were produced, **Fig. 3**. These specimens consist of a large and a small coin, made from the compound material. They are bonded together using adhesives described above. For the bond to be exposed to hydrogen, the large coin with diameter d_L is provided with a central hole d_H. The small coin with a diameter d_S covers that hole. The overlap area of the two coins s is described as the sealing width.

3.4 Manufacturing of bipolar plates by bonding

For fuel cell operation, in addition to the bipolar plates, two edge plates are also required in the fuel cell stack as a final bipolar plate with contact to the current collector plates. These edge plates were made from four individual layers. Due to good results at the resistance measurements, the adhesive 2k_42 was used for this setup. The individual channels of the flow field can easily be moved after the laser process. To ensure accurate positioning, these loose bars were fixed with a transfer adhesive tape before the adhesive roller-application. This adhesive tape was removed after the joining process. To position the individual layers in relation to each other during the joining process, a special joining device was used. The ports were used to position the sheets precisely using a mandrel. The adhesive was cured individually for each foil layer at 60°C for two hours. The clamping pressure of the individual foils was approx. 1.1 MPa. The contact pressure was maintained for another 24 h to ensure the adhesive is completely set.

3.5 Measuring method – test rig

Bipolar plates can be tested close to the application with an in-situ fuel cell test rig at the ZBT. For this purpose, a single-cell stack was built and operated. It consisted of two four-layer edge plates, where every layer was adhesively bonded.

The process gases were fed into the edge plate at 300 mbar. The single-cell stack was operated at a constant operating point for 379 h.

4 Results and evaluation

4.1 Material results

The compound foil could be produced with a material thickness of 600 µm. The surface energy of the compound foil could be increased with the help of plasma activation to approx. 40 mN/m with a polar portion of approx. 14 mN/m.

The tensile test, according to EN ISO 527, was determined for the foil with a result of 48 MPa as tensile strength. The maximum possible tensile shear stress of 3.3 MPa was achieved with a cohesive joint fracture of the compound foil. The peel tests carried out, reached maximum values of 1.8 N / 25 mm, with a cohesive joint fracture of the foil close to the surface.

The cohesive strength of the compound material is greatly reduced due to the high mass content of graphite and carbon black, which causes a near-surface failure of the substrate even at low loads. This greatly reduces the strength of the bonded joints. However, the setup of a stack provides clamping forces of up to 10 kN, which is why hardly any or no peeling or shearing loads occur on the foil or in the bond during operation.

4.2 Electrical conductivity

A single layer of the compound foil, which was developed during the project, could achieve an area-specific volume resistance of 19 mΩcm². For the sandwich specimen, the lowest resistance was measured using silver-filled adhesive in combination with a high contact pressure, **Fig. 4**. The reference to the bonded sample,

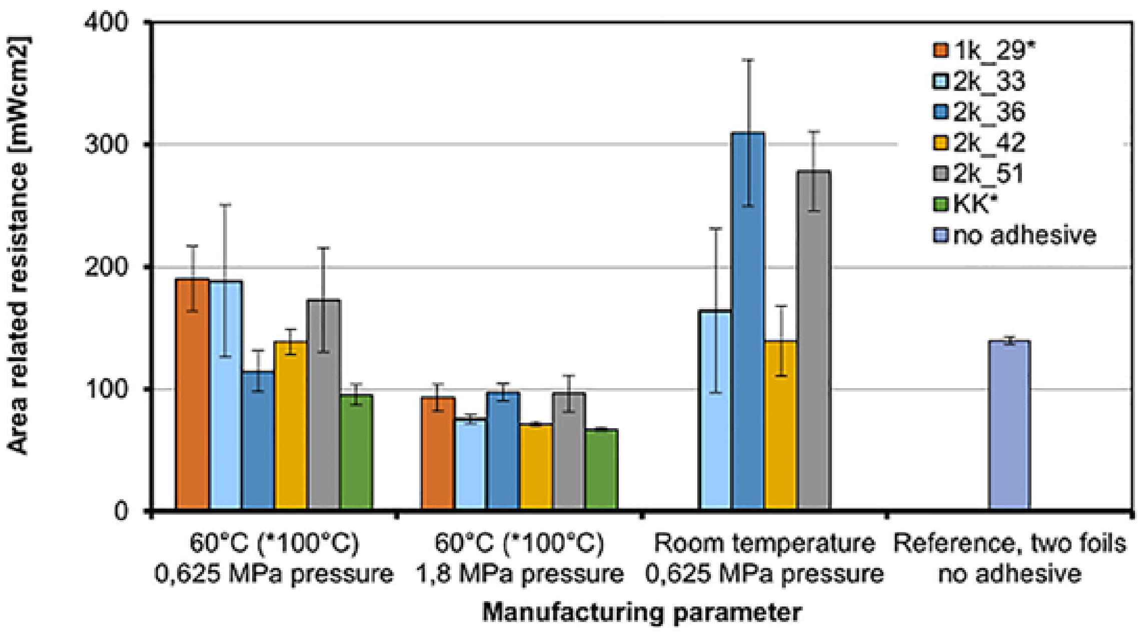

Fig. 4 • Area-specific volume resistances of bonded sandwich specimen and one reference. (Source: ZBT GmbH)

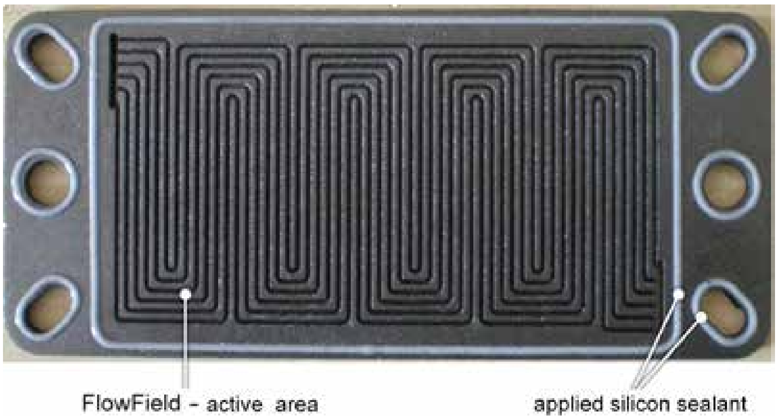

Fig. 5 • Flow field sealed with silicone. (Source: ZBT GmbH)

two foils placed on top of each other without any adhesive, has a resistance of 139 mΩcm². This is more than the resistance of specimen which were bonded using high pressure and high temperature. With these curing parameters, the two adhesives 2k_33 and 2k_42 showed lower resistance than the adhesive formula filled with the highest proportion of G+R (50% by mass). This shows that the proportion of conductive particles is not the only criterion for a good electrical conductivity in reactive adhesives in conjunction with the compound foil under investigation.

Overall, all adhesives show lower resistances at a high contact pressure than at a lower contact pressure. Furthermore, the resistance can be reduced, by increasing the curing temperature of the two-component epoxy adhesives from RT to 60°C.

4.3 Hydrogen permeability

Compound foil was measured as a reference to determine its hydrogen permeability. The leakage rate of one compound layer is 0.73×10^{-8} cm²/s. The adhesives examined are between 1.0×10^{-8} cm²/s and 1.4×10^{-8} cm²/s.

During the assembling of a fuel cell stack, individual components are sealed against each other with the help of a silicone sealant, **Fig. 5**. The leakage rates of the silicones used are usually between 15×10^{-8} cm²/s and over 100×10^{-8} cm²/s. From this point of view, none of the newly developed and investigated adhesives showed any leakage against hydrogen and both the substrate and the adhesive can be rated as technically impermeable.

4.4 Manufacturing of bipolar plates by bonding

The bonded, multi-layer bipolar plate was made from five individual layers of foil. The total thickness of this component was 2.14 mm, the injection-moulded reference is 5.08 mm, **Fig. 6**. By using layer based BPP the component thickness can be reduced by approx. 60%. Due to the combination of several bonded foils, the final bipolar plate was no longer flexible like one single sheet. Nevertheless, in contrast to the reference, small mechanical deformations could be carried out without the plate suffering a brittle fracture.

The volume resistivity of the four-layer edge plate was 748 mΩcm² which is significantly higher than the reference with 61 mΩcm². There is a need for further research here.

4.5 Test rig

The endurance test of the single-cell unit was carried out as planned for 379 h and completed successfully, as neither leaks nor power losses occurred over the entire measurement period. At a current density of 0.25 A/cm², a voltage of approx. 0.3 V was achieved, **Fig. 7**. The reference, a bipolar plate produced by injection moulding, achieved a voltage of 0.8 V at the same current density. The difference in performance is mainly due to the ohmic losses caused by the greatly increased volume resistivity of the edge plates used (748 mΩcm²), compared to the injection-moulded reference (61 mΩcm²).

At the end of the test, small plastic deformations of the compound material could be observed in the area of the applied silicone seals and the flow field. The cooling channel structure within the edge plate was pressed into the flow field, underlining the flexibility of the foil. The combination of operating pressure and high operating temperature of 80°C shows special demands on the structural strength of the thin compound material. The goal for a durable foil-based bipolar plate is a compromise between thin-walled material and mechanical rigidity under operating conditions.

5 Summary and conclusion

The experiments have shown that it is possible to manufacture bipolar plates without moulds and thus with a high degree of flexibility. The degrees of freedom that can be achieved for the variance of the individual structures can be extremely helpful for the development of new bipolar plate designs and further development of existing solutions through cost-effective experiments. A realisation of the layer-by-layer structure in combination with an industrial roll-to-roll process can lead to the large-scale suitability of this production method for bipolar plates.

The adhesives investigated showed sufficiently high hydrogen impermeability. The tests carried out with the variance of the mass fraction of graphite and carbon

Fig. 6 • Comparison of an injection-moulded BPP (left) and a foil-based BPP (right). (Source: ZBT GmbH)

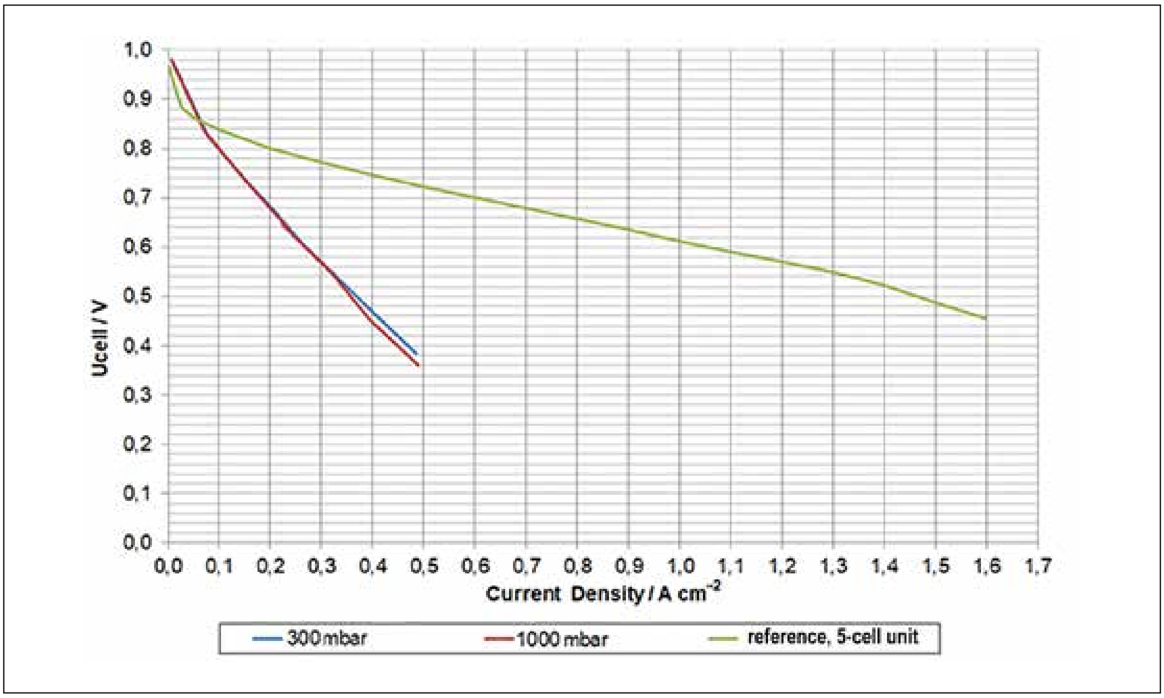

Fig. 7 • Voltage – current density curves of a foil-based edge plate operated in the test rig. (Source: ZBT GmbH)

black could not be brought into line with a linear reduction of the electrical contact resistance. On the contrary, an ideal filling level was found at 42% mass fraction in the adhesive. A further increase of the contact forces during the joining process seems to be target-oriented. The consideration of the volume shrinkage of the adhesives in connection with their curing temperature and the effect on a further reduction of the resistance is a further step in the direction of efficient, bonded bipolar plates.

The layered bipolar plate had a component thickness approx. 60% less than the reference made of injection-moulded material. The electrical conductivity, on the other hand, was much higher than that of the reference, which resulted in a much lower performance in the voltage-current density test than with the reference plate. Curing the adhesive used under higher contact pressure may solve this challenge.

The deformations of the foils due to the combination of increased temperature and pressure show that the mechanical loads have been too high for the compound material at hand. For this reason, the compound foil is being further developed at the ZBT to get closer to the reference in this respect.

The presented production method provides SMEs with the possibility for design variation and flexible production that does not require high investment costs for moulding tools. This facilitates an active entry into the energy transition market and enables rapid product development.

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Increase in understanding of the welding process through simulation of laser beam and gas-shielded metal arc welding

In welding structure simulation, the thermal effect of welding in the component is represented by an equivalent heat source. In order to be able to capture phenomena such as grain growth and structural transformation in the structure simulation, in addition to the amount of heat input, its distribution on mesoscopic, spatial scales must also be specified. With known approaches for the equivalent heat source, the physical process is still not sufficiently understood, and an exact calibration is very complex. With the aim of finding more accurate equivalent heat sources for the consideration of mesoscale phenomena, this work analyses laser beam and gas-shielded metal arc welding (GMAW) in selected areas of the process parameters and discusses process properties that should be taken into account when formulating the heat source. These include formation of welding capillary in laser deep welding, which is significantly influenced by the absorption properties of the metallic material surface, as well as the distribution of heat flow and electrical current density on the cathode in the GMAW process, which are significantly influenced by evaporation.

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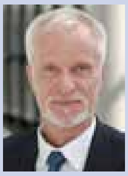

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1 Introduction

According to [1], welding structural simulation deals with the prediction of residual stresses and distortion due to transient temperature fields on macroscale components during welding. This is contrasted with material simulation, which deals with the microstructure and material properties, and welding process simulation, which aims to accurately determine the heat introduced and its distribution in the process. These three areas are interdependent. Of outstanding importance for industrial applications, however, is the weld structural simulation, since it supports component design and the planning of welding instructions, where it enables many expensive preliminary tests to be saved.

It corresponds to the state of the art in weld structure simulation that the microstructural transformations are also taken into account as essential factors when calculating residual stresses and distortion [2]. However, while for the calculation of the temperature fields in the entire component the mesoscale distribution of heat is secondary and primarily the amount of heat coupled into the weld pool is decisive, the exact temperature-time histories in the heat-affected zone (HAZ) are necessary for the determination of the influence of the heat input on the microstructure. Since the HAZ is

KEYWORDS

laser welding, gas-shielded arc welding, simulation and calculation, heat distribution

adjacent to the molten pool and gradients there can vary greatly in both spatial and temporal dimensions, the most accurate possible description of the process is critical for accounting for processes that are sensitive to the precise distribution of heat.

These consequences for structure simulation are currently becoming even more important when applied to new materials (for example duplex or TWIP steels) for which no empirical values are yet available. Although limited information about the process can also be obtained via experimental measurements, for example by recording temperature-time histories with thermocouples, these reach their limits particularly in heat-affected zones where high temperature gradients occur. This is partly due to the local resolution of the measuring points, but also to the distance from the weld pool and the reaction time. An ordinary temperature measurement with thermocouples gives a good indication of the amount of heat that is introduced, but it is hardly sensitive to the exact distribution of heat in the heat-affected zone.

Process simulation, on the other hand, provides insight into areas that are not accessible experimentally. These include the processes in the melt and the details of the heat input by the real energy source used. In particular, the temporally and spatially resolved distribution of heat flows near the melt pool boundary can be studied, which is not possible with conventional measurement methods. In this way, equivalent heat source (ÄWQ) models can be evaluated with respect to their suitability for mapping the heat distributions near the melt pool in specified process windows and new concepts for the realisation of ÄWQ models can be derived.

2 State of the art

The representation of the coupled physical processes in MSG and laser beam welding in a process model is associated with great numerical effort and long calculation times. In welding structural simulation, the spatial and temporal distribution of the temperature is used as an input variable to consider the thermal history of the component [3]. Here, the thermal effect of the process on the component is abstracted by a heat conduction (WL) model in which the energy input is through a usually volumetric equivalent heat source. This approach neglects the causes and details of the origin of the temperature distribution in the workpiece and allows an efficient calculation of residual stresses and distortion. In addition to the low computation times for the heat conduction task, another advantage of ÄWQ models is the simplicity of their implementation in commercial simulation software.

2.1 Heat conduction models

For the calculation of the three-dimensional temperature distribution, models based on the heat conduction equation have been established, which allow the finding of analytical or numerical solutions. The advantages of the analytical models are the short time required for the calculation of the temperature distribution and the existence of a closed, resolution-independent solution of the heat conduction problem. The solution results from the superposition of individual solutions for a moving point heat source [4], which are weighted according to the heat source distribution used. Finite component dimensions as well as boundary conditions can be taken into account by using virtual heat sources [5].

The analytical models are limited to simple component shapes (plane plates, cuboids) with adiabatic or convective boundary conditions in the butt joint at constant thermophysical material properties [6]. Numerical solution methods, on the other hand, offer great flexibility with respect to component shape, weld arrangement, and material properties, but require much longer computation times [7].

2.2 Equivalent heat source models

Known volumetric heat source models include distributions of both infinitesimal and finite spatial extent. The former include point sources as well as line sources with different dependencies on penetration depth [8]. These are mainly used in analytical heat conduction models, where they lead to a simplification of the mathematical expression for the calculated temperature distribution, since the solution structure here takes the form of a convolution of the source distribution with the Green's function of the heat conduction problem (see Section 2.1). Heat sources with finite spatial extent are applied in analytical and numerical solution. An overview of models is given in [6; 9], specifying the temperature field solutions for analytically solvable heat conduction problems. Arbitrary combinations of the elementary source distributions in the three spatial dimensions are possible and lead to prominent representatives such as the symmetric Gaussian source or the asymmetric double ellipsoidal Goldak source [10]. There are no limits to the creativity of the user. However, it must be taken into account that with an increasing number of free heat source parameters, the calibration process also becomes more elaborate and thus generally requires more skill and time.

In addition to volumetric heat sources, the use of surface sources is common [11]. They can be used, for example, to take into account the workpiece-surface portion of the absorbed energy in laser beam welding, which leads to nail heads in the weld seam. Furthermore, especially in laser beam welding, the energy input into the capillary surface is represented by an infinitesimal line source [8] or a normally distributed heat source [6], also known as a Gaussian source, with a corresponding depth dependence. The final form of the model depends on the process window considered and the physical phenomena involved leading to the energy input. Furthermore, the welding arrangement (for example, in case of position-counterposition welding) and the welded materials, which generally lead to asymmetric welds, have to be taken into account. Application examples for laser beam welding can be found in [7; 8; 11].

2.3 Calibration of the heat source parameters

After the selection of an equivalent heat source model, there is the task of solving an inverse heat conduction problem. The model parameters of the equivalent heat source must be determined under variation by an iterative matching of the calculated temperature distributions with experimental data [3]. The process can be time consuming and requires experiential knowledge and skill in manually adjusting the parameters. The time required to solve the optimisation problem is largely determined by the duration of a single temperature field calculation, which limits the number of possible iteration steps per time. Analytical heat conduction models offer a clear advantage here. They have a better convergence behaviour due to the closed source formulation and can be used in conjunction with global optimisation algorithms for an automated calibration of the equivalent heat source [8]. Numerical temperature calculations can also be used in conjunction with local optimisation methods for automated adjustment of the equivalent heat source parameters, but have longer individual calculation times. Numerical model reduction methods can be used here to accelerate the optimisation steps [7]. Furthermore, due to the discrete formulation of the source, the calibration result generally depends on both the meshing used and the numerical integration method employed and is therefore not directly transferable between different simulation programs.

3 Findings from the process simulation

Process simulation for welding deals with the question of how much heat is introduced into the process zone and in which form the molten pool is formed. The challenge in modelling the energy input for weld structure simulation is physical. Heat input from the real energy source occurs primarily on the surface in both the cathode region for GMAW and laser beam welding. However, the mathematical formulation of a surface source via embedded edges is non-trivial and so far not feasible in the context of a weld structural simulation for the industrial environment. This is especially true for deep penetration welding as well as laser penetration welding, where energy is coupled into the process via the surface of the weld capillary. In the following, the latest findings from process simulations of both manufacturing processes are presented and the distributions of characteristic quantities relevant for modelling the heat input are discussed.

3.1 Gas-shielded metal arc welding (GMAW)

GMAW is an arc welding process and should be distinguished in particular from tungsten inert gas (TIG) welding. An essential difference between the two processes is that in TIG welding the arc burns between the workpiece and a non-melting tungsten electrode, whereas in GMAW the arc burns between the workpiece and a melting wire electrode. Another difference also lies in the current polarity when direct current is used, so that in TIG welding the tungsten electrode is mostly poled as the cathode and the workpiece as the anode, whereas in GMAW the workpiece is commonly the cathode and the wire electrode is the anode.

In TIG welding, the transfer of heat and electric current from the arc to the workpiece occurs via a relatively uniform, so-called anode spot, which can only be additionally activated locally in special cases, for example when a flux is used or by laser radiation. In GMAW, however, heat transfer occurs via the so-called cathode area, the underlying physical mechanisms of which are not yet well understood, and in addition there is a heat input by the molten droplets into the molten pool. It is important to note here that both the effect of the droplets (heat, mass, momentum) and the effect of the cathode region (heat and electric current density, thus also electromagnetic forces) significantly influence the flows in the molten pool, and therefore the shaping of the molten pool in the TIG process differs significantly from the shaping of the molten pool in the MSG process. In the MSG process, however, a distinction is made between the following common variants: the short arc

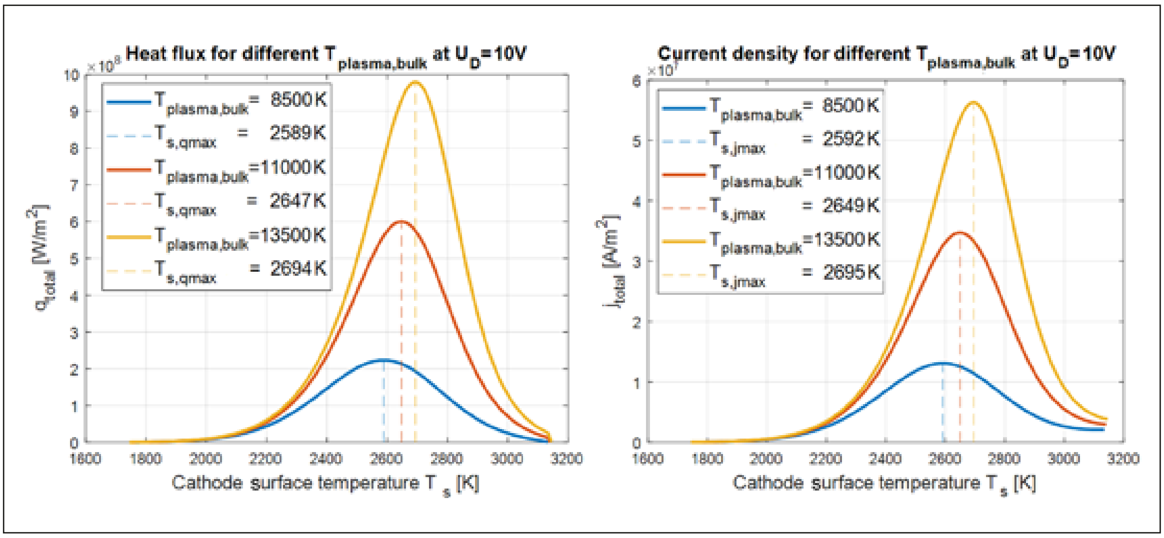

Fig. 1 • Heat flux density and electric current density according to the model from [12].

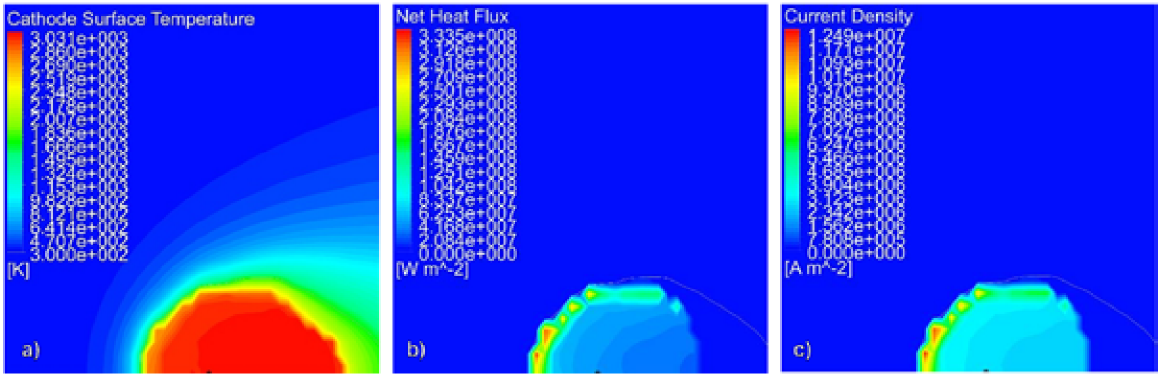

Fig. 2 • Temperature field (a), heat flux density (b) and electric current density of the molten pool (c), after [12].

process, the CMT process, the pulse process and the spray arc process.

In the following, the latest results for understanding the cathode area will be explained in more detail. In [12], a model for the connection of the arc to the workpiece cathode during MSG welding was presented for the first time. The model allows to predict the heat flux density $q(U, T_w, T_{plasma}, n_{plasma})$ and the electric current density $j(U, T_w, T_{plasma}, n_{plasma})$ as a function of cathode drop voltage U, surface temperature T_w, plasma temperature T_{plasma} and plasma density n_{plasma}. The novelty of the model is that this succeeds at temperatures of the melt pool which are below the evaporation temperature, as observed in the experiment, **Fig. 1**. The model explains the mechanism of the binding by an ionisation of the metal vapor in the plasma with a simultaneous local cooling of the plasma by the metal vapor and thus a capping of the ion flow to melt pool temperatures below the boiling point.

The model now makes it possible to calculate the surface temperature of the molten pool, as well as the resulting distribution of heat flux density and electric current density on the surface of the molten pool, **Fig. 2**. It can be clearly seen here that the bonding of the arc to the cathode is not uniform, but that there is a maximum along the front of the molten pool, Figs. 2b and c, across which substantial contributions of heat and electric current are coupled into the molten pool. This is because the cathode processes heat much of the melt pool surface available for bonding to a temperature just below the vaporization temperature, at which point the contributions of heat flux density and electric current density become insignificant, **Fig. 2**. The main contributions occur at cathode surface temperatures of $\approx$2600 K, **Fig. 1**, which corresponds to the transition region between cold workpiece and hot melt pool. Due to a limitation of the connection to a predefined radius, the rear part of the weld pool, which lies within the radius, is thus still too hot to provide significant contributions to heat and current connection. This corresponds to a limitation of the arc radius by factors such as total available power and arc length in the process. For a more detailed consideration, of course, the arc region would also have to be simulated – and there in particular the local plasma temperature above the molten pool.

However, it is important to note that the processes in the cathode region not only cause a mutual coupling of the arc and the molten pool, but also that the previous assumptions of a Gaussian distribution of heat flux density and electric current density in the MSG process do not correspond to reality, and that the previous ideas of heat and current distribution must be adapted, as shown in **Fig. 3**.

As a consequence of the new model, it can no longer be assumed that the heat flux density and the electric current density and thus also the essential boundary conditions for the formation of the weld pool are the same for all variants of the process. For example, a drop causes a temporary local cooling of the melt pool and thus a temporary local increase of the electric current density and thus also of the Lorentz force.

In addition, it also becomes clear that, for example, in the case of the spray arc, an area on the molten pool is constantly brought to a lower temperature by the droplets, which then also leads to stronger electric currents there and a stronger influence of the electromagnetic forces on the melt movement. Thus, a stronger mixing of the weld pool takes place and temperature gradients within the weld pool are equalised very quickly.

3.2 Laser beam welding

In laser beam welding of metals, deep penetration welding can be identified as the most technically relevant process area. Whereas in heat conduction welding a molten pool forms on the upper surface of the workpiece, increasing the laser beam intensity leads to an increase in temperatures in the molten pool and to vaporisation of the molten material. In this case, the outflowing metal vapor exerts a normal force on the surface of the molten pool, which leads to a deepening of the molten pool. If the inclination of the melt pool surface is sufficiently steep, caustics of the reflected components of the laser radiation are formed along the laser beam axis and a narrow and deep capillary is formed. The spatial distribution of the forces exerted by the outflowing metal vapor on the capillary surface leads to tangential components of acceleration and to the flow of molten metal around the capillary. This area of deep welding is characterised by efficient energy coupling due to the utilisation of the energy of the multiple reflected

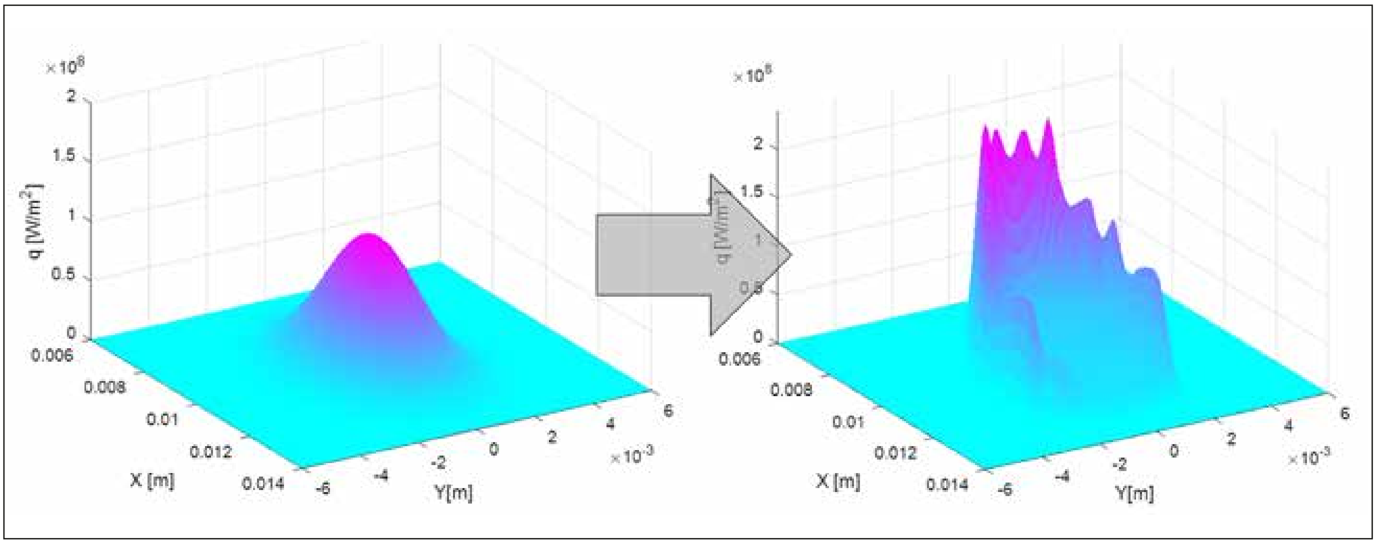

Fig. 3 • Comparison between the conventional (Gaussian) notion of heat flux density (left) and the distribution of heat flux density considering a physics-based cathode model [12].

components of the laser radiation and enables large aspect ratios of the weld.

The absorption of laser radiation in metals occurs close to the surface at optical penetration depths of a few nanometres. Therefore, in the context of process modelling, the description of absorption as a surface phenomenon is appropriate. A phenomenological approach is provided by the Fresnel equations, which establish a relationship between the absorption coefficient, the angle of incidence and the optical constants. A detailed description of the mechanisms involved in absorption can be found in [13]. Especially for metals as good electrical conductors, the form of the equations simplifies and the absorption coefficient depends only on one material parameter [14]. This can strongly depend on the frequency of the laser light used and thus, depending on the process parameters, limit the achievable process ranges for a given laser beam source. An example of this is laser beam microwelding of copper materials with infrared laser light and laser light in the visible range [15]. Furthermore, the polarisation state of the laser light has an influence on the absorption, since the Fresnel coefficients for s-polarised and p-polarised components differ. Since these fractions are determined by the plane of incidence of the light and thus by the local orientation of the surface, the coupling of any light beam generally changes during its propagation through the capillary in deep welding. Ultimately, volume absorption of the laser radiation by the plasma can occur when the metal vapor is ionised. Consequently, the global geometric shape of the welding capillary and the intensity distribution of the absorbed laser radiation are the result of a complex chain of interactions between laser light and material, which is pronounced by locally existing conditions.

The complexity of absorption in laser deep penetration welding indicates a generally sensitive and highly dynamic process and makes a detailed analysis of heat input difficult. In [16], a steady-state geometric shape of the capillary was calculated under simplifying assumptions in an approximate process model. Laser beam microwelding of Cu-ETP (oxygenated copper produced by electrolytic refining with very high conductivity for heat and electricity) with a laser of wavelength 515 nm was considered as the object of research. The model considers a free propagation of the laser radiation within the capillary and solves continuum physical balances at the capillary surface within two-dimensional layers perpendicular to the laser beam axis. The geometric shape of the capillary within the layers is given as circles and parameterised by a radius and a centre position. In addition to a local balance at the capillary apex, an integral power balance between absorbed laser radiation and heat flows in the material is considered in each layer. As a further solution parameter, a surface temperature constant within this layer is obtained for each layer. The result of a three-dimensional geometric capillary shape for a deep weld with the representation of different quantities on the capillary surface is shown in **Fig. 4**.

A comparison of the distribution of the total absorbed laser beam intensity q_a with the distribution of the portion *MR* originating from reflected laser radiation shows the depth at which the formation of the capillary is determined by reflections. Accordingly, the observed local excesses of the absorbed intensity (red areas in **Fig. 4**) indicate non-uniform propagation of the laser radiation along the depth of the capillary. Due to the simplified model structure, they are neither compensated by the heat flux q_l nor by the surface temperature T_S nor by local deviations of the geometric shape from a circle. Nevertheless, the intensity overshoots provide indications for areas of the capillary tending to instabilities. The heat flux q_l is largely determined by the feed rate, the thermal diffusivity and the radius of the capillary layers. Due to the feed (here in the X direction), it varies cosinusoidally with the polar angle of the cylindrical coordinate system used, with a maximum at the apex in the feed direction, and increases with decreasing capillary radius due to heat conduction losses caused by curvature. Another reason for the increase in heat flux at depth is the increase in surface temperature. This results from the consideration of a momentum balance at the apex, in which the recoil forces of the metal vapor are balanced with the capillary forces of the surface tension. The latter also depend inversely proportional on the capillary radius. Due to the non-equilibrium evaporation, temperatures arise which are greater than the equilibrium evaporation temperature of the material at the saturation vapor pressure.

4 Process-relevant aspects for implementation in weld structure simulation

4.1 Gas-shielded metal arc welding

The analysis of the cathode region in GMAW shows that the distribution of heat and electric current density, which significantly contribute to the shaping of the molten pool, depends very much on the present process type and, in particular, on the current (via the plasma temperature). While the short arc should result in a distribution concentrated under the electrode, the pulsed and spray arc processes should result in a distribution which should have a substantial coupling in the front part of the molten pool at the melt front.

Thus, Goldak's equivalent heat source is probably a good assumption for low currents (as well as for non-activated TIG welding). But with increasing currents, the agreement of the heat flux density distribution with that according to Goldak becomes increasingly imprecise. At higher currents, stronger electromagnetic forces are to be expected, and hence stronger currents and consequently stronger melt mixing. In these cases, a power density distribution as predicted by the MR10 equivalent heat source is preferable [17].

A further analysis of the heat input in the moving welding process shows that the main part of the heat is introduced in the front part of the weld pool. This also seems to make sense, since a lot of energy is needed there to melt the material. In addition, the temperature gradients and thus the heat flux densities are also strongest there, while in the trailing part of the melt pool the heat is mainly transported by flows from the front part. This should be taken into account when creating an equivalent heat source for the structural simulation, since an equivalent heat source with a significant energy input in the rear section might also provide a good match in the seam cross-section but would correspond much less to the real process.

However, in welding processes where the weld protrusion is no longer negligible, the case may arise where the intensive melt movement from the front into the rear part of the weld pool dominates, with the result that the main part of the heat must be introduced into the rear part of the weld pool. The front part must then be very spatially restricted in order to still ensure a power density sufficient for melting. A suitable solution here would be the equivalent heat source MR10 in the second modification [17].

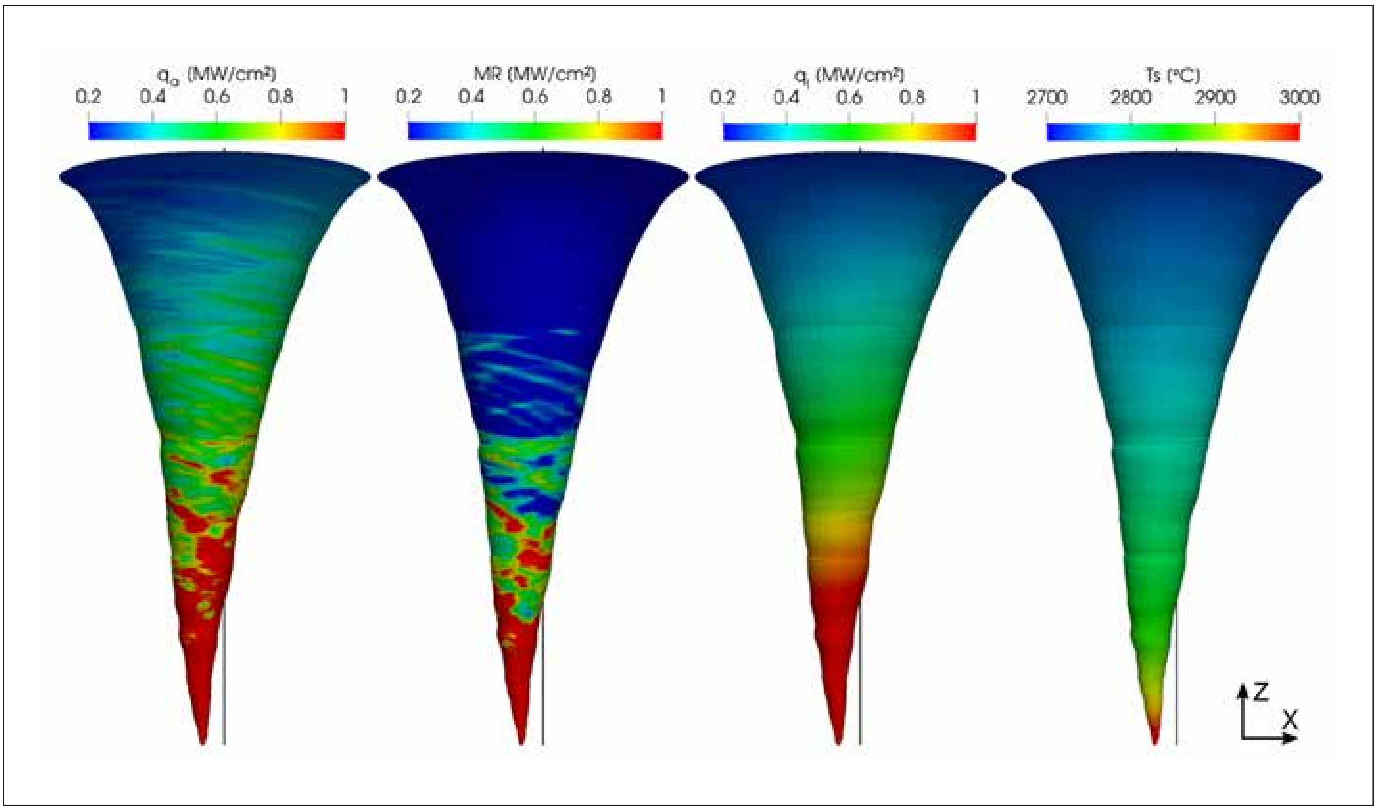

Fig. 4 • Calculated geometrical shape of a capillary during blind welding in Cu-ETP with a laser of wavelength 515 nm (the black vertical lines indicate the laser beam axis; the Péclet numbers formed with the capillary radii are smaller than 0.64; beam diameter 240 µm, feed rate 60 mm/s, laser beam power 920 W); left: distribution of total absorbed laser beam intensity, centre left: distribution of the fraction of the total absorbed laser beam intensity coming from reflected light, centre right: distribution of the heat flow in the material, right: distribution of surface temperature.

4.2 Laser beam welding

For the mapping of the heat effect of laser beam welding, the following statements can be made based on the current understanding of the process: While heat conduction welding or the laser beam heat components absorbed on the top of the workpiece can be implemented in the weld structure simulation by a surface source, the consideration of heat input by the capillary during deep and through welding requires a differentiated view. The observation of an increase of the surface temperature with a simultaneous decrease of the capillary radius with depth initially coincides well with the notion of a volume source whose horizontal expansion decreases (for example linearly) with depth while the power per layer remains constant. However, the geometric shape of the capillary is increasingly affected by the absorbed fractions of the reflected laser radiation when the absorption behaviour is poorer (for example, IR laser radiation on Cu-ETP), which can lead to a nonmonotonic depth dependence. In particular, this applies to joints of materials with strongly different material properties in the lap joint.

A first indication for the evaluation of the heat distribution generated by equivalent heat source is provided by the ratio of the lateral expansions of capillary and melt pool, which can be determined from the isotherms of the temperature distribution. While the capillary radius is of the order of the laser beam radius, the quotient of thermal diffusivity and feed rate gives a measure of the lateral expansion of the melt pool. The ratio of these length scales is the Péclet number formed with the capillary radius. For small Péclet numbers ($Pe \ll 1$), i.e. large melt pools compared to the capillary, the spatial distribution of heat input into the melt pool is no longer resolved by the temperature distribution in the HAZ. For modelling using equivalent heat source, this means that only the power introduced by the source is decisive for the formation of the temperature distribution in the HAZ, but not its spatial distribution. Both Gaussian and line sources give equivalent results when calibrated appropriately. However, the situation is different for larger Péclet numbers. The distributions of the isotherms produced by equivalent heat source models are more sensitive to the spatial distribution of equivalent heat source. Here, differences near the melt pool boundary are expected despite calibration for different source types. Also, the differences in heat flux along the capillary surface calculated from the process model increase, differences in surface temperature between the front and back walls are expected, and flow-induced advective heat transport becomes relevant.

4.3 Influence of fluid flow

The shape of the weld pool during welding is largely dependent on the flows that form. The flows not only influence the shape of the weld pool, but also compensate for the temperatures within the molten area. Without a more precise knowledge of the cause of the flows, the change in shape of the molten pool cannot be compensated, but the temperature gradients in the molten pool can still be equalised. An artificial increase in thermal conductivity in the molten region can be used for this purpose. This method is also called "efficient thermal conductivity" [18]. By using this method, unrealistically high temperatures in the effective centre of the equivalent heat source can be avoided, while the temperatures at the edge of the molten pool are increased, which corresponds more to the real process.

5 Conclusion

The results of a numerical structure simulation are always a compromise between the accuracy and the speed of the calculation as well as the computer capacities and the available material parameters. For large or complex components, the mesh density is one of the critical influencing variables. In this case, the equivalent heat source method is the only way to calculate a transient temperature field in a reasonable time, and the results can be considered reliable to a first approximation, provided that the introduced energy has been properly captured.

However, with higher requirements on the precision of the temperature field calculation, deviations can occur which have their cause in specific process peculiarities which are lost when modelling the heat input with equivalent heat source. The inclusion of these process peculiarities requires a deep understanding of the process, which can be obtained from the process simulation.

For the calibration of a selected heat source in the structural simulation, knowledge about the course of the real process can also bring a clear advantage, since it limits the selection of possible heat sources and the resulting distribution of heat is thus closer to reality.

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On the Mechanism of Evaporation-Determined Arc-Cathode Coupling in GMA Welding

By Marek Sebastian Simon. 144 pages with numerous figures. Shaker Verlag, Düren 2021. Price Euro 45.80.

In gas metal arc welding (GMAW) process simulation, it is desired to predict the energy transferred to the process as well as the weld pool geometry. For this reason, the coupling of the arc to the welded material is of high interest, both at the cathode and the anode. Although there exists a substantial body of work on the coupling of the arc to the cathode, the present models cannot be applied in the conditions of GMAW welding, as they give unphysical results. In particular, the current models usually result in very high cathode surface temperatures, i.e. above boiling temperature of the metals.

After relevant experiments are presented and discussed in this publication, it is concluded that the current state of the art does not reflect the observations and that therefore a new approach needs to be developed. Furthermore, a dialectic argument is developed, namely that the coupling of the arc to the cathode in diffuse attachment of GMAW must be strongly determined by evaporation. The argument concludes that the current transfer is mainly carried by metal ions that are evaporated from the cathode surface and ionised in the near cathode plasma, and that this current transfer must be limited to below boiling temperature. The core hypothesis is that this limit results from a decrease of the ionisation degree, due to cooling of the near cathode plasma by the cold metal vapor.

Based on this argument, a mathematical model for the Evaporation-Determined Arc-Cathode Coupling (EDACC) is introduced in detail. The properties of the model are then analysed by applying it to a simplified computational fluid dynamics (CFD) weld pool simulation and it shows that the model is in line with the observed cathode surface temperatures below boiling. Finally, also an outlook is given on possible applications of this new understanding of the arc-cathode coupling, as well as a discussion of open questions and current limitations of the model.

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▼ Laser welding 180

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▼ Manual metal arc welding 190

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▼ Pulsed arc welding 200

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▼ Multiple-wire welding 240

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The ABC of Joining – International Industry Guide

▼ MIG/MAG (GMA) welding 250

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▼ Plasma-TIG welding 270

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▼ Plasma welding 280

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▼ Tandem welding 360

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▼ Resistance spot welding 410

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▼ TIG (GTA) welding 420

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2 Plant and equipment, including automation, mechanization and industrial robots, for weld surfacing and cladding

▼ Plasma cladding 460

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▼ Gas shielded arc cladding 490

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▼ Submerged arc cladding 500

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3 Plant and equipment, including automation, mechanization and industrial robots, for brazing and soldering

▼ Arc brazing 600

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5 Plant and equipment and joining elements, including automation, mechanization and industrial robots, for positive and non-positive joining

▼ Joining elements (rivets, tubular rivets, tap rivets, pop rivets, blind rivet nuts, bolts, screws) 1000

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Internet: www.soyer.de

6 Plant and equipment, including automation, mechanization and industrial robots, for special applications

▼ Torch cleaning, automatic torch cleaning systems 1010

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▼ Systems for feeding, positioning, tipping or conveying (e.g. nut feeding systems) 1020

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▼ Production equipment and production lines 1030

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▼ Orbital welding equipment 1040

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7 Services

▼ Leasing of welding plant and welding Equipment 1091

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II Plant and equipment for heat treatment and other production processes

2 Plant and equipment, including automation, mechanization and industrial robots, for other production processes

▼ Turning, milling, planing 1240

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▼ Edge preparation (e.g. plate and pipe chamfering machines) 1250

DWT GmbH
Wilhelm-Tenhagen-Str. 5, D-46240 Bottrop
☎ +49 2041 77 144-0 🖷 +49 2041 77 144-99
E-Mail: info@dwt-gmbh.de
Internet: www.dwt-gmbh.de

PROTEM GmbH
Am Hambiegel 27, D-76706 Dettenheim-Liedolsheim
☎ +49 7247 9393-0
E-Mail: info@protem-gmbh.de
Internet: www.protem.fr/de

▼ Sawing 1300

PROTEM GmbH
Am Hambiegel 27, D-76706 Dettenheim-Liedolsheim
☎ +49 7247 9393-0
E-Mail: info@protem-gmbh.de
Internet: www.protem.fr/de

3 Workshop and workplace equipment, safety equipment

▼ Slinging gear, cranes and elevators (crane systems, lifting forks and beams, slewing cranes, lifting magnets, electric chain hoists) 1380

DWT GmbH
Wilhelm-Tenhagen-Str. 5, D-46240 Bottrop
☎ +49 2041 77 144-0 🖷 +49 2041 77 144-99
E-Mail: info@dwt-gmbh.de
Internet: www.dwt-gmbh.de

▼ Work tables (e.g. welding and cutting tables) 1390

Absaugtechnik Kalkhof
Rudolf-Diesel-Str. 2, 59425 Unna
☎ +49 2303 2586459 🖷 +49 2303 9421184
E-Mail: mail@absaugtechnik-kalkhof.de
Internet: www.absaugtechnik-kalkhof.de

Demmeler Maschinenbau GmbH & Co. KG
Alpenstraße 10, 87751 Heimertingen
Postfach: 51, 87751 Heimertingen
☎ +49 8335 9859-0 🖷 +49 8335 9859-27
E-Mail: info@demmeler.com
Internet: www.demmeler.com

Dodek GmbH & Co. KG
Lanzstraße 2, D-88410 Bad Wurzach
☎ +49 7564 948 95-0 🖷 +49 7564 948 95-9
E-Mail: contact@dodek.de
Internet: www.dodek.de

Füchtenkötter GmbH
Von-Liebig-Straße 26, D-33428 Marienfeld
☎ +49 5247 80-048 🖷 +49 5247 80-952
E-Mail: info@fuechtenkoetter.de
Internet: www.fuechtenkoetter.de

KEMPER GmbH
Von-Siemens-Straße 20, D-48691 Vreden
☎ +49 25 6468-0 🖷 +49 25 6468-120
E-Mail: mail@kemper.de
Internet: www.kemper.de

PlymoVent GmbH
Rolandsecker Weg 30, 53619 Rheinbreitbach
☎ +49 22 24 91 99 3-0 🖷 +49 22 24 91 99 3-30
E-Mail: info@plymovent.de
Internet: www.plymovent.de

Bernd Siegmund GmbH
Landsberger Straße 180, 86507 Oberottmarshausen
☎ +49 8203 9607-0 🖷 +49 8203 9607-33
E-Mail: info@siegmund.com
Internet: www.siegmund.com

TEKA Absaug- und Entsorgungstechnologie GmbH
Millenkamp 9 , D-48653 Coesfeld
☎ +49 2863 9282-0 🖷 +49 2863 9282-72
E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Heat recovery systems 1400

Dodek GmbH & Co. KG
Lanzstraße 2, D-88410 Bad Wurzach
☎ +49 7564 948 95-0 🖷 +49 7564 948 95-9
E-Mail: contact@dodek.de
Internet: www.dodek.de

▼ Soldering fume filters 1430

KEMPER GmbH
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Internet: www.kemper.de

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E-Mail: info@teka.eu
Internet: www.teka.eu

▼ At-source welding fume extraction systems (stationary, mobile) 1450

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E-Mail: info@plymovent.de
Internet: www.plymovent.de

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☎ +49 2863 9282-0 🖷 +49 2863 9282-72
E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Sound absorbing materials, soundproof chambers 1460

Dodek GmbH & Co. KG
Lanzstraße 2, D-88410 Bad Wurzach
☎ +49 7564 948 95-0 🖷 +49 7564 948 95-9
E-Mail: contact@dodek.de
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☎ +49 5247 80-048 🖷 +49 5247 80-952
E-Mail: info@fuechtenkoetter.de
Internet: www.fuechtenkoetter.de

▼ Welding booths 1480

Füchtenkötter GmbH
Von-Liebig-Straße 26, D-33428 Marienfeld
☎ +49 5247 80-048 🖷 +49 5247 80-952
E-Mail: info@fuechtenkoetter.de
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☎ +49 2863 9282-0 🖷 +49 2863 9282-72
E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Welding curtains 1490

KEMPER GmbH
Von-Siemens-Straße 20, D-48691 Vreden
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E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Protective screens 1500

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Internet: www.teka.eu

▼ Weld fume filters and filtration systems 1510

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Internet: www.absaugtechnik-kalkhof.de

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Internet: www.plymovent.de

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E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Protection equipment against high energy radiation (e.g. X-rays, laser radiation) 1530

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☎ +49 5247 80-048 🖷 +49 5247 80-952
E-Mail: info@fuechtenkoetter.de
Internet: www.fuechtenkoetter.de

▼ Exhaust and ventilation systems 1550

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☎ +49 25 6468-0 🖷 +49 25 6468-120
E-Mail: mail@kemper.de
Internet: www.kemper.de

4 Health and safety (personal protective equipment)

▼ Laser protection 1650

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☎ +49 2863 9282-0 🖷 +49 2863 9282-72
E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Welder's head screens and shields, protective goggles, eye protective filters 1670

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E-Mail: mail@kemper.de
Internet: www.kemper.de

Optrel AG
Industriestraße 2, CH-9630 Wattwil
☎ +41 71 9874-200 🖷 +41 71 9874-299
Internet: www.optrel.com

5 General accessories

▼ Wire-guide spiral 1740

Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

▼ Wire feeders 1750

SKS Welding Systems GmbH
Marie-Curie-Straße 14, D-67661 Kaiserslautern
☎ +49 6301 7986-0 🖷 +49 6301 7986-119
E-Mail: info@de.sks-welding.com
Internet: www.sks-welding.com

Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

▼ Turntables and tilt-turn positioners, lift tables 1760

Demmeler Maschinenbau GmbH & Co. KG
Alpenstraße 10, 87751 Heimertingen
Postfach: 51, 87751 Heimertingen
☎ +49 8335 9859-0 🖷 +49 8335 9859-27
E-Mail: info@demmeler.com
Internet: www.demmeler.com

MERKLE Schweißanlagen-Technik GmbH
Industriestraße 3, D-89359 Kötz
☎ +49 82 21 915-0 🖷 +49 82 21 915-40
E-Mail: info@merkle.de
Internet: www.merkle.de

▼ Assembly systems, assembling and positioning devices (clamps, roller blocks, line-up clamps) 1910

Demmeler Maschinenbau GmbH & Co. KG
Alpenstraße 10, 87751 Heimertingen
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Internet: www.dwt-gmbh.de

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Landsberger Straße 180, 86507 Oberottmarshausen
☎ +49 8203 9607-0 🖷 +49 8203 9607-33
E-Mail: info@siegmund.com
Internet: www.siegmund.com

▼ Hoses, hose couplings, hose connections, hose packages 1960

Dipl.-Ing. K. Weinhold GmbH & Co. KG
Kreitzweg 8 + 43, D-41472 Neuss
☎ +49 2131 98 13 0 🖷 +49 2131 85 66 6
E-Mail: info@armaturen-weinhold.de
Internet: www.armaturen-weinhold.de

▼ Welding leads and connectors 2020

P. Druseidt Elektrotechnische Spezialfabrik GmbH & Co. KG
Neuenkamper Straße 105, D-42855 Remscheid
☎ +49 2191 9352-0 🖷 +49 2191 9352-150
E-Mail: info@druseidt.de
Internet: www.druseidt.de

▼ Secondary cables for resistance welding 2030

P. Druseidt Elektrotechnische Spezialfabrik GmbH & Co. KG
Neuenkamper Straße 105, D-42855 Remscheid
☎ +49 2191 9352-0 🖷 +49 2191 9352-150
E-Mail: info@druseidt.de
Internet: www.druseidt.de

▼ Clamping systems, clamping elements 2040

Demmeler Maschinenbau GmbH & Co. KG
Alpenstraße 10, 87751 Heimertingen
Postfach: 51, 87751 Heimertingen
☎ +49 8335 9859-0 🖷 +49 8335 9859-27
E-Mail: info@demmeler.com
Internet: www.demmeler.com

Bernd Siegmund GmbH
Landsberger Straße 180, 86507 Oberottmarshausen
☎ +49 8203 9607-0 🖷 +49 8203 9607-33
E-Mail: info@siegmund.com
Internet: www.siegmund.com

▼ Drying cabinets (electrodes and fluxes), heated quivers, baking ovens 2060

DWT GmbH
Wilhelm-Tenhagen-Str. 5, D-46240 Bottrop
☎ +49 2041 77 144-0 🖷 +49 2041 77 144-99
E-Mail: info@dwt-gmbh.de
Internet: www.dwt-gmbh.de

▼ Tools for joint preparation 2090

DWT GmbH
Wilhelm-Tenhagen-Str. 5, D-46240 Bottrop
☎ +49 2041 77 144-0 🖷 +49 2041 77 144-99
E-Mail: info@dwt-gmbh.de
Internet: www.dwt-gmbh.de

7 Filler materials for welding and coating specific materials (classified by material groups)

▼ Filler materials for high alloy steels 2160

EWM AG
Dr.-Günter-Henle-Straße 8, D-56271 Mündersbach
☎ +49 2680 181-0 🖷 +49 2680 181-244
E-Mail: info@ewm-group.com
Internet: www.ewm-group.com

Hyundai Welding GmbH
Bahnhof Weidenau 6, 57076 Siegen
☎ +49 271 7701759-0 🖷 +49 271 7701759-2
E-Mail: hendrik@hyundaiwelding.com
Internet: www.hyundaiwelding.com

Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

Welding Alloys Deutschland GmbH
Ostring 52, D-47669 Wachtendonk
☎ +49 2836 9119-0 🖷 +49 2836 9119-18
E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

▼ Filler materials for high alloy cast steels 2170

Welding Alloys Deutschland GmbH
Ostring 52, D-47669 Wachtendonk
☎ +49 2836 9119-0 🖷 +49 2836 9119-18
E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

▼ Filler materials for plastics 2180

Welding Alloys Deutschland GmbH
Ostring 52, D-47669 Wachtendonk
☎ +49 2836 9119-0 🖷 +49 2836 9119-18
E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

▼ Filler materials for non-ferrous metals and alloys 2190

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Staalindustrieweg 15, NL-2952 AT Alblasserdam
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Internet: www.welding-alloys.com

▼ Filler materials for unalloyed and low alloy steels 2200

Bavaria Schweißtechnik GmbH
Wiesenweg 23, D-85716 Unterschleißheim
☎ +49 89 3171 035
E-Mail: bavaria@subarcflux.com
Internet: www.subarcflux.com

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Internet: www.welding-alloys.com

Westfälische Drahtindustrie GmbH
Wilhelmstraße 7, 59067 Hamm
☎ +49 2381 276-438 🖷 +49 2381 276-232
E-Mail: schweissdraht@wdi.de

▼ Filler materials for unalloyed and low alloy cast steels 2210

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E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

▼ Filler materials for wear and corrosion resisting deposits 2220

Deloro Wear Solutions GmbH
Zur Bergpflege 51-53, D-56070 Koblenz
☎ +49 261 8088-0 🖷 +49 261 8088-23
E-Mail: info@deloro.com
Internet: www.deloro.com

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Carl-Friedrich-Benz-Straße 7, D-47877 Willich
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VAUTID GmbH
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Brunnwiesenstraße 5, D-73760 Ostfildern
☎ +49 711 4404-0 🖷 +49 711 4420-39
E-Mail: vautid@vautid.de
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E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

8 Filler materials for welding, cutting and coating (classified by types)

▼ Wires, strips and plates for submerged arc and electroslag welding 2250

Bavaria Schweißtechnik GmbH
Wiesenweg 23, D-85716 Unterschleißheim
☎ +49 89 3171 035
E-Mail: bavaria@subarcflux.com
Internet: www.subarcflux.com

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Carl-Friedrich-Benz-Straße 7, D-47877 Willich
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☎ +49 711 4404-0 🖷 +49 711 4420-39
E-Mail: vautid@vautid.de
Internet: www.vautid.com

▼ Wire electrodes for gas metal-arc welding 2270

Deloro Wear Solutions GmbH
Zur Bergpflege 51-53, D-56070 Koblenz
☎ +49 261 8088-0 🖷 +49 261 8088-23
E-Mail: info@deloro.com
Internet: www.deloro.com

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Wilhelmstraße 7, 59067 Hamm
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E-Mail: schweissdraht@wdi.de

▼ Flux cored wires and strips 2280

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Internet: www.hyundaiwelding.com

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▼ Tubular stick electrodes 2290

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E-Mail: info@durum.de
Internet: www.durmat.com

▼ Welding fluxes 2300

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☎ +49 89 3171 035
E-Mail: bavaria@subarcflux.com
Internet: www.subarcflux.com

Deloro Wear Solutions GmbH
Zur Bergpflege 51-53, D-56070 Koblenz
☎ +49 261 8088-0 🖷 +49 261 8088-23
E-Mail: info@deloro.com
Internet: www.deloro.com

▼ Gas welding rods 2310

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E-Mail: schweissdraht@wdi.de

▼ TIG (GTA) welding rods 2320

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Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

▼ Covered electrodes (manual metal arc welding) 2360

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

▼ Filler materials for laser beam welding 2370

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

9 Filler materials for thermal spraying (classified by composition)

▼ Carbide powders 2380

Deloro Wear Solutions GmbH
Zur Bergpflege 51-53, D-56070 Koblenz
☎ +49 261 8088-0 🖷 +49 261 8088-23
E-Mail: info@deloro.com
Internet: www.deloro.com

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

▼ Metal powders and wires 2400

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

Welding Alloys Deutschland GmbH
Ostring 52, D-47669 Wachtendonk
☎ +49 2836 9119-0 🖷 +49 2836 9119-18
E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

▼ Powder mixtures 2410

Deloro Wear Solutions GmbH
Zur Bergpflege 51-53, D-56070 Koblenz
☎ +49 261 8088-0 🖷 +49 261 8088-23
E-Mail: info@deloro.com
Internet: www.deloro.com

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

10 Filler materials for thermal spraying (classified by process and type of spray material)

▼ Filler materials for flame spraying (wires, rods, powders) 2440

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

▼ Filler materials for arc spraying(wires) 2450

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

Westfälische Drahtindustrie GmbH
Wilhelmstraße 7, 59067 Hamm
☎ +49 2381 276-438 🖷 +49 2381 276-232
E-Mail: schweissdraht@wdi.de

▼ Filler materials for plasma spraying (powders) 2460

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

▼ Filler materials for molten metal spraying 2470

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

11 Solders (classified by composition)

▼ Lead-tin solders 2510

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Tin-lead solders with or without Cu, Ag, P additions 2530

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Leadfree solders 2540

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Other solders 2550

PFARR Stanztechnik GmbH
Am kleinen Sand 1, D-36419 Buttlar
☎ +49 36967 747-0 🖷 +49 36967 747-47
E-Mail: info@pfarr.de
Internet: www.pfarr.de

12 Brazing fillers (classified by composition)

▼ Aluminium brazing fillers 2560

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Gold containing brazing fillers 2570

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Copper/brass brazing fillers 2580

INNOBRAZE GmbH für Löt- und Verschleisstechnik
Fritz-Müller-Straße 97, D-73730 Esslingen
☎ +49 711 3154 76-0 🖷 +49 711 3154 76-29
E-Mail: info@innobraze.de
Internet: www.innobraze.de

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Nickel base brazing fillers 2590

INNOBRAZE GmbH für Löt- und Verschleisstechnik
Fritz-Müller-Straße 97, D-73730 Esslingen
☎ +49 711 3154 76-0 🖷 +49 711 3154 76-29
E-Mail: info@innobraze.de
Internet: www.innobraze.de

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Palladium containing brazing fillers 2600

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

PFARR Stanztechnik GmbH
Am kleinen Sand 1, D-36419 Buttlar
☎ +49 36967 747-0 🖷 +49 36967 747-47
E-Mail: info@pfarr.de
Internet: www.pfarr.de

▼ Phosphorus containing brazing fillers 2610

INNOBRAZE GmbH für Löt- und Verschleisstechnik
Fritz-Müller-Straße 97, D-73730 Esslingen
☎ +49 711 3154 76-0 🖷 +49 711 3154 76-29
E-Mail: info@innobraze.de
Internet: www.innobraze.de

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Internet: www.johnson-matthey.ch

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Platinum containing brazing fillers 2620

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Silver brazing fillers 2630

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

PFARR Stanztechnik GmbH
Am kleinen Sand 1, D-36419 Buttlar
☎ +49 36967 747-0 🖷 +49 36967 747-47
E-Mail: info@pfarr.de
Internet: www.pfarr.de

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Other brazing fillers 2650

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

13 Forms of solders and brazing filler

▼ Flux cored rods 2660

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Flux coated rods 2670

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Brazing and soldering wires, rods and strips 2680

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

PFARR Stanztechnik GmbH
Am kleinen Sand 1, D-36419 Buttlar
☎ +49 36967 747-0 🖷 +49 36967 747-47
E-Mail: info@pfarr.de
Internet: www.pfarr.de

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Preforms and foils 2690

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Fritz-Müller-Straße 97, D-73730 Esslingen
☎ +49 711 3154 76-0 🖷 +49 711 3154 76-29
E-Mail: info@innobraze.de
Internet: www.innobraze.de

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E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

PFARR Stanztechnik GmbH
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E-Mail: info@pfarr.de
Internet: www.pfarr.de

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Brazing and soldering pastes 2700

INNOBRAZE GmbH für Löt- und Verschleisstechnik
Fritz-Müller-Straße 97, D-73730 Esslingen
☎ +49 711 3154 76-0 🖷 +49 711 3154 76-29
E-Mail: info@innobraze.de
Internet: www.innobraze.de

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Filler precoated plates 2710

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Brazing and soldering powders 2720

INNOBRAZE GmbH für Löt- und Verschleisstechnik
Fritz-Müller-Straße 97, D-73730 Esslingen
☎ +49 711 3154 76-0 🖷 +49 711 3154 76-29
E-Mail: info@innobraze.de
Internet: www.innobraze.de

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Stranded rods 2730

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

III Plant equipment, including automation, mechanization and industrial robots, for thermal cutting and erosion

1 Plant equipment, including automation, mechanization and industrial robots, for thermal cutting and erosion

▼ Oxy-fuel gas cutting 2740

Dodek GmbH & Co. KG
Lanzstraße 2, D-88410 Bad Wurzach
☎ +49 7564 948 95-0 🖷 +49 7564 948 95-9
E-Mail: contact@dodek.de
Internet: www.dodek.de

Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

▼ Laser beam cutting and drilling, electron beam drilling 2810

PTR Strahltechnik GmbH
Am Erlenbruch 9, D-63505 Langenselbold
☎ +49 61 84 20 55-0 🖷 +49 61 84 20 55-300
E-Mail: zentrale@ptr-ebeam.com
Internet: www.ptr-ebeam.com

Steigerwald Strahltechnik GmbH
Emmy-Noether-Straße 2, D-82216 Maisach
☎ +49 81 41 35 35-0 🖷 +49 81 41 35 35-215
E-Mail: info@sst-ebeam.com
Internet: www.sst-ebeam.com

▼ Plasma cutting 2860

Carl Cloos Schweißtechnik GmbH
Carl-Cloos-Straße 1, D-35708 Haiger
☎ +49 27 73 85-0 🖷 +49 27 73 85-275
E-Mail: info@cloos.de
Internet: www.cloos.de

Dodek GmbH & Co. KG
Lanzstraße 2, D-88410 Bad Wurzach
☎ +49 7564 948 95-0 🖷 +49 7564 948 95-9
E-Mail: contact@dodek.de
Internet: www.dodek.de

JÄCKLE & ESS System GmbH
Riedweg 4 + 9, D-88339 Bad Waldsee
☎ +49 7524 9700-0 🖷 +49 7524 9700-30
E-Mail: sales@jaeckleess.com
Internet: www.jaeckleess.com

OTC DAIHEN EUROPE GmbH
Krefelder Straße 675-677, D-41066 Mönchengladbach
☎ +49 2161 69497-60 🖷 +49 2161 69497-61
E-Mail: info@otc-daihen.de
Internet: www.otc-daihen.de

Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

2 Plant for production of filler materials

▼ Gas manufacturing and liquefying plants 2900

DWT GmbH
Wilhelm-Tenhagen-Str. 5, D-46240 Bottrop
☎ +49 2041 77 144-0 🖷 +49 2041 77 144-99
E-Mail: info@dwt-gmbh.de
Internet: www.dwt-gmbh.de

3 Plant for production of consumbales

▼ Welding electrode and flux cored wire production plants 2930

Welding Alloys Deutschland GmbH
Ostring 52, D-47669 Wachtendonk
☎ +49 2836 9119-0 🖷 +49 2836 9119-18
E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

IV General productions equipment for automation

1 General productions equipment, systems for computer aided manufacture, data processing, manual and automatic control engineering

▼ CAD, CAM, CAQ, CIM and CAP systems 2950

simufact engineering gmbh
Tempowerkring 19, 21079 Hamburg
☎ +40 790 128-000 🖷 +40 790 128-199
E-Mail: sales@simufact.de
Internet: www.simufact.de

▼ Capture, checking and processing of process and production parameters 2960

EWM AG
Dr.-Günter-Henle-Straße 8, D-56271 Mündersbach
☎ +49 2680 181-0 🖷 +49 2680 181-244
E-Mail: info@ewm-group.com
Internet: www.ewm-group.com

SKS Welding Systems GmbH
Marie-Curie-Straße 14, D-67661 Kaiserslautern
☎ +49 6301 7986-0 🖷 +49 6301 7986-119
E-Mail: info@de.sks-welding.com
Internet: www.sks-welding.com

▼ Optics for laser beam welding and/or cutting 3000

OTC DAIHEN EUROPE GmbH
Krefelder Straße 675-677, D-41066 Mönchengladbach
☎ +49 2161 69497-60 🖷 +49 2161 69497-61
E-Mail: info@otc-daihen.de
Internet: www.otc-daihen.de

▼ Programs (software) 3010

simufact engineering gmbh
Tempowerkring 19, 21079 Hamburg
☎ +40 790 128-000 🖷 +40 790 128-199
E-Mail: sales@simufact.de
Internet: www.simufact.de

SKS Welding Systems GmbH
Marie-Curie-Straße 14, D-67661 Kaiserslautern
☎ +49 6301 7986-0 🖷 +49 6301 7986-119
E-Mail: info@de.sks-welding.com
Internet: www.sks-welding.com

▼ Mass production, flexible production facilities and welding lines 3030

pro-beam GmbH & Co. KGaA
Zeppelinstraße 26, 82205 Gilching
☎ +49 89 899 233-0 🖷 +49 89 899 233-11
E-Mail: info@pro-beam.com
Internet: www.pro-beam.com

PTR Strahltechnik GmbH
Am Erlenbruch 9, D-63505 Langenselbold
☎ +49 61 84 20 55-0 🖷 +49 61 84 20 55-300
E-Mail: zentrale@ptr-ebeam.com
Internet: www.ptr-ebeam.com

10 Other consumables

▼ Pickling pastes 3830

Chemetall GmbH
Aarauerstrasse 51, CH-5200 Brugg
☎ +41 56 616 90 30 🖷 +41 56 616 90 40
E-Mail: chemetall.schweiz@basf.com
Internet: www.chemetall.com

▼ Brazing and soldering fluxes 3890

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

Solvay Fluor GmbH
Hans-Böckler-Allee 20, D-30173 Hannover
☎ +49 511 857-2035 🖷 +49 511 857-3176
E-Mail: werner.schmitt@solvay.com
Internet: www.solvay.de

H.P. Wirth GmbH
Weberstraße 46, D-75239 Eisingen
☎ +49 7232 809 78-0 🖷 +49 7232 809 78-15
E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Solder masks and resists 3960

INNOBRAZE GmbH für Löt- und Verschleisstechnik
Fritz-Müller-Straße 97, D-73730 Esslingen
☎ +49 711 3154 76-0 🖷 +49 711 3154 76-29
E-Mail: info@innobraze.de
Internet: www.innobraze.de

11 Measurement and sensor technology

▼ Manual and miscellaneous measuring devices for arc welding (current, voltage, wire-feed rate, gas-feed rate, welding speed and energy per unit length) 4200

EWM AG
Dr.-Günter-Henle-Straße 8, D-56271 Mündersbach
☎ +49 2680 181-0 🖷 +49 2680 181-244
E-Mail: info@ewm-group.com
Internet: www.ewm-group.com

Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

▼ Calibration 4220

EWM AG
Dr.-Günter-Henle-Straße 8, D-56271 Mündersbach
☎ +49 2680 181-0 🖷 +49 2680 181-244
E-Mail: info@ewm-group.com
Internet: www.ewm-group.com

▼ Coat-thickness, wall-thickness and crack-depth measurement 4370

KARL DEUTSCH
Prüf- und Messgerätebau GmbH + Co KG
Otto-Hausmann-Ring 101, D-42115 Wuppertal
Postfach: 132354, D-42050 Wuppertal
☎ +49 202 71-920 🖷 +49 202 71-4932
E-Mail: info@karldeutsch.de
Internet: www.karldeutsch.de

▼ Monitoring devices for arc welding 4440

Valk Welding B.V.
Staalindustrieweg 15, NL-2952 AT Alblasserdam
☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

12 Testing Technology – Non-Destructive Testing

▼ Determination and testing of products, joining processes and fabrication operations 4561

Ingenieurbüro Jürgen Bialek
Halsbrücker Straße 34, D-09599 Freiberg
☎ +49 3731 1625-29 🖷 +49 3731 1625-30
E-Mail: bialek@bialek-ing.de
Internet: www.bialek-ing.de

▼ consultancy and planning of fabrication and application of materials, energy and processes 4562

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Halsbrücker Straße 34, D-09599 Freiberg
☎ +49 3731 1625-29 🖷 +49 3731 1625-30
E-Mail: bialek@bialek-ing.de
Internet: www.bialek-ing.de

▼ Leak testing 4670

Helling GmbH
Werkstoffprüfung und Gerätebau
Spökerdamm 2, D-25436 Heidgraben
☎ +49 4122 922-0 🖷 +49 4122 922-201
E-Mail: info@helling.de
Internet: www.helling.de

▼ Radiographic testing 4710

Helling GmbH
Werkstoffprüfung und Gerätebau
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Internet: www.helling.de

▼ Dye-penetration testing 4820

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Otto-Hausmann-Ring 101, D-42115 Wuppertal
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Internet: www.karldeutsch.de

Helling GmbH
Werkstoffprüfung und Gerätebau
Spökerdamm 2, D-25436 Heidgraben
☎ +49 4122 922-0 🖷 +49 4122 922-201
E-Mail: info@helling.de
Internet: www.helling.de

Helmut Klumpf
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☎ +49 2366 1003-0 🖷 +49 2366 1003-11
E-Mail: klumpf@diffu-therm.de
Internet: www.diffu-therm.de

▼ Design and analysis of welded structures 4905

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☎ +49 3731 1625-29 🖷 +49 3731 1625-30
E-Mail: bialek@bialek-ing.de
Internet: www.bialek-ing.de

▼ Magnetic testing 5110

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☎ +49 2366 1003-0 🖷 +49 2366 1003-11
E-Mail: klumpf@diffu-therm.de
Internet: www.diffu-therm.de

▼ Supervision of welding and fabrication operations, on site and in-plant 5505

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E-Mail: bialek@bialek-ing.de
Internet: www.bialek-ing.de

▼ Miscellaneous non-destructive testing procedures 5580

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E-Mail: info@helling.de
Internet: www.helling.de

▼ Ultrasonic testing 5730

KARL DEUTSCH
Prüf- und Messgerätebau GmbH + Co KG
Otto-Hausmann-Ring 101, D-42115 Wuppertal
Postfach: 132354, D-42050 Wuppertal
☎ +49 202 71-920 🖷 +49 202 71-4932
E-Mail: info@karldeutsch.de
Internet: www.karldeutsch.de

▼ ultraviolet lamps 5755

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Helling GmbH
Werkstoffprüfung und Gerätebau
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15 Testing Technology – Testing Procedures/ Testing Facilities

▼ Test tables 6125

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☎ +49 2303 2586459 🖷 +49 2303 9421184
E-Mail: mail@absaugtechnik-kalkhof.de
Internet: www.absaugtechnik-kalkhof.de

V Contract work and services for joining, separating and coating

2 Sub-contracting – Processing of specific materials

▼ Coated and plated materials 7050

DURUM VERSCHLEISS-SCHUTZ GMBH
Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
E-Mail: info@durum.de
Internet: www.durmat.com

VAUTID GmbH
Pioneering Wear Protection
Brunnwiesenstraße 5, D-73760 Ostfildern
☎ +49 711 4404-0 🖷 +49 711 4420-39
E-Mail: vautid@vautid.de
Internet: www.vautid.com

Welding Alloys Deutschland GmbH
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E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

▼ Platinum, gold, silver 7320

Johnson Matthey & Brandenberger AG
Glattalstrasse 18, CH-8052 Zürich
☎ +41 44 307 19-30 🖷 +41 44 307 19-20
E-Mail: info@matthey.com
Internet: www.johnson-matthey.ch

▼ Superalloys (hot isostatic pressure) 7390

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E-Mail: info@durum.de
Internet: www.durmat.com

4 Sub-contracting – Application of joining and other manufacturing processes

▼ Surfacing 7710

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E-Mail: vautid@vautid.de
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Internet: www.welding-alloys.com

▼ Electron, laser beam welding 7770

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Internet: www.pro-beam.com

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Internet: www.ptr-ebeam.com

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Internet: www.slv-service.de

Steigerwald Strahltechnik GmbH
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☎ +49 81 41 35 35-0 🖷 +49 81 41 35 35-215
E-Mail: info@sst-ebeam.com
Internet: www.sst-ebeam.com

▼ High-temperature brazing in vacuum 7805

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E-Mail: info@harnischmacher.de
Internet: www.harnischmacher.de

▼ Metal spraying 7890

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Internet: www.durmat.com

▼ Robot welding TIG/MIG/MAG 7940

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Valk Welding B.V.
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☎ +31 78 691-7011 🖷 +31 78 691-9515
E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

▼ Friction stir welding 7960

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E-Mail: buero@schweissen-aber-sicher.de
Internet: www.schweissen-aber-sicher.de

▼ Maintenance, servicing, repair 8070

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☎ +49 25 6468-0 🖷 +49 25 6468-120
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Internet: www.kemper.de

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Ostring 52, D-47669 Wachtendonk
☎ +49 2836 9119-0 🖷 +49 2836 9119-18
E-Mail: info.germany@welding-alloys.com
Internet: www.welding-alloys.com

5 Organizations, education and training, certification, research, information transfer, technical literature and regulations

▼ Accreditation and certification organizations 8090

DVS – Kursstätten
Internet: www.DVS-Bildungseinrichtungen.de

▼ Acceptance, approval, examination and supervisory organizations 8100

DVS – Kursstätten
Internet: www.DVS-Bildungseinrichtungen.de

▼ Technical publishers, Libraries (literature, codes of practice, educational films, software, CD-ROM services, audiovisual media, digital media) 8130

DVS Media GmbH
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E-Mail: media@dvs-media.info
Internet: www.dvs-media.eu

Index to Companies

Index to Companies

I Plant and equipment for joining, surfacing and cutting processes

1 Plant and equipment, including automation, mechanization and industrial robots, for the welding of metal, ceramic and composite materials

- ❐ 10 Flash welding
- ❐ 20 Stud welding
- ❐ 30 Projection welding
- ❐ 40 Diffusion welding
- ❐ 50 Electrogas welding
- ❐ 60 Electron beam welding
- ❐ 70 Electroslag welding
- ❐ 80 Narrow gap welding
- ❐ 90 Tubular wire welding
- ❐ 100 Flux cored arc welding
- ❐ 110 Gas pressure welding
- ❐ 120 Gas welding
- ❐ 130 Thermit welding
- ❐ 140 Induction welding
- ❐ 150 Cold pressure welding
- ❐ 160 Enclosed resistance fusion welding
- ❐ 170 Capacitor discharge welding
- ❐ 180 Laser welding
- ❐ 190 Manual metal arc welding
- ❐ 200 Pulsed arc welding
- ❐ 210 Light beam welding
- ❐ 220 Linear friction welding, Friction stir Welding
- ❐ 230 Magnetic pulse welding
- ❐ 240 Multiple-wire welding
- ❐ 250 MIG/MAG (GMA) welding
- ❐ 260 Microwelding
- ❐ 270 Plasma-TIG welding
- ❐ 280 Plasma welding
- ❐ 290 Resistance butt welding
- ❐ 300 Seam welding
- ❐ 310 Butt seam welding with rotary transformer
- ❐ 320 Frictin stir welding
- ❐ 330 Explosive welding
- ❐ 340 Butt seam welding with sliding contacts
- ❐ 350 Magnetically impelled arc butt (MIAB) welding
- ❐ 360 Tandem welding
- ❐ 370 Ultrasonic welding
- ❐ 380 Firecracker welding
- ❐ 390 Submerged arc welding
- ❐ 400 Roll butt seam welding
- ❐ 410 Resistance spot welding
- ❐ 420 TIG (GTA) welding

2 Plant and equipment, including automation, mechanization and industrial robots, for weld surfacing and cladding

- ❐ 430 Additive manufacturing
- ❐ 440 Electroslag cladding
- ❐ 450 Laser cladding
- ❐ 460 Plasma cladding
- ❐ 470 Friction cladding
- ❐ 480 Explosive and roll cladding
- ❐ 490 Gas shielded arc cladding
- ❐ 500 Submerged arc cladding

3 Plant and equipment, including automation, mechanization and industrial robots, for brazing and soldering

- ❐ 510 Surfacing by brazing and soldering
- ❐ 520 Hot bar reflow soldering
- ❐ 530 Electron beam brazing
- ❐ 540 Debrazing, desoldering
- ❐ 550 Flame brazing and soldering
- ❐ 560 High-temperature brazing
- ❐ 570 Induction brazing and soldering
- ❐ 580 Bit soldering, block brazing, roller tinning
- ❐ 590 Laser beam brazing
- ❐ 600 Arc brazing
- ❐ 610 Light beam brazing and soldering
- ❐ 620 Bath, wave and drag soldering
- ❐ 630 Microbrazing and soldering
- ❐ 640 Furnace brazing and soldering
- ❐ 650 Friction soldering
- ❐ 660 Salt bath brazing
- ❐ 670 Wave soldering
- ❐ 680 Wave Soldering
- ❐ 690 Dip brazing and soldering
- ❐ 700 Ultrasonic soldering
- ❐ 710 Hot gas soldering
- ❐ 720 Resistance brazing
- ❐ 730 Reflow soldering

4 Plant and equipment, including automation, mechanization and industrial robots, for the welding of plastics

- ❐ 740 Extrusion welding
- ❐ 750 Heated tool welding
- ❐ 760 High frequency welding of plastics
- ❐ 770 Infrared-welding
- ❐ 780 Laser welding of plastics
- ❐ 790 Light beam welding of plastics
- ❐ 800 Friction welding of plastics
- ❐ 810 Rotational friction welding
- ❐ 820 Ultrasonic welding of plastics
- ❐ 830 Vibration welding of plastics
- ❐ 840 Hot gas welding of plastics

5 Plant and equipment and joining elements, including automation, mechanization and industrial robots, for positive and non-positive joining

- ❐ 850 Flanging
- ❐ 860 Wire netting, wire weaving
- ❐ 870 Tamp joining
- ❐ 880 Hanging, expanding, clamping, wedging, extending
- ❐ 890 Seaming
- ❐ 900 Joining by extrusion or drawing
- ❐ 910 Joining by forming
- ❐ 920 Joining by lockforming (lockseaming)
- ❐ 930 Joining by compression or squeezing
- ❐ 940 Joining by widening or tightening (rolling in of tubes, botting, beading)
- ❐ 950 Joining by winding
- ❐ 960 Stapeling (using by wirestaples)
- ❐ 970 Riveting
- ❐ 980 Pressure joining (press-fitting, shrink-fitting, expansion-fitting)
- ❐ 990 Screwing
- ❐ 1000 Joining elements (rivets, tubular rivets, tap rivets, pop rivets, blind rivet nuts, bolts, screws)

6 Plant and equipment, including automation, mechanization and industrial robots, for special applications

- ❐ 1010 Torch cleaning, automatic torch cleaning systems
- ❐ 1020 Systems for feeding, positioning, tipping or conveying (e.g. nut feeding systems)
- ❐ 1030 Production equipment and production lines
- ❐ 1040 Orbital welding equipment
- ❐ 1050 Stack cutting
- ❐ 1060 Repair welding and cutting
- ❐ 1063 Welding trainer
- ❐ 1070 Underwater cutting
- ❐ 1080 Underwater welding
- ❐ 1090 Welding, brazing, soldering and thermal cutting and surfacing in aerospace applications

7 Services

- ❐ 1091 Leasing of welding plant and welding Equipment
- ❐ 1092 leasing of welding manipulators

II Plant and equipment for heat treatment and other production processes

1 Plant and equipment, including automation, mechanization and industrial robots, for heat treatment

- ❐ 1100 Diffusion annealing
- ❐ 1110 Flame stress relieving
- ❐ 1120 Flame straightening
- ❐ 1130 Flame heating
- ❐ 1140 Hardening, tempering, annealing
- ❐ 1150 Induction heating
- ❐ 1160 Normalizing
- ❐ 1170 Furnace heating
- ❐ 1180 Stress relief annealing
- ❐ 1190 Soft annealing
- ❐ 1200 Resistance heating

2 Plant and equipment, including automation, mechanization and industrial robots, for other production processes

- ❐ 1210 Bending, pipe bending
- ❐ 1220 Millining, compressing, drawing
- ❐ 1230 Drilling
- ❐ 1240 Turning, milling, planing
- ❐ 1250 Edge preparation (e.g. plate and pipe chamfering machines)
- ❐ 1260 Casting
- ❐ 1270 Surface preparation and finishing
- ❐ 1280 Polishing
- ❐ 1290 Cold dressing
- ❐ 1300 Sawing
- ❐ 1310 Sintering and hot isostatic pressing
- ❐ 1320 Grinding
- ❐ 1330 Cutting (e.g. plate shearing), slamping, nibbling
- ❐ 1340 Welding conditioning
- ❐ 1345 Impact treatment
- ❐ 1350 Blasting
- ❐ 1360 Vibratory stress relieving
- ❐ 1370 Pumping

3 Workshop and workplace equipment, safety equipment

- ❐ 1380 Slinging gear, cranes and elevators (crane systems, lifting forks and beams, slewing cranes, lifting magnets, electric chain hoists)
- ❐ 1390 Work tables (e.g. welding and cutting tables)
- ❐ 1400 Heat recovery systems
- ❐ 1410 Load turning devices
- ❐ 1420 Transparent/opaque screens
- ❐ 1430 Soldering fume filters
- ❐ 1440 Machine protection gates
- ❐ 1450 At-source welding fume extraction systems (stationary, mobile)
- ❐ 1460 Sound absorbing materials, soundproof chambers
- ❐ 1470 Safety device for industrial robots (e.g. door locking systems, control boards,
- ❐ visual supervision systems)
- ❐ 1480 Welding booths
- ❐ 1490 Welding curtains
- ❐ 1500 Protective screens
- ❐ 1510 Weld fume filters and filtration systems
- ❐ 1520 Protection devices against fires and explosions
- ❐ 1530 Protection equipment against high energy radiation (e.g. X-rays, laser radiation)
- ❐ 1540 Stationary vacuum cleaners for industrial use
- ❐ 1550 Exhaust and ventilation systems
- ❐ 1560 Work benches, workshop lockers

❐ 1570 Workshop stools, aids to stability
❐ 1580 Workshop trolleys, cylinder trolleys
❐ 1590 Tools
❐ 1600 Other protective and safety devices (e.g. signs warning against possible Hazards, fire extinguishers, fire blankets)

4 Health and safety (personal protective equipment)

❐ 1610 Respiratory protection (filters-, insulating devices)
❐ 1620 First aid equipment, medicines
❐ 1630 Externally ventilated welding helmets
❐ 1640 Ear protection (wadding, ear plugs, ear muffs)
❐ 1650 Laser protection
❐ 1660 Protective clothing (helmets, aprons, garments, shoes, gloves)
❐ 1670 Welder's head screens and shields, protective goggles, eye protective filters
❐ 1680 Other protective equipment

5 General accessories

❐ 1690 Equalizing systems (e.g. for spot welding guns)
❐ 1700 Weld backings and adhesive tapes (for one sided welding)
❐ 1710 Torch-neck changing systems
❐ 1720 Torch and welding head manipulation systems
❐ 1730 Controlled feeding devices (e.g. for adhesives, solders and powders)
❐ 1740 Wire-guide spiral
❐ 1750 Wire feeders
❐ 1760 Turntables and tilt-turn positioners, lift tables
❐ 1770 Pressure cylinders for pressure and resistance welding
❐ 1780 Workpiece storage equipment (belts, pallets, stores)
❐ 1790 Resistance welding electrodes
❐ 1800 Materials for resistance welding electrodes
❐ 1810 TIG (GTA) welding electrodes
❐ 1820 Electrode holders
❐ 1830 Electrode grinding devices
❐ 1840 Gas lighters
❐ 1850 Globoidal drive
❐ 1860 Clamps (terminals, earthing, workpiece) and polarity testers
❐ 1870 Cooling systems
❐ 1880 Magnetic valves
❐ 1890 Water-, oil-, air-cooler
❐ 1900 Magnets for welding, magnetic handling equipment
❐ 1910 Assembly systems, assembling and positioning devices (clamps, roller blocks, line-up clamps)
❐ 1920 Plasma valves
❐ 1930 Spot welding guns
❐ 1940 Robot holding bracket
❐ 1950 Chipping hammers and wire brushes
❐ 1960 Hoses, hose couplings, hose connections, hose packages
❐ 1970 Hose press
❐ 1980 Welding-sets, diesel or gasoline driven
❐ 1990 Filler, wire spools
❐ 2000 Welding flux feeding and recovery devices
❐ 2010 Welding mirrors
❐ 2020 Welding leads and connectors
❐ 2030 Secondary cables for resistance welding
❐ 2040 Clamping systems, clamping elements
❐ 2050 Steel-wire brushes and hand brushes for welds
❐ 2060 Drying cabinets (electrodes and fluxes), heated quivers, baking ovens
❐ 2070 Workpiece handling systems (lift and shift systems, dial tables) other accessories, pumps and other auxiliary equipment
❐ 2080 Tool changing systems
❐ 2090 Tools for joint preparation
❐ 2100 Other accessories, pumps and other auxiliary equipment

6 Gas supply accessories

❐ 2110 Gas sources/tanks with pipework and valves (storage tanks, tankers, containers, cylinder racks and batteries, individual cylinders)
❐ 2120 Central switching, pressure regulating and safety units, gas mixing units and valves for supply pipework (switching, pressure regulating and safety devices, valves, gas filters, gas flow and pressure meters)
❐ 2130 Equipment for gas take-off stations (stop valves, pressure regulators, gas mixers, safety devices, take-off boards)
❐ 2140 Individual cylinders (pressure reducers and anti-flashback and backflow devices)
❐ 2150 Special equipment and general accessories (automatic switching and pressure control systems, gas analyzers, pipe identification stickers, clamps etc.)

7 Filler materials for welding and coating specific materials (classified by material groups)

❐ 2160 Filler materials for high alloy steels
❐ 2170 Filler materials for high alloy cast steels
❐ 2180 Filler materials for plastics
❐ 2190 Filler materials for non-ferrous metals and alloys
❐ 2200 Filler materials for unalloyed and low alloy steels
❐ 2210 Filler materials for unalloyed and low alloy cast steels
❐ 2220 Filler materials for wear and corrosion resisting deposits
❐ 2230 Filler materials for underwater welding
❐ 2240 Filler materials for other materials

8 Filler materials for welding, cutting and coating (classified by types)

❐ 2250 Wires, strips and plates for submerged arc and electroslag welding
❐ 2260 Wires and strips for micro welding
❐ 2270 Wire electrodes for gas metal-arc welding
❐ 2280 Flux cored wires and strips
❐ 2290 Tubular stick electrodes
❐ 2295 Metal powder for welding, coating and additive finishing as well as cored wire and rod electrode manufacture
❐ 2300 Welding fluxes
❐ 2310 Gas welding rods
❐ 2320 TIG (GTA) welding rods
❐ 2330 Gouging and thermal cutting electrodes
❐ 2340 Underwater welding and cutting electrodes
❐ 2350 Thermit welding materials
❐ 2360 Covered electrodes (manual metal arc welding)
❐ 2370 Filler materials for laser beam welding

9 Filler materials for thermal spraying (classified by composition)

❐ 2380 Carbide powders
❐ 2390 Ceramic powders (metal oxides/nitrides)
❐ 2400 Metal powders and wires
❐ 2410 Powder mixtures
❐ 2420 Suspensions
❐ 2430 Thermoplastics

10 Filler materials for thermal spraying (classified by process and type of spray material)

❐ 2440 Filler materials for flame spraying (wires, rods, powders)
❐ 2450 Filler materials for arc spraying(wires)
❐ 2460 Filler materials for plasma spraying (powders)
❐ 2470 Filler materials for molten metal spraying
❐ 2480 Filler materials for HVOF-spraying (powder)
❐ 2490 Filler materials for coldgas spraying (powder)
❐ 2500 Filler materials for suspension spraying (suspension)

11 Solders (classified by composition)

❐ 2510 Lead-tin solders
❐ 2520 Solders for aluminium
❐ 2530 Tin-lead solders with or without Cu, Ag, P additions
❐ 2540 Leadfree solders
❐ 2550 Other solders

12 Brazing fillers (classified by composition)

❐ 2560 Aluminium brazing fillers
❐ 2570 Gold containing brazing fillers
❐ 2580 Copper/brass brazing fillers
❐ 2590 Nickel base brazing fillers
❐ 2600 Palladium containing brazing fillers
❐ 2610 Phosphorus containing brazing fillers
❐ 2620 Platinum containing brazing fillers
❐ 2630 Silver brazing fillers
❐ 2640 Special brazing fillers (cobalt, titanium, zirconium base)
❐ 2650 Other brazing fillers

13 Forms of solders and brazing filler

❐ 2660 Flux cored rods
❐ 2670 Flux coated rods
❐ 2680 Brazing and soldering wires, rods and strips
❐ 2690 Preforms and foils
❐ 2700 Brazing and soldering pastes
❐ 2710 Filler precoated plates
❐ 2720 Brazing and soldering powders
❐ 2730 Stranded rods

III Plant equipment, including automation, mechanization and industrial robots, for thermal cutting and erosion

1 Plant equipment, including automation, mechanization and industrial robots, for thermal cutting and erosion

❐ 2740 Oxy-fuel gas cutting
❐ 2750 Oxygen lancing
❐ 2760 Flame scarfing
❐ 2770 Flame gouging
❐ 2780 Spark erosion and chemical machining
❐ 2790 Flame cleaning
❐ 2800 Carbon arc cutting
❐ 2810 Laser beam cutting and drilling, electron beam drilling
❐ 2820 Air arc gouging
❐ 2830 Arc-oxygen cutting
❐ 2840 Flame and fusion cutting with metal or mineral powder
❐ 2850 Plasma scarfing
❐ 2860 Plasma cutting
❐ 2870 Water jet cutting, water abrasive jet cutting

2 Plant for production of filler materials

❐ 2880 Acetylene generators and filling stations
❐ 2890 Conveying systems
❐ 2900 Gas manufacturing and liquefying plants

List of Products

3 Plant for production of consumbales

❒ 2910 Brazing filler and solder production plants
❒ 2920 Welding wire production plants
❒ 2930 Welding electrode and flux cored wire production plants
❒ 2940 Welding flux production plants

IV General productions equipment for automation

1 General productions equipment, systems for computer aided manufacture, data processing, manual and automatic control engineering

❒ 2950 CAD, CAM, CAQ, CIM and CAP systems
❒ 2960 Capture, checking and processing of process and production parameters
❒ 2970 Industrial plant
❒ 2980 Camera systems for monitoring design and production processes
❒ 2990 Seam tracking and welding head guidance systems
❒ 3000 Optics for laser beam welding and/or cutting
❒ 3010 Programs (software)
❒ 3020 Computers and other hardware (mini and microcomputers, PCs, mainframes, process computers, printers, plotters, processors, etc.)
❒ 3030 Mass production, flexible production facilities and welding lines
❒ 3040 Control engineering (pressure switches, solenoid and plasma valves, etc.)

2 Adhesives

❒ 3050 Epoxy resins (1C, 2C)
❒ 3060 Polyurethanes (1C, 2C)
❒ 3070 Reactive hotmelts
❒ 3080 Cyanoacrylates
❒ 3090 Anaerobically curing adhesives
❒ 3100 Curing on demand via UV radiation
❒ 3110 Silan netted polymer adhesives
❒ 3120 Phenol-formaldehyde resol adhesives
❒ 3130 Pressure sensitive adhesives
❒ 3140 Acrylate adhesives
❒ 3150 Silicones
❒ 3160 MS-polymers
❒ 3170 Structural pressure sensitive adhesives (PSA)
❒

3 Adhesive application

❒ 3180 Cartridges
❒ 3190 Application systems
❒ 3200 Automatisation
❒ 3210 Control system adhesive application
❒ 3220 Metering appliances
❒ 3230 Supply/Metering pumps
❒ 3240 Mixers (dynamic, static)

4 Surface treatment

❒ 3250 Solvent containing systems
❒ 3260 Mechanical processes (grinding, blasting)
❒ 3270 Water based systems (neutral, acid, alkaline)
❒ 3280 Wet chemical processes (etching, phosphatating, anodizing, others)
❒ 3290 Dry chemical processes (silicoater, low pressure plasma, atmospheric pressure plasma, others)
❒ 3300 Primer/Adhesion promoters

5 Consulting

❒ 3310 Adhesive selection
❒ 3320 Design in adhesive bonding
❒ 3330 Characterisation of adhesives
❒ 3340 Quality management
❒ 3350 Auditing of processes
❒ 3360 Auditing of companies
❒ 3370 Plant construction (Plasma equipment)
❒ 3380 Paint/lacquer technology
❒ 3390 Fibre reinforced plastic technology
❒ 3400 Adhesive application
❒ 3410 Integration into the production (production planning)
❒ 3420 Health and safety
❒ 3430 Surface analysis
❒ 3440 Adhesive development
❒ 3450 Electrochemistry/corrosion
❒ 3460 Testing of materials and components
❒ 3470 Simulation and calculation of adhesive bonded joints

6 Research and development

❒ 3480 Adhesive selection
❒ 3490 Design in adhesive bonding
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❒ 3570 Molecular modelling
❒ 3580 Adhesive development
❒ 3590 Electrochemistry/corrosion
❒ 3600 Testing of materials and components
❒ 3610 Simulation and calculation of adhesive bonded joints

7 Workforce qualification

❒ 3620 European Adhesive Bonder (EAB)
❒ 3630 European Adhesive Specialist (EAS)
❒ 3640 European Adhesive Engineer (EAE)
❒ 3650 Fiber Composite Assembler

8 Others

❒ 3660 Specialist printer
❒ 3670 Technology broker
❒ 3680 Certification body of the Federal Railway Authority

9 Gases

❒ 3690 Fuel gases (acetylene, butane, natural gas, methane)
❒ 3700 Active gas
❒ 3710 Doping and test gas
❒ 3720 Compressed air
❒ 3730 Liquid gas
❒ 3740 Hydrogen-nitrogen mixture
❒ 3750 Inert gases (argon, neon, helium)
❒ 3760 Carbon dioxide
❒ 3761 lasing gas
❒ 3762 gas for laser welding and cutting processes
❒ 3770 Gas mixtures
❒ 3780 Oxygen
❒ 3790 Nitrogen
❒ 3800 Hydrogen

10 Other consumables

❒ 3810 Asbestos substitutes
❒ 3820 (weld) backing
❒ 3830 Pickling pastes
❒ 3840 Calcium carbide
❒ 3850 Leak-test materials
❒ 3860 Anti-spatter compounds
❒ 3870 Electro-burnish chemicals
❒ 3880 Paints and varnishes
❒ 3890 Brazing and soldering fluxes
❒ 3900 Auxiliary materials for thermit welding
❒ 3910 Heat protection equipment for welding work
❒ 3920 Impregnating compounds
❒ 3930 Ceramic performs
❒ 3940 Ceramic powders
❒ 3950 Solvents
❒ 3960 Solder masks and resists
❒ 3970 Surface cleaner
❒ 3980 Deadener
❒ 3990 Cleaning agents
❒ 4000 Raw materials for electrode coatings
❒ 4010 Anti-rust compounds
❒ 4020 Oxygen and powder lances
❒ 4030 Marking paints
❒ 4040 Explosives
❒ 4050 Lubricants
❒ 4060 Cutting powders for concrete, cast iron and other materials
❒ 4070 Chalk
❒ 4080 Weld primers
❒ 4090 Weld cleaning
❒ 4100 Sprays, technical
❒ 4110 Abrasives
❒ 4120 Cutting and snagging wheels

11 Measurement and sensor technology

❒ 4130 Chemical analysis
❒ 4140 Elongation, path and angle measurement
❒ 4150 Throughput and flow-rate measurement
❒ 4160 Scanning electron microscopes
❒ 4170 Ferrite-content measuring devices
❒ 4180 Photography and cinematography
❒ 4190 Speed and rotational-speed measurement
❒ 4200 Manual and miscellaneous measuring devices for arc welding (current, voltage, wire-feed rate, gas-feed rate, welding speed and energy per unit length)
❒ 4210 Holography
❒ 4220 Calibration
❒ 4230 Capacitance and inductance measurement
❒ 4240 Force measuring systems
❒ 4250 Gauges and weld gauges
❒ 4260 Power measurement
❒ 4270 Mass, density, force, torque and pressure measurement
❒ 4280 Measuring devices for gases, fumes and dusts
❒ 4290 Measuring devices for sound/noise
❒ 4300 Measuring devices for radiation
❒ 4310 Measuring devices for resistance welding (pulses, periods, current and voltage) and Rogovski belts
❒ 4320 Measuring and monitoring devices for the electrode-penetration depth in resistance welding
❒ 4330 Microscopy
❒ 4340 Surface quality (cut-surface quality)
❒ 4350 Specimen-preparation installations
❒ 4360 Roughness measurement of surfaces / roughness depths
❒ 4370 Coat-thickness, wall-thickness and crack-depth measurement
❒ 4380 Sensor technology
❒ 4390 Miscellaneous measurement technology and measuring devices
❒ 4400 Photoelasticity
❒ 4410 Current and voltage measurement
❒ 4420 Temperature measurement (optical, electrical, chemical and mechanical)
❒ 4430 Thermography
❒ 4440 Monitoring devices for arc welding
❒ 4450 Monitoring devices for resistance welding
❒ 4460 Hydrogen determination
❒ 4470 Resistance and insulation measurement
❒ 4480 Time, event-number and frequency measurement

12 *Testing Technology – Non-Destructive Testing*

- ❒ 4490 Acoustic measuring devices
- ❒ 4500 Acoustic microscopy
- ❒ 4510 Analysis devices
- ❒ 4520 Atomic-absorption spectrometers
- ❒ 4530 Auger probes
- ❒ 4540 Automation and computer assistance for non-destructive testing
- ❒ 4550 Automatic testing systems
- ❒ 4560 Automation in measurement and testing technology
- ❒ 4561 Determination and testing of products, joining processes and fabrication operations
- ❒ 4562 consultancy and planning of fabrication and application of materials, energy and processes
- ❒ 4570 Betatron and linear accelerators
- ❒ 4580 Image-processing installations
- ❒ 4590 Image intensifiers
- ❒ 4600 CAQ
- ❒ 4610 CCD cameras
- ❒ 4620 CIM
- ❒ 4630 Computerised tomography
- ❒ 4640 Elongation and stress determination methods
- ❒ 4650 Elongation gauges
- ❒ 4660 Densitometers Leak-testing installations and devices
- ❒ 4670 Leak testing
- ❒ 4680 Thickness measuring devices
- ❒ 4690 Dose and dose-rate measuring devices
- ❒ 4700 Darkroom facilities
- ❒ 4710 Radiographic testing
- ❒ 4720 Real-time radiographic systems
- ❒ 4730 Borescope
- ❒ 4740 Residual-stress measuring devices
- ❒ 4750 Penetration testing installations
- ❒ 4760 Electrical testing
- ❒ 4770 Electrodynamic testing
- ❒ 4780 Scanning electron microscopy
- ❒ 4790 Electronic measuring devices
- ❒ 4800 Demagnetization installations
- ❒ 4810 Dye penetrants
- ❒ 4820 Dye-penetration testing
- ❒ 4830 Color measuring devices
- ❒ 4840 Field-strength measuring devices
- ❒ 4850 Production measuring devices
- ❒ 4860 Production monitoring
- ❒ 4870 Configuration measuring devices
- ❒ 4880 Photographic devices
- ❒ 4890 Filling-level measuring devices
- ❒ 4900 Structural testing
- ❒ 4905 Design and analysis of welded structures
- ❒ 4910 Gammagraphic devices
- ❒ 4920 Hardness testing
- ❒ 4930 ICP spectrometers
- ❒ 4940 Information systems
- ❒ 4950 Infrared measurement technology
- ❒ 4960 Infrared thermography
- ❒ 4970 Calibration
- ❒ 4980 Parameter determination
- ❒ 4990 Nuclear magnetic resonance
- ❒ 5000 Corrosion testing
- ❒ 5010 Laboratory quality assurance
- ❒ 5020 Length measuring and testing devices
- ❒ 5030 Laminography
- ❒ 5040 Laser-beam testing
- ❒ 5050 Laser technology
- ❒ 5060 Leak detection
- ❒ 5070 Light measuring devices
- ❒ 5080 Light microscopy
- ❒ 5090 Magnetic powders
- ❒ 5100 Magnetic-powder testing devices and installations
- ❒ 5110 Magnetic testing
- ❒ 5120 Manipulators
- ❒ 5130 Marking systems
- ❒ 5140 Mathematics, statistics and computers
- ❒ 5150 Measured-data collection
- ❒ 5160 Measuring systems
- ❒ 5170 Metallography
- ❒ 5180 Metallographic tests
- ❒ 5190 Microfocus x-ray installations
- ❒ 5200 Mobile spectrometers
- ❒ 5210 Neutron-beam testing
- ❒ 5220 Surface testing devices
- ❒ 5230 Optical testing
- ❒ 5240 Penetration installations and penetrants
- ❒ 5250 Physical tests
- ❒ 5260 Testing documentation
- ❒ 5270 Testing machines
- ❒ 5280 Testing agents for magnetic-powder testing
- ❒ 5290 Testing-agent monitoring
- ❒ 5300 Testing of welded joints
- ❒ 5310 Quality control
- ❒ 5320 Quality planning
- ❒ 5330 Quality assurance in process monitoring
- ❒ 5340 Quality assurance in repair/maintenance
- ❒ 5350 Quality assurance in series production
- ❒ 5360 Radioactive materials
- ❒ 5370 Radiography
- ❒ 5380 X-ray film
- ❒ 5390 X-ray apparatus
- ❒ 5400 X-ray diffractometers
- ❒ 5410 X-ray-film viewers
- ❒ 5420 X-ray fluorescence analysis
- ❒ 5430 X-ray tubes
- ❒ 5440 X-ray carriages
- ❒ 5450 X-ray accessories
- ❒ 5460 Scanners
- ❒ 5470 Damage analysis
- ❒ 5480 Acoustic-emission analysis
- ❒ 5490 Acoustic-emission devices
- ❒ 5500 Coat-thickness measuring devices
- ❒ 5505 Supervision of welding and fabrication operations, on site and in-plant
- ❒ 5510 Weld testing
- ❒ 5520 Vibration measurement
- ❒ 5530 Safety technology
- ❒ 5540 Visual inspection
- ❒ 5550 Signal and image processing
- ❒ 5560 Computional Modeling/Simulation
- ❒ 5570 Software packages
- ❒ 5580 Miscellaneous non-destructive testing procedures
- ❒ 5590 Spectral analysis
- ❒ 5600 Spectral-analysis devices
- ❒ 5610 Spectral photometers
- ❒ 5620 Spectrometers
- ❒ 5630 Radiation measuring devices
- ❒ 5640 Radiation-protection measuring devices, components and materials
- ❒ 5650 Control systems
- ❒ 5660 Stray-flux testing devices
- ❒ 5670 Temperature measuring devices
- ❒ 5680 Thermal analysis
- ❒ 5690 Thermal testing
- ❒ 5700 Thermographic installations
- ❒ 5710 Ultrasonic applications
- ❒ 5720 Ultrasonic testing devices and installations
- ❒ 5730 Ultrasonic testing
- ❒ 5740 Ultrasonic cleaning installations
- ❒ 5750 Ultrasonic transducers
- ❒ 5755 ultraviolet lamps
- ❒ 5760 Wear tests / erosion tests
- ❒ 5770 Confusion testing
- ❒ 5780 Vibration analysis
- ❒ 5790 Video installations and cameras
- ❒ 5800 Thermal-conductivity measuring devices
- ❒ 5810 Materials testing
- ❒ 5820 Eddy-current testing
- ❒ 5830 Eddy-current testing devices and installations
- ❒ 5840 Non-destructive testing
- ❒ 5850 Accessories for testing facilities

13 *Testing Technology – Destructive Testing*

- ❒ 5860 Dynamic fracture testing (Battelle, drop-weight, double-torsion, explosion-bulge, Esso notched-bar bend impact, notched-bar tensile impact, Niblink and Robertson tests)
- ❒ 5870 Hardness testing
- ❒ 5880 Resources, automation and computer assistance for destructive testing
- ❒ 5890 Kic test and crack-opening displace-ment (COD) test
- ❒ 5900 Weldability testing (cold-cracking and hot-cracking testing and others)
- ❒ 5910 Miscellaneous and mechanical-technological tests
- ❒ 5920 Static fracture testing (longitudinal-weld bend, bursting, deep-notch, bend, notched-bar bend, notched-bar tensile and wide-plate tests)
- ❒ 5930 Universal testing facilities
- ❒ 5940 Creep rupture and fatigue-endurance strength testing and vibration-fatigue testing installations
- ❒ 5950 Tensile, pressure, torsion and bend testing

14 *Testing Technology – Materials Testing*

- ❒ 5960 Plant monitoring and production monitoring
- ❒ 5970 Parameter determination
- ❒ 5980 Quality and defect testing
- ❒ 5990 Environmental-protection tests
- ❒ 6000 Properties to be tested
- ❒ 6010 Materials to be tested
- ❒ 6020 Components to be tested (areas of application)

15 *Testing Technology – Testing Procedures/ Testing Facilities*

- ❒ 6030 Component testing / design testing
- ❒ 6040 Fracture-mechanical parameters
- ❒ 6050 Chemical tests
- ❒ 6060 Strength and toughness
- ❒ 6070 Structural investigations
- ❒ 6080 Resources for metallography (etching agents, polishing agents and embedding compounds)
- ❒ 6090 Mechanical testing procedures
- ❒ 6100 Physical tests
- ❒ 6110 Weldability tests
- ❒ 6120 Technological testing procedures
- ❒ 6125 Test tables

16 *Quality Assurance (According to Masing's "QA Manual")*

- ❒ 6130 A+F in QM
- ❒ 6140 Bilatrometry
- ❒ 6150 Ergonomics of workplaces
- ❒ 6160 Instructions for use
- ❒ 6170 Mathematics, statistics and computers
- ❒ 6180 Measurement technology
- ❒ 6190 Organization for QA and insurance policies
- ❒ 6200 Quality planning and assessment
- ❒ 6210 Quality assurance in packing, storage and transport
- ❒ 6220 Quality assurance in small and medium-sized businesses and in skilled trades
- ❒ 6230 Quality assurance of software

17 *Miscellaneous*

- ❒ 6240 Training and education
- ❒ 6250 Consultancy companies
- ❒ 6260 Data processing
- ❒ 6270 Service companies
- ❒ 6280 Trade journals / specialist books
- ❒ 6290 Research institutes
- ❒ 6300 Information systems
- ❒ 6310 Calculation systems
- ❒ 6320 Societies and organizations
- ❒ 6330 Certification

V Contract work and services for joining, separating and coating

2 Sub-contracting – Processing of specific materials

- ❐ 7030 Aluminum
- ❐ 7040 Free machining steels
- ❐ 7050 Coated and plated materials
- ❐ 7060 Concrete
- ❐ 7070 Concrete reinforcing bars
- ❐ 7080 Lead, bismuth, cobalt, cadmium
- ❐ 7090 Cermets
- ❐ 7100 Chromium
- ❐ 7110 Duplex steels
- ❐ 7120 Termosets
- ❐ 7130 Elastomers
- ❐ 7140 Fiber reinforced materials
- ❐ 7150 Fine grained structural steels
- ❐ 7160 Refractory materials
- ❐ 7170 Glass
- ❐ 7180 Cast iron
- ❐ 7190 High alloy steels
- ❐ 7200 High temperature materials
- ❐ 7210 Ceramics
- ❐ 7220 Carbon
- ❐ 7230 Copper
- ❐ 7240 Laminates
- ❐ 7250 Leather
- ❐ 7260 Magnesium
- ❐ 7270 Brass
- ❐ 7280 Nickel
- ❐ 7290 Low alloy steels
- ❐ 7300 Niobium, manganese
- ❐ 7310 Cardboard, paper
- ❐ 7320 Platinum, gold, silver
- ❐ 7330 Compression moulding compounds (polymers)
- ❐ 7340 Pipe steels
- ❐ 7350 Rail steels
- ❐ 7360 Shipbuilding steels
- ❐ 7370 Sintered materials
- ❐ 7380 Cast steel
- ❐ 7390 Superalloys (hot isostatic pressure)
- ❐ 7400 Thermoplastics
- ❐ 7410 Titanium
- ❐ 7420 Unalloyed steels
- ❐ 7430 Tool steels
- ❐ 7440 Weathering steels
- ❐ 7450 Tungsten, tantalum, molybdenum
- ❐ 7460 Tin, zinc
- ❐ 7470 Zirconium, vanadium, beryllium
- ❐ 7480 New materials (high strength, light weight constructions and superhard materials, nanomaterials, light and electricity conducting materials, magnetic materials, implant materials etc.)

3 Sub-contracting – Processing of specific semi-finished products

- ❐ 7490 Strip and wide strip
- ❐ 7500 Reinforcing bars and mesh
- ❐ 7510 Sheet, plate, checker plate, perforated plate
- ❐ 7520 Wires
- ❐ 7530 Springs
- ❐ 7540 Foils, thin strip
- ❐ 7550 Castings
- ❐ 7560 Plastic films, strips, sheets
- ❐ 7570 Plastic pipes, flanges and other plastic semi-finished products
- ❐ 7580 Plastic tubes and sleeving
- ❐ 7590 Plastic products
- ❐ 7600 Copper pipes
- ❐ 7610 Brass pipes
- ❐ 7620 Sections (girders)
- ❐ 7630 Pipes and flanges
- ❐ 7640 Circular blanks
- ❐ 7650 Rails
- ❐ 7660 Hoses (metal)
- ❐ 7670 Forgings
- ❐ 7680 Sintered parts
- ❐ 7690 Extruded products

4 Sub-contracting – Application of joining and other manufacturing processes

- ❐ 7700 Flash welding
- ❐ 7710 Surfacing
- ❐ 7720 Pickling, sand blasting, polishing, deburring and/or grinding
- ❐ 7730 Stud welding
- ❐ 7740 Flame cleaning
- ❐ 7750 Flame cutting blanks
- ❐ 7760 Spark erosion
- ❐ 7770 Electron, laser beam welding
- ❐ 7780 Electroslag welding
- ❐ 7790 Gas pressure welding
- ❐ 7800 Gas welding
- ❐ 7810 Adhesive bonding of plastics
- ❐ 7820 Adhesive bonding of metals
- ❐ 7830 Welding of plastics
- ❐ 7840 Plastic spraying
- ❐ 7850 Laser beam welding and/or cutting
- ❐ 7860 Manual metal arc welding
- ❐ 7870 Brazing and soldering
- ❐ 7880 Metallizing, dip coating and anodizing
- ❐ 7890 Metal spraying
- ❐ 7900 Oxidized ceramic spraying
- ❐ 7910 Computional modeling of processes
- ❐ 7920 Resistance spot and/or projection welding
- ❐ 7930 Friction welding
- ❐ 7940 Robot welding TIG/MIG/MAG
- ❐ 7950 Seam welding
- ❐ 7960 Friction stir welding
- ❐ 7970 Gas shielded arc welding
- ❐ 7980 Magnetically impelled arc butt welding (MIAB)
- ❐ 7990 Computional modeling/Simulation of weld processes
- ❐ 8000 Computional modeling/Simulation of structures
- ❐ 8010 Thermal cutting
- ❐ 8020 Ultrasonic welding
- ❐ 8030 Firecracker, electrogas and/or submerged arc welding
- ❐ 8040 Scrapping
- ❐ 8050 Vibratory stress relieving
- ❐ 8060 Heat treating and/or quenching and tempering
- ❐ 8070 Maintenance, servicing, repair
- ❐ 8080 Comutational modeling of materials
- ❐ 8085 waste containing precious metal

5 Organizations, education and training, certification, research, information transfer, technical literature and regulations

- ❐ 8090 Accreditation and certification organizations
- ❐ 8100 Acceptance, approval, examination and supervisory organizations
- ❐ 8110 Training, continuing education and examination of specialist personnel
- ❐ 8120 Supervisory bodies, Chambers of Trade, Employers Associations
- ❐ 8130 Technical publishers, Libraries (literature, codes of practice, educational films, software, CD-ROM and diskette services, audiovisual media)
- ❐ 8140 Joining research and education
- ❐ 8150 Consultants, experts
- ❐ 8160 Information services (literature and factual database searches, expert systems, expert certification, literature appraisal, state of the art and trend analyses)
- ❐ 8170 Codes of practice, standardization, patents (incl. organizations)
- ❐ 8180 Technical and scientific associations, industrial associations

VI Plant and equipment, including automation, mechanization and industrial robots, for thermal spraying

1 Plant and equipment, including automation, mechanization and industrial robots, for thermal spraying

- ❐ 6340 Flame spraying with wire or rod
- ❐ 6350 Flame spraying with powder
- ❐ 6360 Plastic Flame spraying
- ❐ 6370 High-velocity oxy-fuel spraying (HVOF)
- ❐ 6380 Detonation spraying
- ❐ 6390 Plasma spraying
- ❐ 6400 Suspension spraying
- ❐ 6410 Laser spraying
- ❐ 6420 Arc spraying
- ❐ 6430 Cold gas spraying
- ❐ 6440 Plasma transfer arc welding (PTA)
- ❐ 6450 Pressure & vacuum blasting
- ❐ 6460 Masking compounds & tapes
- ❐ 6470 Blasting media
- ❐ 6480 Finishing tools/grinding wheels
- ❐ 6490 Sand-blasting equipment
- ❐ 6500 Sealants
- ❐ 6510 Exhaust systems / bag houses
- ❐ 6520 Automated spraying systems
- ❐ 6530 Flow controller
- ❐ 6540 Air compressors
- ❐ 6550 Manipulators
- ❐ 6560 Wet collectors
- ❐ 6570 Testing equipment
- ❐ 6580 Powder feeder
- ❐ 6590 Robotics
- ❐ 6600 Soundproof rooms
- ❐ 6610 Spray booths
- ❐ 6620 Other powders
- ❐ 6630 Wires
- ❐ 6640 Intermetallic powders
- ❐ 6650 Carbide powders
- ❐ 6660 Ceramic powders (metal oxides/nitrides)
- ❐ 6670 Ceramic rods
- ❐ 6680 Metal powders
- ❐ 6690 Self Fluxing powders
- ❐ 6700 Powder mixtures
- ❐ 6710 Suspensions
- ❐ 6720 Thermoplastics
- ❐ 6730 Superfinishing
- ❐ 6740 Grinding
- ❐ 6750 Machining
- ❐ 6760 Other
- ❐ 6770 Education
- ❐ 6780 Market research
- ❐ 6790 Test coupons
- ❐ 6800 Testing services / equipment / supplies
- ❐ 6810 Virtual spraying
- ❐ 6820 Atmospheric corrosion
- ❐ 6830 Abradable applications
- ❐ 6840 Electrical / electronics
- ❐ 6850 Clearance control
- ❐ 6860 High temperature corrosion
- ❐ 6870 Reclamation
- ❐ 6880 Vacuum plasma
- ❐ 6890 Wear resistance
- ❐ 6900 Thermal barrier
- ❐ 6910 Aluminizing
- ❐ 6920 Anodizing
- ❐ 6930 CVD (chemical vapor deposition)
- ❐ 6940 Electrolytic oxidation
- ❐ 6950 Enameling
- ❐ 6960 Painting, varnishing
- ❐ 6970 Flame cleaning and phosphatising
- ❐ 6980 Plastic coating
- ❐ 6990 Metallizing
- ❐ 7000 PVD (physical vapor deposition)
- ❐ 7010 Dip coating
- ❐ 7020 Tin, zinc, nickel, copper and chromium plating

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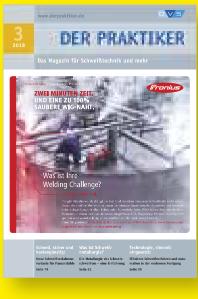

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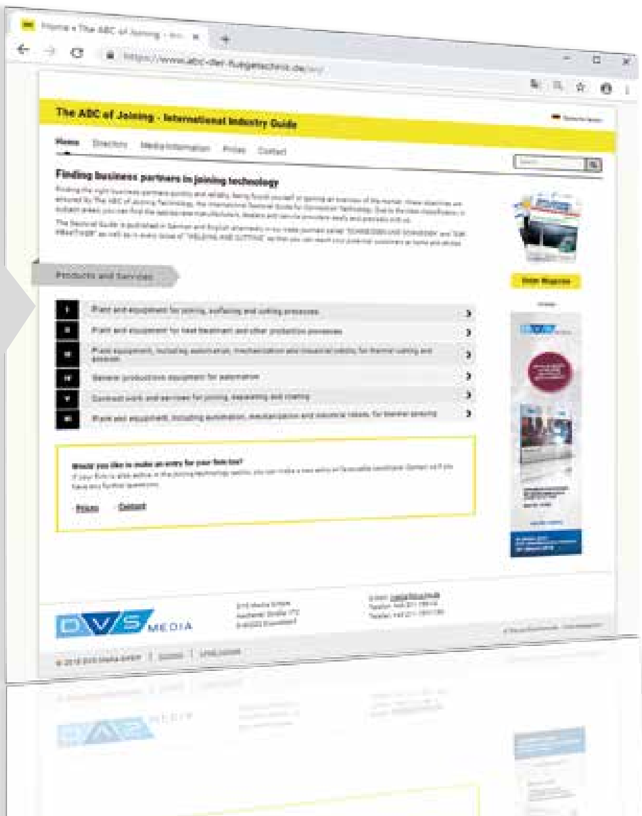

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