DVS | IS Institut de Soudure | The Welding Institute

Issue 04 2020

WELDING AND CUTTING

www.welding-and-cutting.info

Technical journal for welding and allied processes

- Education and career aspirations hard to reach for young people as result of the pandemic
- Mechanical plate edge bevelling – Key to high speed weld preparation and improved weld quality
- Development and evaluation of alternative materials for friction stir welding of steel

DVS MEDIA

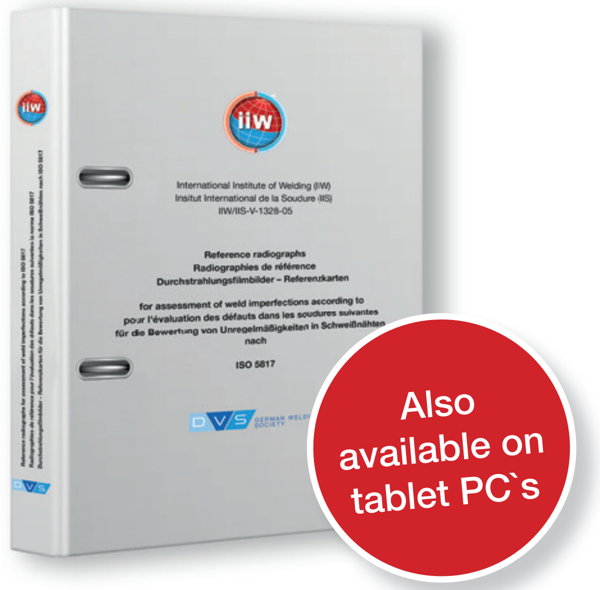
IIW Reference Catalogue ISO 5817

The International Standard ISO 5817: 2003 „Welding; Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded); Quality levels for imperfections" lists the quality requirements for production of arc welded steel joints.

This international standard is a fundamental technical standard and specifies the basic standardized requirements for the evaluation of welded joints in the various fields of application of welding, such as pressure vessels, metal construction, piping, rolling stock etc. Fur thermore, this standard shall be used as the basis for the evaluation of testpieces for the approval testing of welders and welding procedure qualification tests according to ISO-Standard.

The reference catalogue is useful for persons with low experience of transposing individual cases to the limits specified in the standard. Using the reference cards, they will learn to interpret correctly various imperfections and their specific representation and to classify them by size to quality levels of the standard.

The catalogue may also be used by manufacturers, operators and test bodies as a tool for aid and decision about the evaluation of individual items.



IIW Reference Catalogue ISO 5817

Reference radiographs for assessment of weld imperfections according to ISO 5817, interpretation of arc-welded butt joints in steel, 2005, 60 reference cards, DIN A4, ring binder.

Printed catalogue	2.200 EUR incl. VAT
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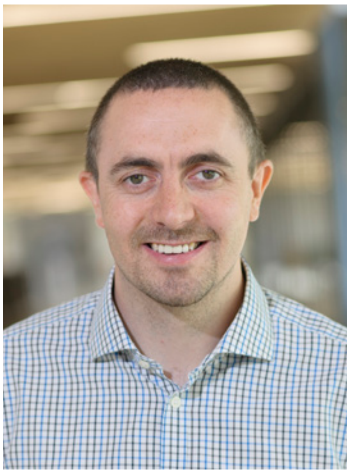
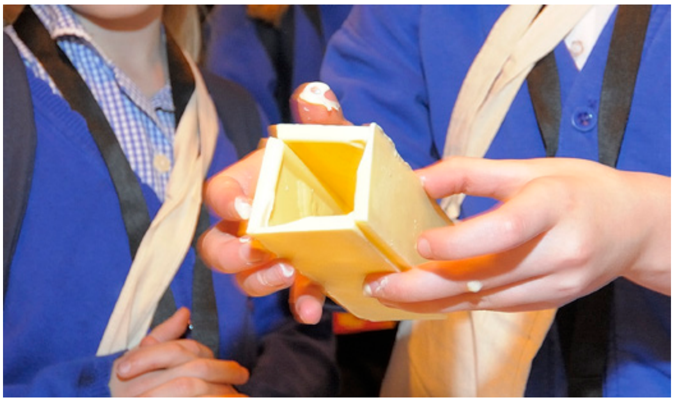
Q&A with Outgoing Younger Members' Committee Chair, Matthew Haslett

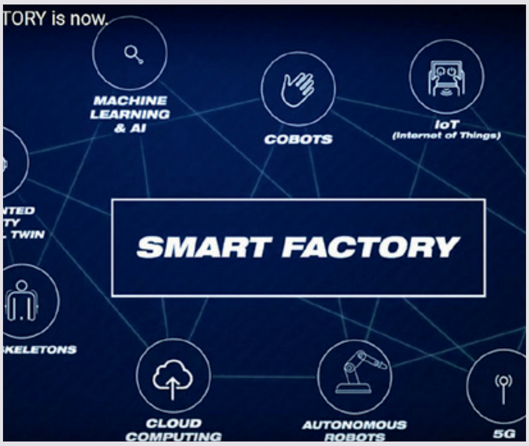


The Welding Institute's Younger Members' Committee (YMC) works to engage young professional engineers to encourage and assist their professional and career development. In addition, the Committee also provides science, technology, engineering, and mathematics (STEM) outreach activities around the UK to promote these subjects to school children and students of different ages.

Matthew Haslett MWeldI served as the chair of the Committee from 2013 until he stepped down in October 2020. It seemed like this was the perfect opportunity to ask Matt about his work over this time and how he has seen the Committee grow and encourage others.

Read more in the Editorial on page 295.





The video-infographic provides an overview on how digitalisation is impacting on the factory. 262

The "Tempest" concept model on the airfi eld at BAE Systems in Warton, Lancashire, UK. (Photos: BAE Systems) 283

Torch light sparkles. 290

WELDING AND CUTTING

www.welding-and-cutting.info Technical journal for welding and allied processes

Technical journal for welding and allied processes of
the **DVS – German Welding Society,** Düsseldorf,
the Professional Division of The Welding Institute, Cambridge,
and **the Institut de Soudure,** Paris

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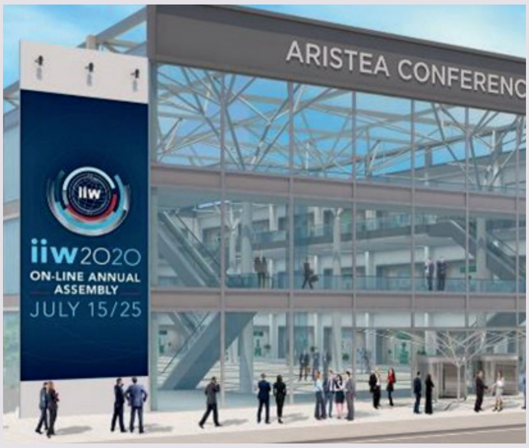
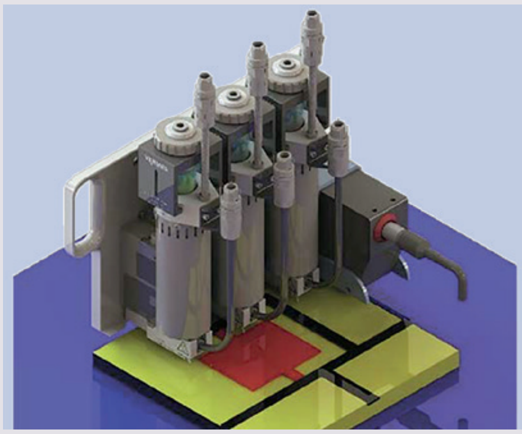


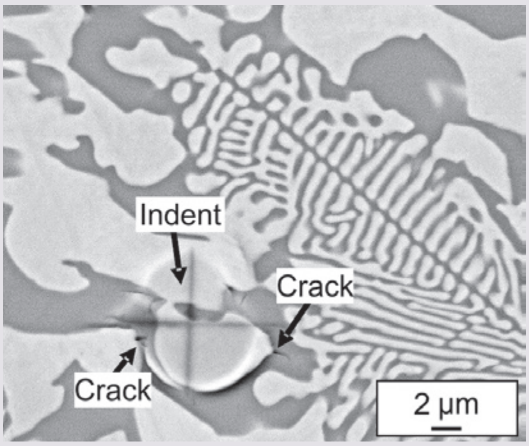
The virtual conference centre for the 73rd IIW Annual Assembly.

302



Schematic illustration of the micro-dosing systems.

310



Indent in the eutectic consisting of Fe-enriched Ni-Cr-Si solid solution and the Cr-enriched Ni-P intermetallic resulting in crack formation (BSD contrast).

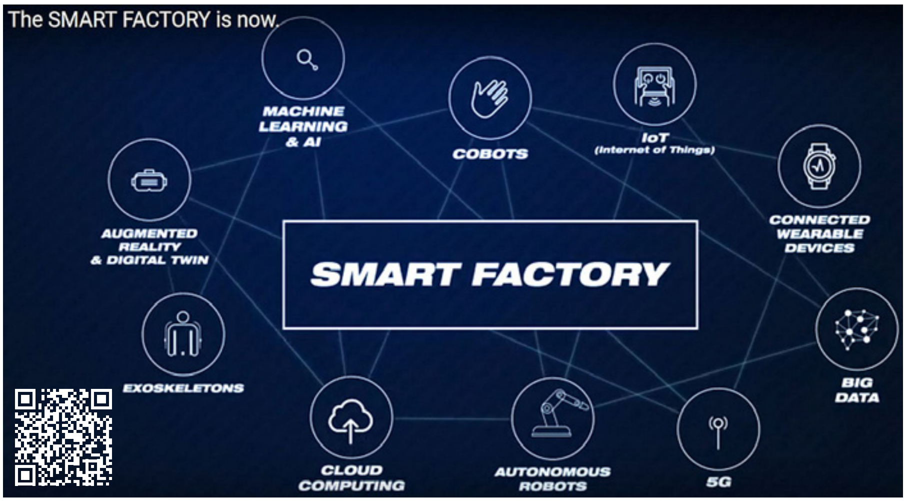
319

New video infographic about Smart Factory latest trends

As a result of digitalisation, many everyday objects are able to collect data, analyse external information and communicate with each other. But what happens when this type of technology is applied to the factory, both large companies and SMEs? What elements will characterise the factory of the future? Industry 4.0 has a value creation potential for manufacturers and suppliers of $3.7 trillion in 2025, but today only 30% of global companies are capturing value from Industry 4.0 solutions on a large scale.

The Italian company Comau from Grugliasco near Torino (www.comau.com) – which is internationally operating in the industrial automation field –, has launched a new video-infographic about the Smart Factory latest trends. These new technologies are used to digitalise expanding parts of the manufacturing process and to design the factories of the future jointly with companies. From wearables to exoskeletons, from artificial intelligence and machine learning to collaborative robots: smart factories will use these technologies to generate value. Benefits include increased productivity while reducing time to market, the ability to remotely manage more tasks through IoT (Internet of Things) and augmented reality.

At this link (https://www.youtube.com/watch?v=LENqgfisK9s&feature=youtu.be) you can watch a video-infographic providing an overview on how digitalisation is impacting on the factory and how large companies and SMEs are capturing value from Industry 4.0 solutions. (According to press information from Comau)



The video-infographic provides an overview on how digitalisation is impacting on the factory (please see link below or follow the QR code in the figure).

The fall and rise of metal additive manufacturing

There is little doubt that additive manufacturing will become a key enabling technology across a wide range of sectors. Over the past few years, revenues have grown, notable new entrants have emerged, investments have been significant and material portfolios broadened. However, the Covid-19 pandemic has halted that growth in its tracks. At this key moment, the international market research company IDTechEx, headquartered in Cambridge/UK, has released a comprehensive technical report, ”Metal Additive Manufacturing 2020-2030” (www.IDTechEx.com/MetalAM), assessing all elements of the inevitable fall and subsequent rise of this industry.

Metal additive manufacturing has been used for prototypes, tooling, replacement parts and small to large production runs. Unsurprisingly, the initial success has been in high-value industries prominently aerospace & defense and medical & dental. There are many emerging sectors beyond this, such as automotive and oil & gas, and the long-term future looks bright. However, onset by the Covid-19 global pandemic, the industry will see a significant decline in 2020 with multiple years needed for recovery.

Profound market impact – no immediate recovery

There is good evidence that pre-arranged investments, certifications and orders have all carried on. There are even potential viewpoints that additive manufacturing has gained prominence during this pandemic, as manufacturers address vulnerabilities in their supply chain, and capabilities have been demonstrated in essential circumstances (such as for the need for ventilator parts). The reality, beyond these small victories, is that the market impact has been profound, and the recovery will not be immediate.

The market has fallen in the immediate timeframe, as both internal and client operations ground to a halt for large parts of Q1 and Q2 2020. The short-to-mid-term recovery will differ for each sector with the longest recovery to be for civil aviation. The material demand is forecast to “spring back” faster, but the printer sales will take longer to recover temporarily stagnating the total installed base. IDTechEx forecasts are built on extensive experience in the industry and through primary-interviews to bring the reader the latest and most accurate information on the industry.

Mid-to-long-term growth is still anticipated

Despite this inevitable setback, a mid-to-long-term growth is still anticipated in this industry and the metal AM is supposed to exceed $10 billion within the next decade. Although returns will take longer to be realised, it is important that printer manufacturers, investors and players across the supply chain do not lose faith in this market. As with any new (primarily) B2B technology with a large price tag, it will take time for end users to have confidence in the process and value-add to warrant the investment. Powder bed fusion processes (DMLS – Direct Metal Laser Sintering and EBM – Electron Beam Melting) have been commercial for the longest time which results in this technology underpinning most installations. However, the next generation of technologies are gaining more traction and within the next decade, a more diverse installation base will be observed.

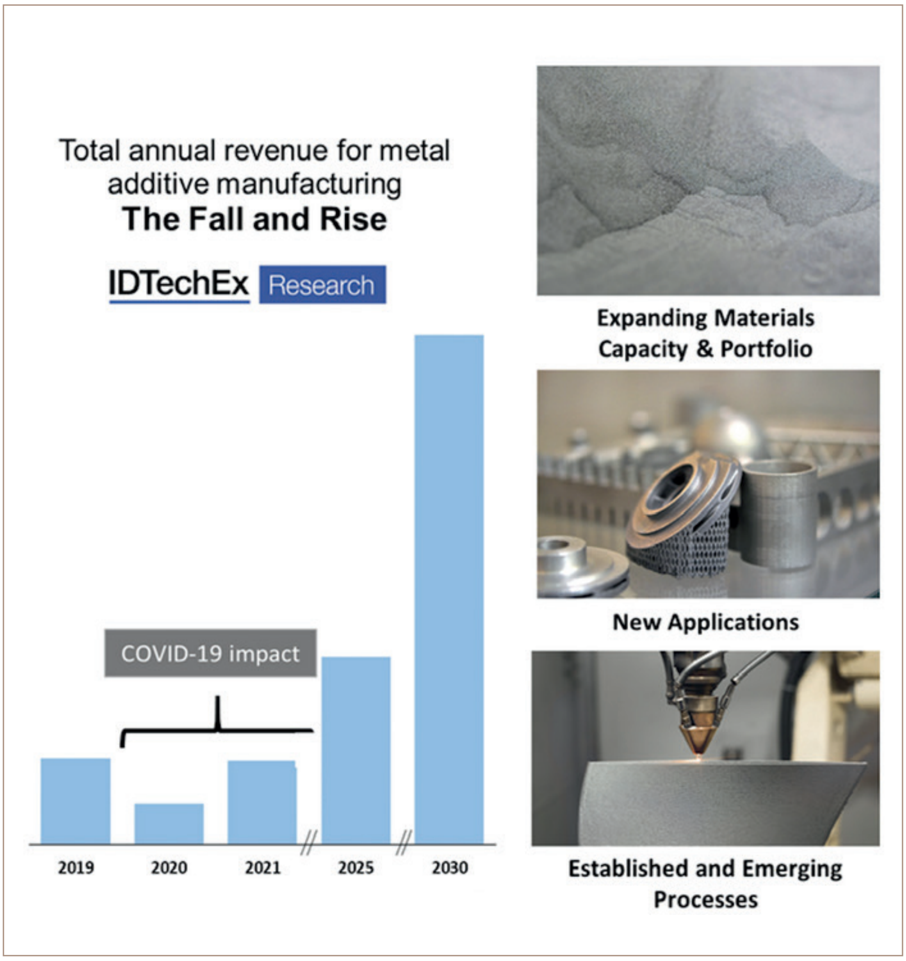
A common tactic for new entrants is to invent new terms for their technology to differentiate from the competition. Some of these are unique, but most are aligned with existing processes introducing only subtle variations. The IDTechEx report cuts through this marketing and provides accessible impartial categorisation for the industry. The reality is that every process must compromise on something, be it the rate, price, precision, size, material compatibility or more. IDTechEx provides critical benchmarking studies of these processes; an essential process for identifying gaps in the market and end-use applications.

Wide range of applications by 2030

By 2030 there will be a wide range of applications, some that the industry is rapidly progressing towards and many that are currently unknown. Partnerships, strategic investments and vertical integrations are all indicative of markets preparing for these future opportunities.

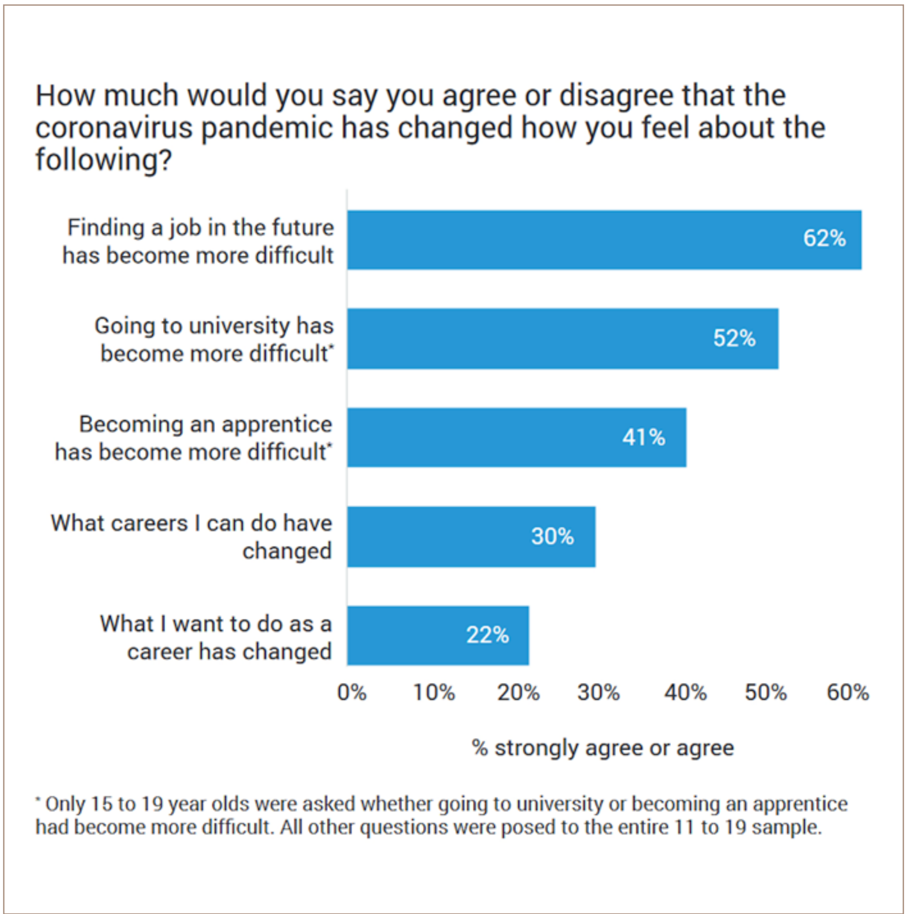
The IDTechEx report, "Metal Additive Manufacturing 2020-2030", provides a critical technical assessment of the industry at a crucial time, providing detailed analysis on the printer processes, material opportunities and end-use applications all with granular forecasts. The report supplies over 50 company profiles ranging from established players to emerging start-ups and material companies.

Dr Richard Collins, Principal Analyst, IDTechEx, Cambridge/UK



Despite the inevitable setback because of the Covid-19 pandemic, a mid-to-long-term growth is still anticipated in the metal additive manufacturing industry. (Source: IDTEchEx)

Education and career aspirations hard to reach for young people as result of pandemic



Impact of the pandemic on young people's career plans and considerations (Graphic: EngineeringUK)

The Covid-19 pandemic has significantly affected all aspects of life, from public health to the economy. Students of all ages have had their education and exam timetables disrupted, and there is talk of the deepest recession the UK has seen for 300 years, with the impact of this predicted to hit young people particularly hard.

New research commissioned by the non-profit organisation EngineeringUK (www.engineeringuk.com) has revealed that educational and career aspirations have already been affected by the pandemic, with just over half (52%) of the 15 to 19 year olds asked agreeing or strongly agreeing that going to university would become more difficult and 41% saying the same of becoming an apprentice. 62% of the 11 to 19 year olds asked agreed or strongly agreed that finding a job in the future has become more difficult as a result of the pandemic.

The research makes it clear that the pandemic has had a bearing on young people and the careers they're thinking about choosing in the future. It reveals over 2 in 5 young people reported that the pandemic has made 'having a job that you can be certain you can keep' (44%) and 'availability of jobs' (41%) more important to them when considering their future career choices. Considerations such as 'liking what I do' and 'being able to progress in my career' are sadly lower (33% and 26%).

Importance of jobs to make a positive societal contribution

For some young people the pandemic also appeared to raise the importance of having a job that enabled them to make a positive societal contribution, with around a third of respondents indicating that the pandemic has made 'having a positive impact on society' (36%), 'helping people with the work they do' (34%), and 'ethics and social responsibility' (33%) more important when considering career choices.

Findings from the research, which surveyed over 1,100 11 to 19 year olds, also suggests that some young people felt their career choices have been constrained because of the pandemic. 30% say the careers they could do have changed as a result of the pandemic and 22% say what they wanted to do as a career has changed.

Often significant gender differences

Throughout the survey there were often significant gender differences, with girls/young women more likely than boys/young men to say 'ethics and social responsibility' (89% vs 80%) and 'helping people with the work you do' (89% vs 79%) were important factors when thinking about jobs they want to do in the future.

Exams, home learning and thinking about future education or careers has been tough during lockdown so the survey also looked at whether young people searched out information online, spoke to their parents or took part in any careers activity during this time, with the results showing a gender disparity. Girls/young women were more likely to have used the time to research their futures – 60% of girls/young women, compared to 49% of boys/young men had taken part in a careers activity during lockdown. 44% of girls/young women had discussed career options with their parents, compared with 30% of boys/young men and 27% of girls/young women compared to just 19% of boys/young men had searched for careers information online.

Dr Hilary Leevers, Chief Executive of EngineeringUK, says: "Young people are going to be greatly affected by the pandemic for years to come and they are well aware of it. To hear that children as young as 11 are concerned about their ongoing education and careers is not what anyone wants, but their interest in job security and availability is balanced by an increased desire to benefit people and society.

Considerably more interest in a career in STEM

"It is encouraging that the pandemic has resulted in young people being considerably more interested in a career in STEM (Science, Technology, Engineering and Maths). Young people know about the role that engineers have played in efforts to combat the pandemic –we need to translate this insight into career aspiration. Interest in engineering careers lags behind that in science and technology so we need to emphasise the opportunities, as the country invests in its infrastructure and net zero, and provide young people with every opportunity to hear about and experience the breadth and societal impact of modern engineering.

STEM outreach and work experience needs to be targeted to the schools and students that need it most, including those who are underrepresented in the STEM and engineering workforce and those that are most affected by the pandemic. We need to give these young people the opportunities they deserve and, in turn, we need them to ensure the diversity of thought for a thriving future workforce."

The findings report, "Young people and Covid-19: How the pandemic has affected careers experiences and aspirations", is available for download free of charge here: https://www.engineeringuk.com/media/232314/young-people-and-covid-19.pdf. (According to press information from EngineeringUK)

The "WELDONE" project: Next-generation learning and knowledge assessment methodologies

Traditional learning methods are being challenged by the potential that technologies, coupled with new pedagogical approaches, hold to create a different way of learning, based on active learning and interaction. This is particularly felt in technical fields of knowledge, such as Manufacturing and STEM (Science, Technology, Engineering and Mathematics), where there is a lack of professionals to support the growth of new and existing companies. And new learning methodologies and technologies are one important way to attract students to these professions.

Bridging that gap between today's technologies' capabilities and attractive learning methods

Bridging that gap between today's technologies' capabilities and attractive learning methods is the role of the "WELDONE" project (http://www.weldone-project.eu/), the aim of which is to provide EWF's system and STEM's educational staff with the knowledge, ability and expertise on pedagogical approaches and methodologies that promote active learning, that can be leveraged for a better training.

As an end result, the project will develop a Training of Trainers' (ToT) curricula, based on seven Competence Units, organised in a modular approach to be delivered using the "Workshop Methodology", including practical resources focusing on the development of specific key competences to be embedded in technical training.

EWF and its education system are the main focus of the project, as all its results will be developed for application on Approved Training Bodies (ATBs) belonging to the EWF network. In addition, the project results will also be available for STEM educators as a way to broaden their impact beyond the manufacturing sector.

Curriculum with seven Competence Units

The "WELDONE" curriculum has seven Competence Units, organised in a modular approach, focusing on:

- Multiple Intelligences and Learning Styles;
- Learner Centered Didactics (i.e. Problem-Based Learning, Critical Thinking and Collaborative Learning);
- Gamification;
- Digital Competences and using digital resources;
- News Media Didactics (the use of social media and micro-learning);
- Personal, social and learning competence and
- Entrepreneurship competences.

By fostering an active learning environment, with experiential learning and project work methods, where schools' environment can encourage creativity and risk-taking as well as accept mistakes as a valuable learning opportunity, teachers and trainers from the EWF Training system, as well as educators from STEM sectors, will be able to embed the development of key competences on their own educational resources, following the European Commission's Council Recommendations.

Bringing trainees closer to real-life situations

"WELDONE" also paves the way for educators to be flexible in framing various pedagogical strategies and to be adaptable to diverse content. It aims to maximise the use of digital tools and environments available today in order to bring trainees closer to real-life situations, thus making learning a meaningful process for students of today and tomorrow. Also, teachers and trainers will be actively involved in this continuous professional development programme and on the process of raising their awareness to the importance of updating training methodologies and delivery in technical and scientific fields.

The project is implemented by a consortium of seven partners from Croatia, Belgium, Greece, Hungary, Portugal and Romania and, within its ambitious goals, it also aims at improving the provision of Higher VET (Vocational Education and Training, increasing its attractiveness and relevance, and promoting an assessment framework that will help trainers and teachers to deal with the challenges of evaluating the "WELDONE way". (According to press information from EWF; www.ewf.be)

WELDONE
BOOSTING INNOVATION IN WELDING TRAINING

UFI – The Global Association of the Exhibition Industry elects Monica Lee-Müller as new president

The UFI Board of Directors has elected Monica Lee-Müller as president of the association for the 2021/22 period. (Photo: UFI)

The UFI Board of Directors has elected Monica Lee-Müller as President of UFI – The Global Association of the Exhibition Industry (www.ufi.org) for the 2021/22 period. The UFI Presidential Trio for the 2020/21 term will therefore comprise of:

- Monica Lee-Müller (Managing Director of Hong Kong Convention and Exhibition Centre (Management) Limited (HML), Hong Kong), Incoming President,
- Anbu Varathan (Indian Machine Tool Manufacturers' Association - IMTMA, India), President 2020/21,
- Mary Larkin (Diversified Communications, Portland, USA), Outgoing President.

This decision becomes effective at the conclusion of the 87th UFI Global Congress, which runs from 15-20 November 2020.

Monica Lee-Müller is the Managing Director of Hong Kong Convention and Exhibition Centre (Management) Limited (HML) since 2012. HML is the professional private company responsible for the management and operation of the 306,000 m^2 Hong Kong Convention and Exhibition Centre (HKCEC). About 1,000 events are held there every year.

Monica Lee-Müller has been active in UFI for many years, supporting the association's mission and driving developments, especially on diversity and sustainability projects. She has served as a Board Member of UFI for the past 12 years.

As UFI's Incoming President, Monica Lee-Müller will work closely with the incumbent President and Outgoing President to make up the Presidential Trio, managing UFI at the highest level, and helping UFI continue on its global mission to connect, support, and promote the exhibition industry around the world.

UFI – The Global Association of the Exhibition Industry was founded in 1925 as a non-profit, non-partisan international association, and today is the global association for the exhibitions industry, directly representing more than 50,000 exhibition industry professionals in almost 90 countries around the world. UFI operates four regional offices in addition to the headquarters in Paris/France.

UFI's recent presidents were from South Africa (Craig Newman 2018/19), Italy (Corrado Peraboni 2017/18), Germany (Andreas Gruchow 2016/17), Russia (Sergey Alexeev 2015/16), Colombia (Andrés López-Valderrama 2014/15) and France (Renaud Hamaide, 2013/14). (According to press information from UFI)

“DIGIMAN” project to lay the groundwork for a new Master’s Degree in Digital Manufacturing

Digital technologies are sweeping through all economic sectors, transforming traditional ways of doing business, while rendering other obsolete. Manufacturing is also quickly integrating digital as part of its processes, and all its ecosystem is feeling the impact, from ideation to design, from manufacturers to their supply chain, and from the former to buyers.

Working in this complex environment requires more than the knowledge of a specific digital tool or how it applies to manufacturing, it demands professionals capable of grasping the full ecosystem and the implications of digital transformation in each and every area of manufacturing. The “DIGIMAN” project (digimanproject.eu) aims to do just that by laying the foundation of a Master in Science focused on Digital Manufacturing that encompasses all relevant technologies towards the 4th Industrial Revolution.

This two-year project brings together a total of seven partners from six countries – Romania, Belgium, Portugal, Spain, Hungary and Germany – and targets the overall ecosystem of manufacturing, touching teachers, students, technology developers, industry and higher education institutions. Its expected outcomes encompass increasing the level of digital competences for students and teachers, as well as the level of cooperation between higher education institutions and industry stakeholders.

On a broader scale, it also aims at improving transnational cooperation between universities, technology developers and industry’s stakeholders and to improve the teaching/learning framework within Europe by providing lesson materials and real-life case studies to be used in a blended learning environment, leveraging the best of both e-learning and classroom learning.

Upon the completion of the project, the new digital manufacturing Master of Science programme will be integrated as part of the educational offering of the University of Craiova/Romania, with the continuous update of the content of lessons materials for the next four years and the continuous consultation of industry stakeholders to improve the educational materials.

Deliverables and complementarity with other programs

To achieve its objectives, the program will develop a number of activities in all countries that participate on the consortium, starting with surveys to assess the digital manufacturing competences required in industrial engineering fields, to evaluate Industry 4.0 requirements, and a last one, to all stakeholders, to assess the competences provided by the foreseen curriculum and a specific one for teachers/students related to the overall quality of the project’s products.

The project will provide one curriculum for the master program, 12 lessons materials covering the programme study, while also developing one database with questions and answers for the examination process, and one learning management system for the master programme study and the three short-term courses developed. The short-term courses will be provided to 16 teachers, which will be awarded certificates, with an additional 14 teachers trained after that.

The project consortium comprises a combination of industry representatives and institutions from the training side. University of Craiova (https://www.ucv.ro/en/), a Romanian prestigious institution of higher education, is leading the project, which also includes EWF – The European Federation of Welding, Joining and Cutting (www.ewf.be), Lisbon’s University (https://www.ulisboa.pt/), the Budapest University of Technology and Economics (https://www.bme.hu), the Technical University of Cluj-Napoca (https://www.utcluj.ro/), Augmented Training Services, S.L. (www.soldamatic.com) and UniTyLab of Heilbronn University (https://www.unitylab.de). (According to press information from EWF)

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"MULTI-FUN" project aims to enable multi-material additive manufacturing for complex 3D parts

Metal Additive Manufacturing (MAM) technologies versatility makes them most suitable for producing from unique parts up to full series production. Yet, even the mostly used MAM technology, Powder Bed Fusion (PBF), is not capable of going beyond single materials, and even the range of standard alloys is rather small.

The "MULTI-FUN" project (http://www.multi-fun.eu) aims to address those shortcomings in two ways: First, by improving performance and efficiency in metal additive manufacturing through the integration of multi-functionalities based on novel active materials and the development of new structural materials for Wire Arc Additive Manufacturing (WAAM), including high strength aluminium alloys and low alloyed steel grades. And secondly by enabling multi-material design in geometrically complex 3D parts without being hindered by size.

Applying combinations of different materials

The project focuses on MAM by applying combinations of different materials, combined with the most appropriate AM technology for the deposition, to maximise the benefits. Wire and powder based directed energy deposition (DED) and material jetting are employed in new AM equipment combining different AM technologies with tailored software.

The inclusion of nanomaterials allows the integration of novel features, such as heat sink materials with the highest thermal conductivity, a high degree of integral design that makes it possible to embed electrical conductors in complex shaped metal structures, and the addition of sensing and data transfer capabilities to the equipment and software development. In addition, the integration of tailored optical fibres will enable bringing advanced thorough sensing capabilities to the manufactured parts to perform Structural Health Monitoring (SHM).

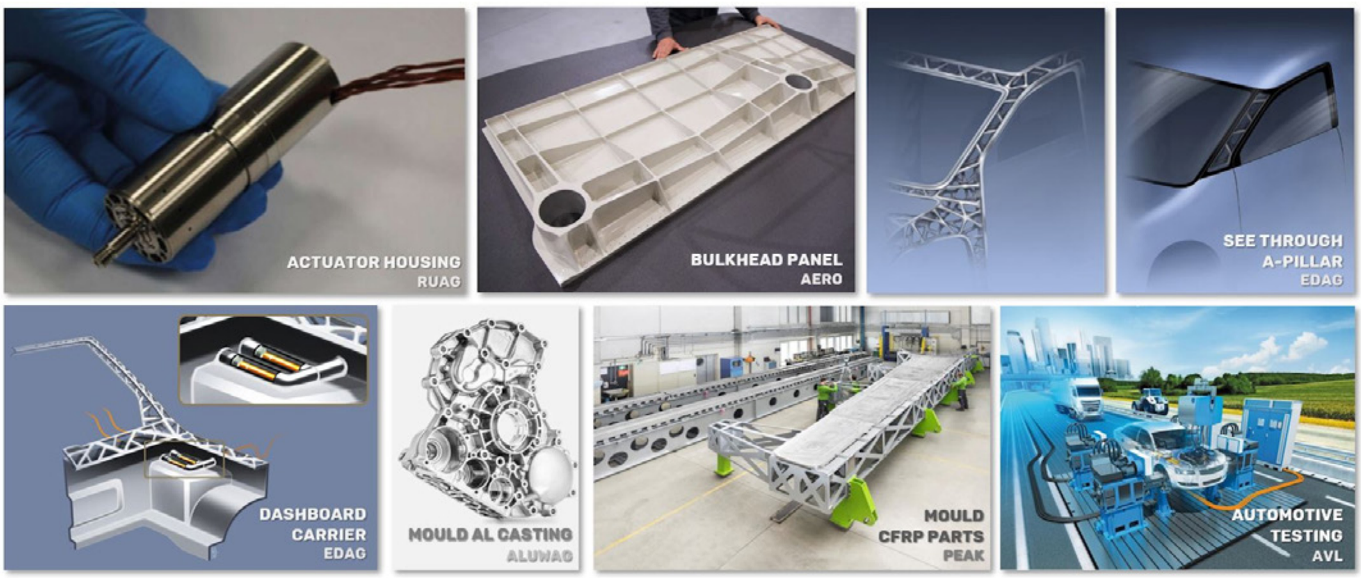
Broaden the scope of usage for metal additive manufacturing

The project has a total of four science and technology objectives. The first objective pertains to the development of five new materials customised for additive manufacturing, with a minimum of three of them using nanotechnology. This will allow for the creation of new products by maximising thermal conductivity, minimising electrical conductivity and/or improving wear resistance of metals. As a result of this objective, the development of new products is expected thanks to the advanced structural metals and corresponding active material solutions for innovative multiple functionalities.

The second objective addresses new processes and it entails the development of AM equipment and software to produce the requested material compositions during the layer build-up. In total, at least ten new material combinations applying five new materials will be shown by the seven demonstrators for different applications. The expected result is an innovative additive manufacturing equipment that integrates several additive manufacturing technologies working in parallel.

The third science and technology objective aims to manufacture and evaluate seven physical demonstrators with multi-material design and integrated multi-functionalities, for three use cases (structural parts, molds, test equipment), addressing four different markets (automotive, aviation, space and production industry). The expected end result is related to new methods and it will contribute to the development of new knowledge on increased efficiency of parts & molds due to integrated, multi-material-based functions.

The last objective relates to the constant assessment and improvement through a feedback loop of the reduction of environmental and economic impact, by evaluating additive manufacturing materials, hardware, process strategy and demonstrator design. The expected key result from this objective relates to new standards and it will enhance knowledge and contribute to standards and support regulatory bodies adapting to multi-material additive manufacturing.



"MULTI-FUN" demonstrators. (Photos: EWF)

Manifold impact expected

The expected impact will be felt manifold. The defined KPIs (Key Performance Indicators) fall into three main groups, including:

- First, the improvement of the efficiency, quality and reliability of the product by at least 40%;
- Secondly, a better usage of raw materials and resources with reduced environmental impact and lowering costs by 35% as demonstrated by Life Cycle Assessment; and
- Lastly, it will provide new opportunities & business for SMEs across Europe, namely for the key players in advanced materials research in AM.

This three-year project brings together a total of twenty-one partners from eight countries – Austria, Switzerland, Germany, Spain, United Kingdom, Poland, Portugal and Belgium. It sets a clear focus on market-creating innovation, developing advanced materials and equipment for AM of multi-material parts. Leading experts in AM process & equipment manufacturing will fully cover the physical integration of these advanced materials into metallic substrates. (According to press information from EWF; www.ewf.be)

MULTI-FUN
ENABLING MULTI-FUNCTIONAL PERFORMANCE THROUGH MULTI-MATERIAL ADDITIVE MANUFACTURING

PLEASE NOTE: Due to the worldwide spread of the Coronavirus, numerous events have been cancelled or postponed. This table shows the status as of October 2020. 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

24.11.-26.11.2020	Bilbao/ Spain	**"31BIEMH" – international fair of machine tools and advanced manufacturing** Information: Bilbao Exhibition Centre, Internet: https://biemh.bilbaoexhibitioncentre.com/en/
25.11.2020	Online	**"VAE2020" – 3rd International Conference on Vehicle and Automotive Engineering** Information: University of Miscolc, Internet: https://www.uni-miskolc.hu/~jk2016/vae2020/
26.11.2020	Online	**Metal Additive Manufacturing Symposium** Information: TWI, Internet: https://www.twi-global.com/media-and-events/events-diary/metal-additive-manufacturing-symposium
03.12.2020	Online	**Digital Manufacturing Conference 2020** Information: TWI, Internet: https://www.twi-global.com/media-and-events/events-diary/digital-manufacturing-conference-2020
07.12.-10.12.2020	Düsseldorf/ Germany	**International Trade Fairs "wire 2020" and "Tube 2020"** Information: Messe Düsseldorf, Internet: www.wire-tradefair.com; www.tube-tradefair.com
09.03.-10.03.2021	Aachen/Germany	**"IEBW 2021" – 6th International Conference on Electron Beam Welding** Information: DVS, Internet: https://www.dvs-ev.de/iebw2021/
09.03.-12.03.2021	Hanover/Germany	**"EuroBlech" – 26th International Sheet Metal Working Technology Exhibition** Information: Mack Brooks Exhibitions, Internet: https://www.euroblech.com/2020/english/
25.03.-27.03.2021	Mumbai/India	**International Trade Fairs "wire India" and "Tube India"** Information: Messe Düsseldorf, Internet: https://www.wire-india.com; https://www.tube-india.com
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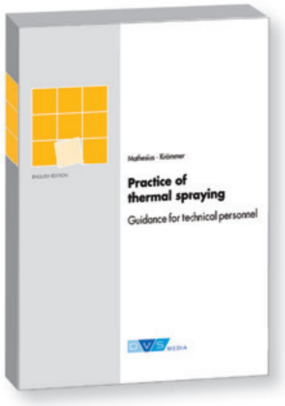

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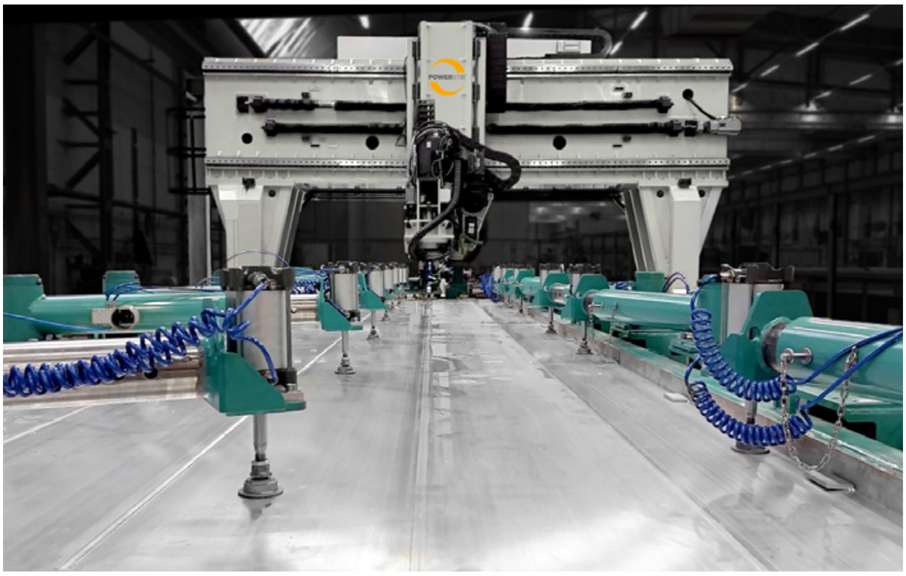
Major European train builders invest in Powerstir friction stir welding

Specially developed Powerstir friction stir welding (FSW) machines from UK-based Precision Technologies Group (PTG; www.ptgltd.com), that incorporate a 30 m × 4 m moving gantry, could soon redefine the way in which Europe's leading manufacturers of railway rolling stock produce aluminium carriage bodies.

Manufacturers typically use a combination of TIG and MIG welding to create railway panel welds. However, as the Powerstir friction stir welding process provides superior, high-strength joints, one leading European train builder already anticipates that using its newly purchased Powerstir FSW machine will lead to a reduction in the wall thickness of panels, with the potential for weight savings of as much as 30%. Thanks to the considerable gantry length of Powerstir rail sector machines, the business will also be able to weld some of its longest carriage panels in one single operation.



Specially developed Powerstir FSW machines that incorporate a 30 m × 4 m moving gantry could redefine the way in which Europe's manufacturers of railway rolling stock produce aluminium carriage bodies.

Growing demand for lighter-weight aluminium carriage bodies

Since their launch, PTG's Powerstir gantry-type FSW machines have been used extensively in the production of railway carriage panels for some of the world's fastest trains. With a growing demand for lighter-weight aluminium carriage bodies across the wider rail industry, increasing numbers of European-based manufacturers are now placing orders for PTG's British-built Powerstir machines.

Developed by Precision Technologies Group specifically for use in the railway industry, Powerstir gantry machines are renowned for their ability to produce particularly long friction stir welds. For example, a Powerstir machine is used to create what are believed to be the longest single FSW railway panel welds in China at over 15 m in length.

PTG is considered to be a leader in the development of FSW technologies for transport applications. Over recent years, Powerstir friction stir welders have found favour with companies from across the automotive, aviation and high-speed rail sectors. The Powerstir FSW process provides a clean, aesthetic alternative to traditional welding. It delivers proven weld quality, excellent mechanical properties, virtually no porosity and the opportunity for reduced wall thickness in many applications. Reduced wall thickness provides important opportunities for saving weight, while virtually no porosity helps minimise the ingress of moisture over time – an important attribute especially where railway carriages are operated in harsh environments. With welding speeds of up to 3.000 mm/min, the Powerstir process is typically more than three times faster than conventional automated welding techniques.

High-strength joints that are virtually defect free

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, Powerstir friction stir welding can also be applied to magnesium, copper, titanium and steel alloys. (According to press information from PTG)

Significant weight reduction in tipper manufacturing through new steel grades

Turkish trailer and tipper manufacturer Fesan Makina (https://www.fesanmakina.com/?dil=en), situated in Konya in the interior of Turkey, switched to "Hardox" wear plate and "Strenx" performance steel manufactured by the Nordic and US-based steel company SSAB (www.ssab.com), to meet customer demand for stronger, lighter equipment. Being part of a continuously growing market, Fesan also looks for contracts in other countries.

Their new tipper model "Dangal", which is used for multipurpose loads such as bulk cargo, pallet loads and scraps, withstands harsh conditions and its design incorporates innovative solutions. By introducing "Strenx 700" and "Strenx 960" steels in place of the previous thick mild steel, Fesan has shaved off about 800 kg in the chassis. "Fesan was the first company to use 'Hardox' in the side and rear doors," says Mehmet Baypınar, who is responsible for domestic sales at the company. "The change to 1.5 mm 'Hardox 450' from 3 mm thickness in the doors has made the vehicle another 600 kg lighter just from the doors."

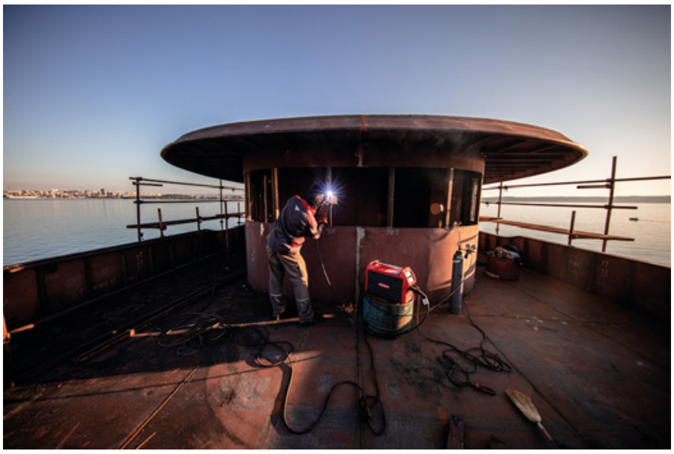
No more dents in the doors

Earlier, the doors in the tipper bodies were made out of mild steel, so deformation and severe dents would be a big issue for heavy loads. But in 2015, Fesan decided to test using "Hardox 450" steel for the side doors with supporting parts made of "Strenx" steel, and the result was very positive. "We got remarkable feedback about the quality, and customer satisfaction was exceptionally high," company founder Selim Selvi says. "Before, our trailers in Turkey would weigh about 9 or 9.5 t. After we began using 'Hardox' and 'Strenx', we were able to decrease the weight in phases, first to 8,000 kg, then to 7,000, and now 6,200 kg."

Why is less weight so important to their customers? "Less weight of the vehicle means the possibility of carrying more product load and this translates into better productivity for the end user," Selvi explains. "Less fuel consumption saves money and is also positive from a sustainability point of view." (According to press information from SSAB)

Fesan's new lightweight tipper model "Dangal" withstands harsh conditions; a video is available at https://www.facebook.com/fesanmakina/videos/fesan-dangal/574470816388589/.

Sun, salt and steel: Welding and its challenges in shipbuilding



The Croatian shipyard Gulet has been building ships for four years. Since it was founded, it has already completed eight ships. (Photos: Fronius International GmbH)

Welding in shipbuilding – certainly a Herculean task. Croatian shipyard Gulet j.d.o.o, which has been building ships for four years, knows all about this. The limited space calls for great skill and a reliable selection of the right welding position. Welding while lying down or kneeling is a matter of course. Gulet focuses solely on the construction of cruise liners and has been using welding technology from Fronius (www.fronius.com) from the outset.

The rugged, rocky Adriatic coast of Croatia spans 6,000 km. Set against the backdrop of turquoise waters, it is a paradise for those who love sailing or other water-related activities. All kinds of water sports are gaining in popularity, as are cruises along the idyllic archipelago, which are mainly offered on mega yachts. The starting points include the many historic coastal towns – such as Trogir with its captivating old town. Trogir is also the home port of Gulet shipyard. Since it was founded in 2015, the company, which currently has 16 employees, has already completed eight ships: “We allow around six months for one ship. However, as all the welding is done outside, the actual construction time is heavily dependent on the weather,” explains Mirko Purić, owner of Gulet.

The shipbuilder is subject to strict inspections. X-rays are taken of around 30% of the cross joints on a ship.

Small company – huge challenges

Needless to say, Purić’s shipyard performs manual welding. Steel is the main material used, which is why the four trained professional welders largely rely on the MIG welding process. However, finding highly skilled welders is difficult, explains the shipyard owner, as they have to master all three welding positions during their welder test: vertical, horizontal and angular welding. As a result, he has used Fronius welding systems right from the start, as these fully support the necessary manual skills.

There have been no failures, despite the tough conditions on site. At Gulet, all the ships are constructed outdoors at the pier, which makes launching easier due to the proximity to the water. However, as there are no covered halls, workers and machinery are exposed to the weather 365 days a year: rain, humidity and high temperatures of up to 50°C in summer. Just three small containers are used as a storage area for machinery, gas cylinders and also for office space.

The burning summer sun and limited space within the ship mean it can be exhausting work. Around 50% of a ship needs to be welded while lying down or kneeling. Because of the hull shape, it gets steadily narrower, particularly as you approach the sides of the ship. In the bow – the frontmost part of the ship – it is not unusual to find areas of less than 40 cm. “This makes work very difficult and is another reason why it is so hard to find highly skilled welders,” says Purić.

Meticulous checks of the steel plates and weld seams

Gulet primarily constructs cruise ships with a maximum length of up to 120 m. Shipbuilding steel is the primary material and flux-cored wires with a diameter of 1.2 mm are mainly used with this. The powder filling forms a slag around the weld seam, which significantly reduces spatter. This is extremely important for later acceptance tests, as both the strength and appearance of a seam are crucial.

The shipbuilder is also subject to other strict inspections. All the plates used in the ship are tested and must bear a Lloyd stamp when they leave the shipyard. Germanischer Lloyd (GL) is an international testing institute. “I have to take plates without test certificates from Lloyd to the shipyard in Split for a hardness and bending test. This is the only way I can be sure that the steel plates we are using are free from quality defects,” Purić continues.

Everything is welded manually in the shipyard. Steel is the main material used, which is why the trained professional welders mainly rely on the MIG welding process.

Ships constructed in individual sections

The ships are constructed in individual sections at Gulet. Once an element has been joined, an examiner from the expert body comes. This happens at least ten times during the construction process. For example, when the keel – the main longitudinal structural element of a ship – is joined to the shell plating, all the materials are checked by the expert. The weld seams on the shell plating of the outer hull are usually coated with chalk, and with petroleum on the inside. If the petroleum makes its way through to the other side, there must be a hole in the weld seam. The weld seam then has to be repaired – which involves milling it out, grinding it down and re-welding.

X-rays are also taken of around 30% of the cross joints on a ship. Small black dots on the image indicate areas where a slither of slag may have been welded. This makes the seam porous and therefore repair is essential. If there are several weld layers, the slag must be meticulously removed, starting with the root pass, through to the intermediate layers and filler beads: “The requirements are rigorous. We are committed to providing our customers with quality,” stresses Purić. His customers are mainly private companies from the nautical sector.

The shipbuilder’s portfolio also includes boats for deep-sea fishing – the first trawler is currently being constructed. The shell plating of these ships cannot be more than 16 mm, as this is the maximum to which Gulet is certified. Anything over this and the company has to apply for additional test certificates, which in turn means significant costs.

Low weight and ease of use

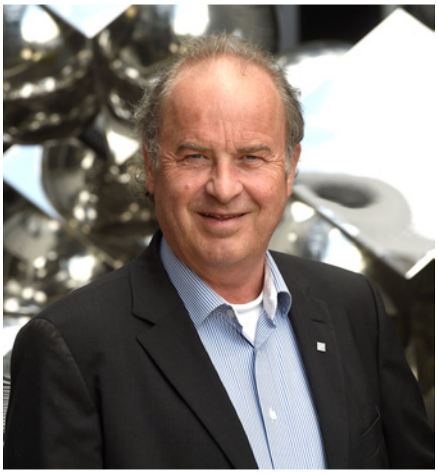
According to Purić, what really sets the Fronius systems apart, in addition to their other quality features, is their low weight: “The machines are lightweight so they are easy to transport around the construction site and in the ship. The ‘TransPocket 1500’ weighs less than 5 kg, which is why we mainly use it for tacking work, where we employ the electrode welding process. For all the MIG welding work, we use the ‘TransSteel 5000’, which weighs around 30 kg. We have four of these.” The ease of use is a decisive advantage for the welders too: “Say a new employee joins us; they will be able to master the machine after just an hour’s worth of instruction,” says Purić. “However, the main reason I opted for Fronius is the quality of the welding systems – they work perfectly. I don’t have any idle time now, so I’m saving money.” When a service, which includes the annual calibration specified by the testing organisation, is required, a Fronius technician carries this out on site quickly.

In Croatia, this responsibility falls to Fronius representative Eurotechnika in Zagreb. Fronius works with numerous sales partners and service partners worldwide to provide customers with the best possible levels of after-sales service. (According to press information from Fronius)

Mirko Purić, owner of Gulet j.d.o.o.

At Gulet, all the ships are constructed outdoors. As there are no covered halls, workers and machinery are exposed to the weather. This also has a huge impact on the construction time for each ship.

Swift integration into the workflow: Collaborative welding robots in metal working



Thomas Kaysser, Managing Partner at H. P. Kaysser GmbH + Co. KG. (Photo: H. P. Kaysser)

H. P. Kaysser GmbH + Co. KG from Nellmersbach near Stuttgart/Germany (https://www.kaysser.de/en/), a specialist in sheet metal working, owes the success of their metal systems solutions across Europe to their knack for tinkering and refining and their state-of-the-art machinery. This is why the company was among the first to put their trust in the Lorch Cobot Welding Package devised by Lorch Schweißtechnik GmbH from Auenwald/Germany (https://www.lorch.eu/en/). Currently still putting the collaborative welding robots to the test in a trial phase, the company is exploring how to systematically switch from welding components manually to producing them in a semi-automated process.

"Two years ago while taking inventory, we counted 16 different makes for our welding machines ranging in age from six months to 30 years. Such a diverse machine inventory poses a major challenge from a maintenance standpoint and calls for experts with special skills," says managing partner Thomas Kaysser, explaining the reasons behind the conversion of their machinery to Lorch Schweißtechnik inverters with a consistent operating logic.

Joining different components into one universal welding tool

The latest addition to their machine inventory comprises two "Lorch Cobot Welding Packages" since January 2019. The sheet metal processing specialist has been looking into all the possibilities that the collaborative welding robot may offer them in the production areas of pipe/steel construction and stainless steel/aluminium engineering. The package is composed of the Universal Robot "UR 10", the power source "S-RoboMIG XT" and Lorch's special welding processes. The "Cobotronic" software joins the different components of the solution seamlessly into one universal welding tool.

"One assisting robot arm that does not need to be housed in a protective cell, we recognised the enormous potential of the Cobot immediately," says Thomas Kaysser. "We are currently at the learning stage." The company employs 450 staff at their location in Nellmersbach near Stuttgart/Germany. They also run a factory in Romania. "We supply more than 30 industries across Europe with products ranging from simple to sophisticated. Our customers present us with challenges for which no solution has yet been found", emphasises Thomas Kaysser.

Spanning an area of 25,000 m², the company's vast halls – which were simply referred to by the owner as the "workshop" – contain a healthy portion of Swabian understatement, house laser cutting machines, 3D metal printers, one of the most cutting-edge powder coating machines, press brakes and the Cobots.

"We need to maintain our competitiveness by operating with highly advanced machinery," says Thomas Kaysser. "Every craftsman needs the tool best suited to make products that customers in the marketplace will accept. and they will if these products measure up to their standards in terms of quality, price and speed. That is a tough business involving a market that makes investments a pivotal necessity; after all, you cannot reap unless you sow."

Trial operation under real-world conditions

H. P. Kaysser's definition of the "proper" tool becomes evident in the way they assess the technology of the Cobot. "We wasted no time and started our trial operation under real-world conditions right away, setting up one collaborative robot each in black sheet production and in white sheet production," reports the manager, who, among other things, is trained as a welding engineer. "Testing the future" is what Ralph Schröppel, head of thin sheet production, calls this approach. "Half of our orders involve volumes of ten units or less. The bulk of these orders are blanket orders, which entails that we manufacture larger batch quantities depending on the work piece. We supply smaller batches

Department head Ralph Schröppel (left) and welder Edgard Arndt of H. P. Kaysser with the Lorch Cobot (Photo: Lorch) from our warehouse as needed by the customer”. The orders range from palm-sized cover caps to machine beds that can measure up to 6 m and weigh a few tonnes.

The ‘new guy’ has assimilated very quickly. “The Cobot is the perfect supplement to our toolbox”, declares the area manager. “Not requiring a safety enclosure and affording us the luxury of easy integration into the work flow at the welding bench, it proves especially useful for welding small quantities of repeat parts. It offers quick and easy installation, and can be controlled and programmed with superior ease thanks to the combination of its ‘Free Drive’ function and the touch display.” The welding sequence, pre-programmed based on the welding processes Lorch ships with every unit, allows the robot to produce a continuous string of welds with consistently flawless quality. This is regardless of whether they are created on fine grain construction steel, aluminium or different grades of stainless steel.

Automation helps avoid complaints from the customers

Edgard Arndt analyses welded parts for processing with the Cobot, that have been welded the traditional manual way, in the company’s “orientation phase”. He underwent further training to learn how to best utilise the qualities of the Cobot for H. P. Kaysser’s steel construction business. The component he is currently working on is a T-beam measuring nearly 80 cm in length and equipped with eyelets used for hanging audio equipment during events. “Such serial parts in quantities of 50 give the Cobot an opportunity to truly shine. Not only because of the weld seam length but also because of the tight customer tolerances the component needs to satisfy. In this application, we clearly benefit from the Cobot’s ability to perfectly reproduce the fillet weld.” An essential asset according to the welding expert, as it eliminates A-measurement variations during manual welding that may cause the weld to be too tall or too short or involve too much spatter. “Automation is a major asset in this regard as it helps us avoid complaints from our customers.”

In almost all cases, the teaching process for the Cobot is completed using the “Free Drive” function. “When dealing with a long linear weld, the welder can also move the torch to the desired position mechanically using a joystick mounted on the touch control panel. In this case, the 45° angle of the torch orientation will be perfectly identical as well”, explains Edgard Arndt. The object coming up next: a machine carriage for a laser die cutting machine that boasts 300 weld seams, which he would like to weld without the aid of marking templates or welding fixtures.

“Experiencing the thrill of technology first hand”

The thin sheet department trained two members of their staff in the in’s and out’s of Cobot. Ralph Schröppel, the head of the department, even spotted a co-worker “who tested and fooled around with the Cobot during his lunch break”. That is how it is supposed to be: “Experiencing the thrill of technology first hand.” An attitude perfectly in line with the company’s philosophy, as proprietor Thomas Kaysser points out: “Blazing new trails as early as 1984, we moved laser cutting from the laboratory to the workshop before advancing to laser welding in 1993. Such endeavours are cornerstones of a survival strategy that also rests on the ability to respond quickly thanks to short decision-making channels and on long-term investment.”

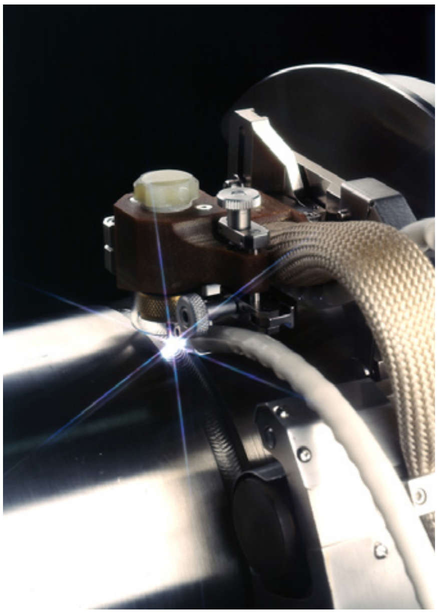
To ensure this approach will work as a team effort, the manager visits the workshop every day. “You cannot handle this type of job while sitting behind a desk.” The appreciation he has been shown for his expertise dates back to the time when

Tidy welding bench and swift integration: A key advantage of Lorch’s collaborative robot welding is the reduced effort when using fixtures. (Photo: Lorch)

he worked in production himself. “Machine intelligence is no substitute for skilled labourers – even a welding robot such as the Cobot can only assist and reduce the strain on the welder. Our certified welding experts are still key as they are the only ones with the valuable, theoretical know-how necessary to fuse specific materials and thicknesses using the right welding conditions.” (According to press information from Lorch)

While the Lorch Cobot accurately draws the weld seams set for a repeat part, the welder can already prepare the next serial part. (Photo: Lorch)

Orbital TIG welding based on efficient electrode selection and preparation



Orbital welding is frequently used in the manufacturing trade, for applications ranging from installing cooling and heating pipes in dairies to welding fuel pipes in the aerospace sector. (Photos: Gesellschaft für Wolfram Industrie GmbH)

Quality pays off: For example, nobody would equip a Formula 1 racing car with inexpensive all-weather tyres. In order to achieve a competitive speed, the vehicle should lie optimally on the track and be perfectly matched to the track conditions. Even with TIG arc welding, the tool used for high-quality welds must be adapted to the respective application – and yet many welders use tungsten electrodes that are not matched to the respective process. However, efficient orbital welding requires a tungsten electrode with an individually adapted tip geometry and surface roughness to match the correct shielding gas. For optimal weld seams, other factors must also be taken into account that influence the arc start properties, arc stability, total heat input and correspond to the characteristics of the weld seam.

The adaptation of all parameters to the respective TIG application enables a service life that is up to six times longer and thus resource savings of more than 350% compared to the use of non-specific electrodes. This can only be achieved, though, with the appropriate know-how, the correct selection and the use of high-quality tungsten. Three central elements can be optimised in this way: the welding process itself, the chemical properties of the tungsten alloy used and the grinding process for the electrode tip.

Increasing demands on the welding process in tube and pipe manufacturing

In today's industrial environment, many manufacturers and processors of metal tubes and pipes are faced with stricter requirements for weld seam properties than was the case in the past. The semiconductor industry, for example, needs narrower weld seams with fine surfaces on the inside of stainless steel pure gas pipes. These tubes transport high-purity gases that are toxic, flammable or corrosive, which is why the weld seams produced using the fusion welding process must be corrosion-resistant and cleanly processed in order to enable trouble-free flow. In addition, designers from all technical disciplines are increasingly pushing the limits of technical feasibility, for example by reducing pipe wall thicknesses to the necessary minimum. The clean processing of the weld seams is therefore becoming increasingly important with regard to the safety and service life of the products.

As the industry continues to evolve and adapt its processes, welders are also finding that their entire work environment is subject to high competitive pressure. Using FMEA (Failure Mode and Effects Analysis) and data analysis of the process variables, the previously underestimated hidden costs when using orbital systems were identified – for example, the production of scrap, reduction in system availability and frequent replacement of the electrodes. This drives the total cost of ownership up, although at the same time it would save as much money as possible. This includes avoiding premature wear of the tungsten electrode and irregularities in the machining process that can result from the use of different tungsten alloys when using electrodes from different manufacturers.

Proper chemistry through powder metallurgy

Another important element for the quality of an electrode is its chemical composition. To improve electrode performance,

Since the melting points of the materials can differ considerably, the electrode manufacturers trust the powder metallurgy process: Specific, extremely fine tungsten grain sizes are mixed in order to achieve a homogeneous oxide distribution in the matrix.

dopants in the form of cerium, lanthanum, zirconium, thorium, terbium and yttrium oxides are often incorporated into tungsten electrodes. Such oxides lower the electron work function – measured in electron volts (eV). For example, pure tungsten has rating of 4.5 eV, whereas a 2% ceriated tungsten has an eV of 2.8. By lowering the eV value or increasing the ionisation potential, the oxides improve arc starting performance and arc stability.

However, the influence of this variable on the welding result is often underestimated and most companies consider the tungsten electrode as a static component. In fact, as soon as the welding current flows, the electrode becomes a dynamic subsystem, the parameters of which influence the properties of the arc significantly. Specifically, the heat of the welding arc causes oxides to migrate from the relatively cooler core of the electrode to the hotter tip. There, the oxides separate (evaporate) from the base element and leave a film on the electrode tip. Small tolerances in the grain size, the purity of the elements and the composition ratio are essential to ensure a consistent oxide movement and evaporation rate, which in turn leads to a consistently high ignitability.

Because the melting points of the materials used for the electrodes can vary substantially – tungsten melts at 3,422°C, cerium oxide at 2,400°C – the electrode manufacturers rely on the powder metallurgy process. Specific, extremely fine tungsten grain sizes are mixed in order to achieve a homogeneous oxide distribution in the matrix. After this process, the tungsten and the oxide powder are pressed together by isostatic pressure, so that a uniform density and microstructure are created.

As a result, the brittle and unconsolidated electrodes are sintered for several hours in a high-purity hydrogen environment and at controlled temperatures. After sintering, the electrodes can be forged to their final shape, which further optimises the grain structure. The complexity of the tungsten electrode manufacturing process offers many opportunities for error, which explains the performance and cost differences between brands. Therefore, extensive know-how about the electrode is required on the one hand, but also extensive knowledge of the area of application itself, on the other hand, in order to be able to optimally adapt the tool for the respective process.

Grinding for a smooth finish

Geometry also plays a critical role in tungsten electrode performance. It is significantly influenced by the grinding method used. For example, the surface is increased by abrasives with a coarse grain, which in turn ensures faster oxide evaporation. Furthermore, the roughness of the surface when processing with a coarse-grained abrasive varies from application to application. Hand-operated and bench tungsten grinders are best left for preparing electrodes for manual GTAW applications, not mechanised processes. In an orbital TIG arc welding system with a modern power source with inverter and good arc start behaviour, companies should use pre-ground tungsten electrodes that have been machined by robot-controlled CNC systems. These machines are able to produce the desired very fine surfaces.

In order to influence boundary layers, voltage drop, cathode spots, evaporation rate or the relative exposed functional surface, the surfaces can be Ra 0.01 µm (0.4 micro inches) low, with high edge sharpness of the contour or 3.2 µm (125 micro inches) with perfectly burr-free flanks. High-quality, pre-ground electrodes made of tungsten also offer a dimensional accuracy of ±0.05 mm at the tip diameter and grinding angle tolerances of ±1 degree.

On the other hand, if a manual grinding machine is used to flatten the end of a pointed electrode, this leaves a microscopic burr without exception. If this burr breaks off during welding, it can get into the weld seam. For pharmaceutical, medical, nuclear, aerospace-related and other critical applications, this often means that the workpiece has to be sorted out.

Outlook on current research results

Much of the previous plasma research in the field of electrode geometry is carried out using the spot-on-plate technique (welding spot on plate), in which an arc strikes a plate at 200 A for 2 s. This technique does not represent the fluid dynamics (molten weld puddle behaviour) that occur during orbital welding. It does not take into account the welding head that moves into the cold material from the weld seam, nor the thermal conductivity and the preheating of the tube during the welding process.

Newer research, conducted under actual orbital welding conditions, incorporated

While tungsten electrodes are frequently used in welding, their structure, sharpening and alloy have a previously underestimated influence on consistently good product results in TIG welding.

more than 500 electrode configurations. Polished cross-sections of the welds were examined with a scanning electron microscope. Based on these results, suppliers of electrode and orbital systems can now recommend suitable tungsten solutions for specific applications. Narrow welds with a weld seam of 2 mm in outer diameter, for example, benefit from the increasing and constant arc pressure from the tungsten electrode, which is achieved by a mixture of mixed oxides, in which different oxide properties are combined.

These research results also help to solve previously hidden problems. For example, recurring deviations in the welding process at a company led to a significantly higher reject rate. To reduce this, extensive measures have been taken to find the cause. The investigation team re-calibrated the power source and welding head and inspected every point in the circuit. This did not improve the welding results though. However, the team never thought of the consumable component in the circuit: the electrode. The change to higher quality, pre-ground tungsten electrodes solved the problem.

Depending on the respective operating conditions, cumulative deviations caused by these factors can easily lead to a total heat input that deviates by as much as 5% under otherwise identical ambient conditions. While that might be acceptable now, it won't likely be acceptable within the next decade when end users require component fabricators to provide more complete data records and analytics.

High quality tungsten electrodes optimise cost efficiency

With every orbital welding process, high-quality electrodes reduce the overall welding costs. Test runs under clean room conditions show that with optimised tungsten electrodes, more than 650 arc starts can be implemented without delays in arc development. Instead of changing the electrode at the start of every shift, welders can use an electrode for several days. For example, one company recorded an arc duration of 27 hours with a single electrode.

Xavier Jauregui, Vice President of the technical area of Arc Machines Inc., Panorama City (CA)/USA, and
Matthias Schaffitz, Managing Director of Wolfram Industrie GmbH, Traunstein/Germany

(Article reprinted with permission from FMA Communications Inc.)

New electron beam welding machines for continuous welding of strip materials

Interview with Klaus Schmelzeisen, Sales Engineer at Steigerwald Strahltechnik in Maisach/Germany

Mr. Schmelzeisen, how do the “Ebocont”-series welding machines differ from those of the “Ebocam” series?”

Both series use the benefits of welding and machining with the electron beam in a vacuum. Whilst the main area of application for the chamber machines of the “Ebocam” series is the individual machining of larger workpieces with complex welded seam geometries and machining zones, the “Ebocont” strip welding systems are used to weld strip materials to each other continually in the longitudinal direction.

What are the areas of application for the “Ebocont” welding technology?

One of the main areas of application is the saw band industry. The raw materials for saw bands are manufactured as bimetal or trimetal strips with high wear resistance and optimum flexibility. Trimetal strip welding systems on the other hand are used for fields

"Ebocont" strip welding system.

Welding strip materials to each other continually in longitudinal direction.

of measuring technology where we are dealing with the production of measuring resistors, also known as shunts.

Would you please explain the functional principle of this type of system?

Of course. I had already mentioned that strip materials are welded, meaning that two or three strips – we are talking about bistrips and tristrips – are introduced into the machine by a winder and welded in the vacuum by the electron beam. If necessary, they pass through a milling machine for edge machining before the welding process. After welding, the finished bistrips or tristrips are rolled out again.

It is therefore a continual process in the longitudinal direction, integrated into complete production lines with upstream and downstream machining stations. Alongside the EB welding system, we also supply our customers with periphery aggregates which are required to construct these types of production lines as a whole.

Where do you see the technical benefits of the "Ebocont" welding process?

The general benefits are most certainly those which the electron beam welding process itself provides – that's to say the high precision, exact reproducibility and excellent cost-effectiveness with high cost saving potential. If you take a closer look at the "Ebocont" technology though, it is the high speed at which the strips are introduced into the vacuum chamber from the atmosphere and removed again – without a pressure loss in the vacuum chamber.

The constant vacuum and a highly precise guidance of the strips in the vacuum chamber ensure a high degree of reproducibility. Moreover, we have developed the REAN residual energy measurement in order to be able to detect fluctuations early. In conjunction with the QA software, it is possible to record and document the quality of the welding process.

One last question: How has the market developed over the last few years? When you look to the future, where do you see potential for development?

The machine type developed at the end of the 60s was first only used for the production of bimetal strips for manufacturing saw bands. There was then a further development to tristrip systems which were also used for saw band manufacturing until around the mid-90s.

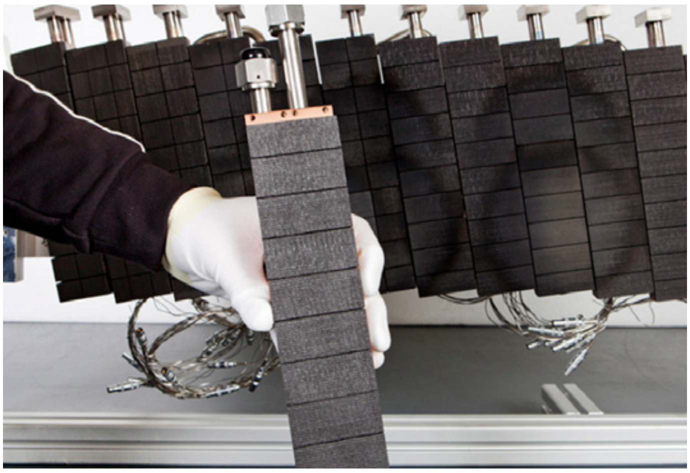
The market has been in constant change since the turn of the millennium: The increasing trend towards electro-technology, which has endured until the present day in almost all sectors, has led to an increased requirement for measuring technology associated with it and therefore for measuring resistors, also known as shunts. This trend continues to grow. Our everyday life has been 'smart' for a long time now – if we think about mobile phones, electric cars, smart homes or Industry 4.0, it's clear that there is a particularly high potential for growth for trimetal strip welding systems for welding semi-finished products in shunt manufacturing.

(According to press information from Steigerwald Strahltechnik; https://www.sst-ebeam.com/en/)

Saw bands manufactured as bimetal or trimetal strips.

Microsection of a tri-band weld (copper–copper manganese–copper)

Innovative electron beam technology for future energy production methods



HHF diverter for W7-X made of CFC and a copper metal alloy. (Photo: IPP, Michael Herdlein)

With the fusion device "Wendelstein 7-X", the Max-Planck-Institute for Plasma Physics in Garching near Munich/Germany (IPP; https://www.ipp.mpg.de/en) is investigating the theoretical and physical principles of future energy production methods. The institute is researching the energy production by means of fusion power plants, in which the atomic nuclei of a plasma mixture of deuterium and tritium weighing only a few grams are to be fused, producing enormous amounts of energy. According to calculations, one gram of the fuel would be able to generate 90,000 kW hours of energy.

But the institute is still doing basic research – the aim at "Wendelstein 7-X" is to produce a stable 30-minute plasma discharge to demonstrate the suitability of this type of device for continuous operation.

Ambitious goal: making the energy source of the sun available on earth

In a fusion power plant the energetic processes of the sun are to be reproduced on earth, i.e. generating energy from fusion of atomic nuclei. The best way to produce fusion energy would be with a mixture of deuterium and tritium, which turns to plasma when exposed to immense heat. The test facility "Wendelstein 7-X", however, will not work with the actual power plant fuel, because its aim is not to produce energy, but to research the suitability of this type of device for a fusion power plant. Nevertheless, this high temperature plasma has to be heated to a temperature of 100 million °C.

Extreme heat and extreme cold require extreme technologies

Three different heating systems are used to heat the plasma to the extreme temperatures of 100 million °C. The main heating system is the microwave heating with 10 high power microwave sources providing approx. 1 MW each – that's nearly 10 million W!

In the plasma vessel, the hot plasma has to be kept away from the vessel walls. To do that, 70 superconducting magnetic coils produce a magnetic field to keep the hydrogen plasma suspended. During operation, liquid helium flows through the magnetic coils and cools them to nearly –270°C.

Despite the use of this complex technology, the outer edges of the hot plasma still touch the walls of the plasma vessel. Although the temperature here has already "cooled" to about 100,000°C, the vessel walls need to be protected effectively and the heat has to be safely conducted away from them. Here, as in many other areas of the facility, the scientists and specialised companies involved in the development of "Wendelstein 7-X" had to continuously come up with new, innovative solutions.

Special high performance heat exchangers

Plansee SE developed special high performance heat exchangers for IPP for the areas of the plasma vessel wall exposed to the highest heat load. These heat exchangers, so-called divertors, consist of carbon fibre reinforced carbon (CFC) and a water-cooled metal block made of a special metal alloy. These divertors are then attached as "wall elements" to the crucial areas to effectively divert the high heat flux as well as remove impurities from the plasma.

A particularly difficult aspect was the joining of the carbon fibre reinforced carbon (CFC) with the metal alloy of the cooling block, as the carbon is exposed to the high temperatures of the plasma while water flows through the cooling block at high pressure at the same time.

Regarding the optimum joining technology for this connection, electron beam welding specialist PTR Strahltechnik of Langenselbold near Frankfurt am Main/Germany (https://www.ptr-ebeam.com/en/) was able to deliver: The cooling block made of copper-chromium-zirconium and the CFC material coated with a thin layer of copper were perfectly joined with PTR electron beam machines to welding depths of up to 30 mm.

The pieces were welded with a pulsed electron beam with acceleration voltage of 150 kV. Thanks to an extremely narrow weld seam with minimum heat penetration, the CFC material remains undamaged, and the required overall heat conductivity from the surface of the carbon layer to the cooling block is guaranteed. (According to press information from PTR Strahltechnik; www.ptr-ebeam.com/en/)

Lowest heat penetration thanks to a particularly narrow weld seam. (Photo: PTR Strahltechnik)

Motorsport inspired technology to aid future fast jet development

The “Tempest” concept model on the airfield at BAE Systems in Warton, Lancashire, UK. (Photos: BAE Systems)

BAE Systems (www.baesystems.com) and Williams Advanced Engineering (WAE; www.wae.com) have joined forces to explore how battery management and cooling technologies from the motorsport industry could be exploited to deliver efficiency and performance gains in the design of future combat aircraft. An Oxfordshire-based specialist team from WAE is working closely with BAE Systems engineers in Lancashire to inform and guide thinking about how future aircraft could fly faster and more efficiently than anything before.

High power at low weight

The project is part of a wider research effort to develop technologies that could be used to develop the most advanced combat air system for the UK. Next generation combat air technologies will need high power at low weight in order to provide long range endurance and mission success. Future systems will also need to generate enough energy to power a small town, which can be managed safely and efficiently throughout the aircraft and its subsystems, with pilots depending on high-performance ‘power when you need it’ combat air capability.

WAE is a leader in the design and delivery of advanced battery technologies that provide durable, fast charging power capability and was recently appointed as the Gen3 exclusive battery system supplier of the ABB FIA Formula E World Championship. Combined with technical expertise from Rolls Royce in the development of power and thermal management systems and BAE Systems’ experience in integrating complex systems, this collaboration is an example of how the UK combat air sector is leveraging the best of wider industry, sustaining critical skills across the country.

Julia Sutcliffe, Chief Technology Officer for BAE Systems’ Air sector, said: “Working in partnership with companies like WAE is vital to drive rapid innovation at the pace the “Tempest” programme demands. Changing how we engage with wider industry and leveraging the best technologies and processes from across the global supply chain is essential in order to deliver value to the UK, our international partners and our allies. This collaboration is a great example of how we're starting to achieve this – finding synergies, great engineering minds and mutually beneficial technology projects with organisations outside of our traditional partnership base."

Paul McNamara, Technical Director, Williams Advanced Engineering, said: "We feel privileged to be involved in this ground breaking project and are confident that our experience in advanced battery development and cooling technologies will allow us to deliver innovative new solutions that can be applied in the defence sector. We have already seen a number of tangible benefits from closer working with BAE Systems, tapping into a rich source of experience from a range of engineering disciplines."

Williams are also applying their expertise to the development of future cockpit designs.

Supporting a fully-connected future combat air system

The UK's ability to generate and employ combat air power is critical to deliver national security and to support the Government's vision for a strong, prosperous, influential and global Britain. This study forms part of a wider UK research effort to develop a set of capabilities designed to support a fully-connected future combat air system, building on the country's strong national heritage of advanced technology programmes and development of world-class military capabilities.

This latest project builds on an agreement signed in 2018 between the two companies to share technology, expertise and skills across a range of areas including augmented reality, cockpit designs and advanced materials to create innovations for the design, performance and production of both fast jets and fast cars. A secondment programme is also in place creating opportunities for graduates and apprentices to share best practice across the two organisations. (According to press information from WAE)

Short messages

Pemamek delivers two production automation lines to Taiwan

Welding automation supplier Pemamek from Loimaa/Finland (https://pemamek.com) has delivered two "Pema" production automation lines, designed for foundation pin pile production, to CSBC Corporation in Taiwan. This investment is a part of CSBC's business development initiative to become an offshore wind energy turnkey provider and expand its operations in the national offshore wind energy markets. The technologically advanced lines have the capacity of processing pin piles up to 350 t and 90 m. The delivery included:

- three longitudinal seam welding stations,
- two assembly stations, capable of welding internal circular seams,
- two welding platforms that weld simultaneously with two welding heads,
- integrated heavy-duty roller beds with polyurethane rollers,
- a high-tech "Pema WeldControl 500" control system with laser-tracking, designed for multi-passwelding.

In addition to the machinery, the agreement includes training, production start-up support, a preventive maintenance package and local service support with an authorised service partner. Manufacturing with the production lines has already started at full speed as CSBC will supply a significant number of foundation pin piles for Ørsted's 900 MW Greater Changhua offshore wind project, scheduled for 2021.


The "Pema" production automation lines are designed to manufacture pin piles for offshore jacket foundations.

"Omax TV" is online

Omax Corp. from Kent, WA/USA, an international manufacturer of abrasive waterjet systems, has announced that "Omax TV" is live at www.omax.com. It offers a great way to access all the video content the company has produced to demonstrate abrasive waterjet technology, waterjet applications and materials capabilities. The site currently hosts more than 50 videos that show both old and new types of waterjet machines. Throughout 2020 and into 2021, watchers can expect to see more engaging interviews with Omax waterjet customers as well as regularly updated tips and tricks from the company's demonstration lab. Omax Corp. hopes that their TV offer will become a resource for potential waterjet users as well as for educational institutions looking for reference material on waterjet use. Access "Omax TV" through Omax.com, the QR code below or via this direct link: https://fast.wistia.net/embed/channel/amyfz6h9fl.

OMAXTV

Padana Tubi selects Thermatool for high-speed flying sheer for tube cutting

Inductotherm Heating & Welding (inductothermhw.co.uk) have announced that Padana Tubi from Guastalla/Italy have placed an order for an "Alpha" high-speed flying shear for the cutting of large diameter stainless steel tube. This shear will be the largest ever developed by Inductotherm/Thermatool and will allow Padana Tubi to extend its production capability to cut materials up to 6 mm wall thickness with an 8" diameter including profiles. Padana Tubi & Profilati Acciaio S.P.A. was established in 1970 by the Alfieri family with the aim to produce welded tubes and carbon steel pipes. With growing success and development within the market, Padana Tubi were encouraged to make a commitment in production of stainless steel tubes, leading them to produce and sell more than 800,000 t of stainless steel tubes and 1,000,000 t of carbon steel tubes every year. Padana Tubi are a longstanding customer of Thermatool for more than 25 years. Inductotherm Group offers advanced technology for the engineering, manufacturing and service of thermal processing equipment used in the melting, heating, heat treating, forging, galvanising, coating, cutting and welding of metals. Bringing together 40 companies with 38 manufacturing facilities located in 23 countries, Inductotherm Group delivers innovative products throughout the world. Customers rely on Thermatool, Inductotherm, Banyard, Inductoheat, Radyne, Consarc and other trusted brands.

Padana Tubi have placed an order for an "Alpha" high-speed flying shear for the cutting of large diameter stainless steel tube from Inductotherm/Thermatool.

Wall Colmonoy celebrates 50 years in Pontardawe, Wales

Wall Colmonoy (www.wallcolmonoy.com) celebrates its golden anniversary of 50 years of making metals work harder in Pontardawe, Wales. The family-owned and -operated organisation with facilities throughout the USA and UK is a global leader in materials engineering, maintaining a reputation for expertise and quality throughout aerospace, automotive, glass, oil & gas, mining, energy and other industrial sectors. The UK company exports over 80% of its products into the Eurozone, Scandinavia, South Africa, Russia, Middle East and India. Wall Colmonoy began its European footprint in 1952, first as a sales office and distribution center in London, importing products from Wall Colmonoy Canada. As the company grew and a need for local manufacturing became apparent, alloy manufacturing began in Motherwell, Scotland before transferring to a larger facility in Brackley, England. Due to continued and rapid growth in the UK and European markets, William P. Clark Sr., Group Chairman, accepted an offer by the Welsh Government, in 1969, to establish its European Headquarters in Pontardawe, Wales and build a larger facility to fulfill growing demand. Over the half-century, Wall Colmonoy has increased capacity of the Pontardawe facility from 33,000 to 70,000 ft^2, opening a 23,500 ft^2 advanced machine shop to support its casting manufacturing facility in 2012. Today, its workforce continues to grow, with 215 employees; a quarter of whom have been with the company for more than a decade.

Aerial view of the Wall Colmonoy facility in Pontardawe after expansion in the 2000s due to increased demands for powder manufacturing.

Acquisition brings expertise in diffractive optical elements

High quality laser scan system manufacturer Scanlab GmbH from Puchheim/Germany (www.scanlab.de/en) has a new affiliate company. TechInvest Holding AG, the parent company of Scanlab, is taking a 25% stake in the Israeli firm HOLO/OR Ltd (www.holoor.co.il) from Ness Ziona. They are recognised as a pioneer in developing diffractive optical elements for industrial applications. By integrating these innovative micro-optical components, such as beam shapers, into its scan solutions, Scanlab can multiply the fields of application for its products. Diffractive optical elements (DOE) can be used to specifically shape laser beams. To achieve the 'diffractive effect', DOEs employ microstructures etched into a substrate using a lithographic process. Glass is typically the substrate – but plastics, metals or semiconductors can also be used. The Israeli company is regarded as an experienced player and leader in this market segment. Founded by Israel Grossinger 31 years ago, HOLO/OR is one of only a few suppliers capable of producing DOEs, e.g. beam splitters and shapers, with high damage thresholds that can stand up to high-power lasers. Its expertise encompasses not just design and fabrication, but also a unique in-house simulation software.

Israel Grossinger is owner and president of HOLO/OR.

Products

Brazing equipment awarded with "Solar Impulse Efficient Solution" label

Castolin Eutectic have announced that their brazing machines "Dyomix OHM 2.4" and " OHM 3.0" (**Fig. 1**) have been awarded with "The Solar Impulse Efficient Solution Label", a certification that applies to products, processes and services which combine economic profitability and environmental sustainability. The label is a new framework that applies to all products, processes and services to indicate the quality and economic competitiveness of clean solutions. The brazing equipment "Dyomix OHM 2.4" and "OHM 3.0" are functioning on the basis of electrolysis, without gas and using water as sole fuel. The perfect flame resulted presents 85% less cabon monoxides (CO) and no damaging UV radiations, so there is no longer a need for tinted lenses for most applications. The noise level is also significantly reduced, which means improved health and safety for the operator. The machines are intended both for plumbing/refrigeration/heating professionals who need mobility and industrial manufacturers seeking great flexibility along with a low total cost of ownership. The "OHM 2.4" runs at 2 kW power and consumes 0,25 l water/h, while "OHM 3.0" runs at 3 kW, consuming 0,4 l water/h. Besides brazing, both machines are also suitable for metal cutting. The "dyomix" flame obtained is compatible with all brazing products (filler metals and fluxes) on the market. (Castolin Eutectic, 22 Avenue du Québec, Villebon-sur-Yvette, NA 91140/France; www.castolin.com)

Fig. 1

New series of welding helmets for reliable protection

Kemppi strengthens its welding safety portfolio with new “Alfa” and “Beta e-series” welding helmets and respirators (**Fig. 2**). Certified to the latest standards, the new models offer excellent protection for arc welding, cutting, grinding, gouging and inspection processes. They feature an impact-rated shell that is both lightweight and strong. The spacious design accommodates eyeglasses and half masks, whilst allowing good access to tight spaces. Several settings and features support easy adjustment for the best personal fit, including a comfort headband, integrated magnifying lens holder and an overall 20% weight reduction, compared to the previous “Beta” models. The “Alfa e-series” welding helmets represent the most compact, lightweight face shields in Kemppi’s welding safety product range – their weight starts at just 467 g. They are durable, low-cost solutions that provide protection for all general welding applications and grinding, and are equipped with either a passive glass welding lens or auto-darkening ADF welding lens. The “Beta e-series” welding helmets are designed for professional welders. Certified for welding, cutting and grinding according to EN175 B and AS/NZS 1337.1, the new lightweight models start at just 473 g. The range includes three models that are equipped with either passive or automatic ADF lenses. (Kemppi Oy, Kempinkatu 1, 15801 Lahti/Finland; www.kemppi.com)

Fig. 2

Corrosion inhibitor coating also effective as weldable rust protection

One of the metalworking industry’s most recognised rust preventive liquids is now proven effective also as a weldable RP (rust preventative), according to new testing by a leading manufacturer of heavy equipment: Daubert Cromwell’s “Nox-Rust 5400 VCI” oil is shown to be a safe, ready-to-use, weldable coating that protects metal surfaces without affecting the quality of the weld (**Fig. 3**). Corrosion protection on welded metals lasts for up to five years, indoors. “Nox-Rust 5400” is known as an effective corrosion inhibitor, providing protection for cold rolled steel and metal stampings, as well as metal parts used in the automotive, heavy equipment and machinery industries. The light oil leaves a lubricating, corrosion preventive film that will not interfere with stamping oils or processing oils. It is now clear that the oil does not interfere with the welding process, either. Recent tests showed plates protected with “Nox-Rust 5400” could be welded together without having to remove the protective coating with solvents or cleaning solution. The welding process and the weld itself were unaffected. (Daubert Cromwell, 12701 S. Ridgeway Ave, Alsip, IL/USA; www.daubertcromwell.com)


Fig. 3

Low-hydrogen stick electrode

As part of the “Excalibur SMAW” (stick) electrode series, Lincoln Electric introduces the new “Excalibur 7018 XMR” low-hydrogen stick electrode. It offers exceptional low moisture content even after 24 hours of exposure – remaining below the moisture content limit for 15 hours more than required under the American Welding Society’s AWS A5.1. Electrodes, when exposed to air, pick up moisture over time. The moisture typically increases the hydrogen content of the weld – and potentially leads to failure. Low hydrogen (or basic) electrodes are designed for applications susceptible to hydrogen cracking, a form of failure occurring when moisture causes porosity in the weld. “Excalibur 7018 XMR” is used for general fabrication in many industries, including structural, pipeline, chemical processing and ship building (**Fig. 4**). Besides its improved coating integrity it is characterised by an extreme bendability – the rod coating maintains integrity when bent for welding in tight spaces to a greater extent than similar competitive rods. (Lincoln Electric, 22801 St. Clair Avenue, Cleveland, OH/USA 44117; www.lincolnelectric.com)


Fig. 4

Flexible PVD coating machine

IHI Hauzer Techno Coating B.V. has announced its latest batch-coating machine for physical vapour deposition (PVD). The new “Hauzer Flexicoat 1250” (**Fig. 5**) builds on the successful “Flexicoat” platform, known for its wide range of technologies. The “Flexicoat 1250” offers an extraordinary seven cathode positions, which can be configured to meet the customer’s business needs and provides more power to those cathodes. This helps keep cycle times low, even with the increase in chamber diameter and loading capacity. For many commercially important substrates and coatings, such as plastics in the decorative sector and tetrahedral amorphous carbon (ta-C) coating in the tribological and tool sector, temperature during deposition needs to stay low. The “Flexicoat 1250” has eight plate positions plus an optional retractable central heating and cooling feature. This reduces the need to pause deposition to avoid exceeding temperature limits, keeping cycle times low for challenging coatings and substrates. Upon purchase, the machine is configured to meet customer needs. And over the decades, it can easily be upgraded and reconfigured as the business moves with the market over time. (IHI Hauzer Techno Coating, Van Heemskerckweg 22, 5928 LL Venlo/The Netherlands; www.hauzer.nl)

Fig. 5

Digital quality management for welding

The “Cloos C-Gate” is a digitalisation platform where users can access information from their welding production in real-time. All information is entered and processed centrally in an integrated information and communication tool. The customised presentation of information enables detailed visualisation, analysis and continued processing of the operating and welding process data collected. This allows users to monitor and control their production processes down to the smallest detail. The “C-Gate”consists of several modules which can be activated depending on the customer’s individual digitalisation strategy. The new quality management module (**Fig. 6**) focuses on the individual component with the production and welding process data. Here, a detailed assessment of the weld quality is already possible during welding. For complex and chained systems, quality statements are made for each production stage in addition. The determined data are summarised in a component protocol and can be called up via the report function or via OPC-UA or REST interface. Whether as central virtual server solution or as system-near edge-gateway implementation – all Cloos robot systems and welding machines can be connected to the platform. Furthermore, existing Cloos systems and welding machines can be integrated. (Carl Cloos Schweißtechnik GmbH, Carl-Cloos-Str. 1, 35708 Haiger/Germany; https://c-gate.cloos.de)

Fig. 6

The principal arc welding processes

Fig. 1 • Torch light sparkles.

There are four basic welding processes that generate the heat necessary to melt metals by striking an electric arc between an electrode and a metal. Other arc processes are in use but have limited application or lack control and quality characteristics. Initially developed towards the end of the 19th century, arc welding quickly became a commercially important processes especially in the shipbuilding sector in the second world war.

An arc is a discharge of energy between two conductors at different voltages. In welding It can be initiated by bringing the conductors, an electrode and the metals to be joined, together momentarily to create a short circuit and then drawing them apart to produce a continuous arc, **Fig. 1**. Experience is necessary so that the two components do not stick together. The arc can only be maintained over a very limited separation and with manual welding this relies on operator skill. Development over the past few decades has resulted in the production of sophisticated power supplies to help stabilise the arc.

The temperature created in an electric arc is typically between 5,000ºC and 20,000°C depending on conditions but this is clearly more than adequate to fuse all common alloys which have melting points up to 1,500°C.

Gas tungsten arc welding (GTAW), often described as tungsten inert gas welding (TIG)

A non-consumable tungsten rod is used as the electrode and an inert gas, usually argon, protects the electrode and the joint area from contamination, primarily from oxidation at the high temperatures prevailing during the welding operation, **Fig. 2**.

Filler metal, selected to ensure optimum joint properties, may be added manually or mechanically.

Advantages

The process is normally limited to joining thin sections because heat input is limited but welds can be made without the use of additional filler metals (autogenous welding). Thicker sections can be accommodated by using multi-pass deposits. GTAW is mostly a manual process but automation can be used when making multiple joints. The process is particularly suitable for making initial high-quality deposits – called a 'root pass' – prior to undertaking multi-pass operations on thick sections with a higher deposition welding process.

GTAW is a controllable, clean technique and is widely used for welding stainless steels and reactive alloys such as titanium, zirconium, aluminium & magnesium.

Disadvantages

The rate of metal deposition is low and welding speed thus limited. Excessive welding current or poor welding technique can cause melting of the tungsten electrode and may results in tungsten inclusions being transferred into the weld zone.

Gas metal arc welding (GMAW) often described as metal inert gas welding (MIG) or metal active gas welding (MAG)

An arc is established between a continuously fed filler wire electrode and protection provided using an inert gas such as argon to protect the wire electrode and the molten weld pool. Helium or inert gas mixtures based on argon and helium are beneficial for some applications. The active gas process, in which carbon dioxide or mixtures of argon, carbon dioxide and oxygen are principally used for welding carbon and low alloy steels, **Fig. 3**.

Advantages

A gas shield protects the weld, filler wire and heat affected areas from contamination. Both the inert gas and active gas techniques offer relatively high weld deposition rates compared to the GTAW process.

Disadvantages

The inert gas process is difficult to use in the vertical position but generally requires less operator skill than the active gas alternative

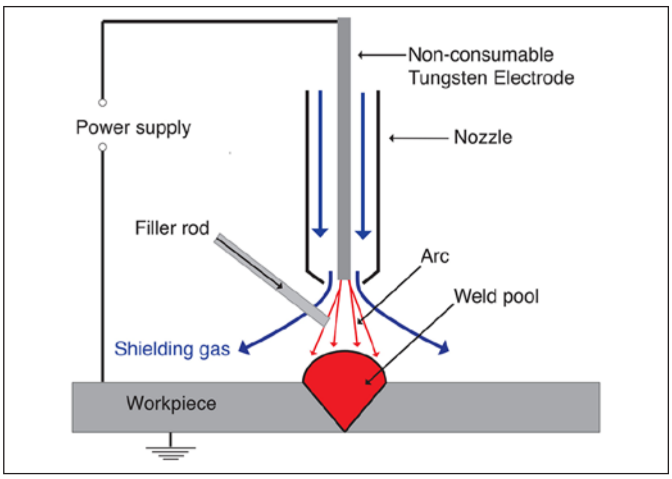


Fig. 2 • The principles of gas tungsten arc welding.

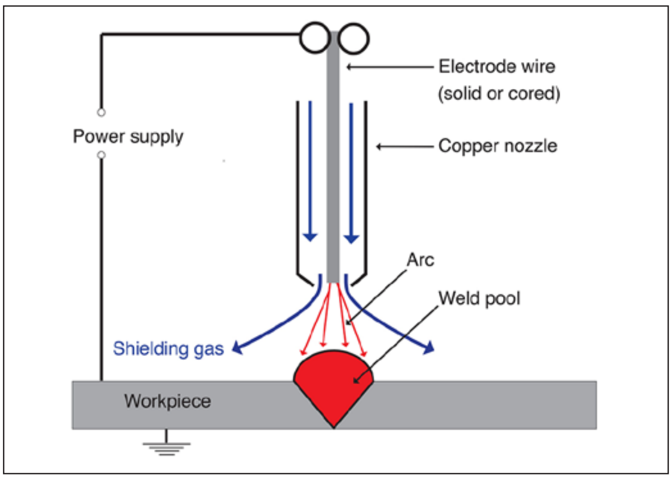


Fig. 3 • The principles of gas metal arc welding.

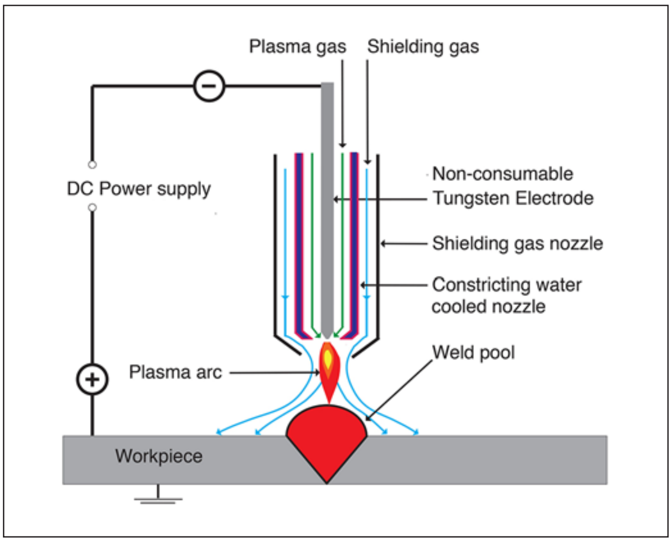


Fig. 4 • The principles of plasma arc welding.

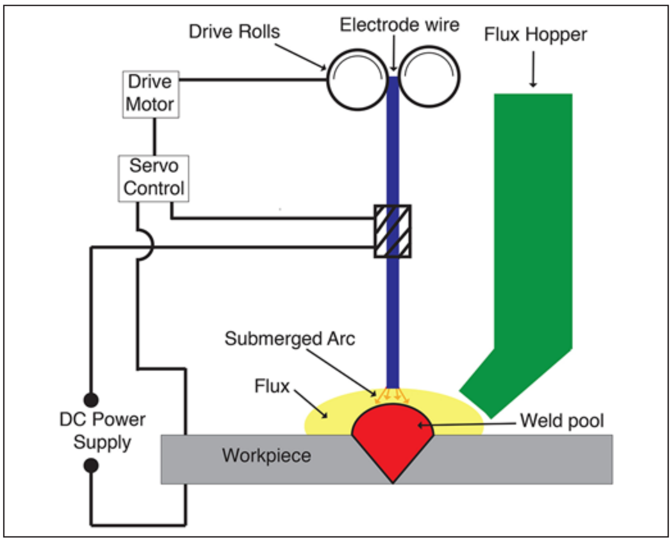


Fig. 5 • The principles of submerged arc welding.

Plasma arc welding (PAW)

The technique is similar in some aspects to GTAW and GMAW welding but heat is generated by a constricted arc between a tungsten electrode and a water-cooled nozzle (non-transferred arc) or between a tungsten electrode and the joint (transferred arc), **Fig. 4.** Filler metal is added separately into the molten weld pool.

Advantages

The tungsten electrode is recessed in the nozzle, so minimising the chance of weld metal contamination. It is not so sensitive to arc length variation as GTAW or GMAW and therefore requires less operator skill for welding. High welding speeds are possible.

Disadvantages

PAW is considerably more complicated than other arc welding processes and requires careful control over the electrode tip configuration and positioning and orifice selection. Equipment is generally more expensive

Submerged arc welding (SAW)

Shielding of the filler wire and workpiece is effected here not by inert gas but with an inert granular flux. The arc is totally hidden by the flux which melts as the arc generates heat. The flux solidifies as the arc traverses along the joint, continuing to protect the weld during cooling, and is replaced by new flux from a hopper, **Fig. 5.**

Advantages

Heat losses are low because the arc is submerged in an inert and insulating flux. It is possible to add alloying materials to the flux to control weld metal composition. Welding speeds and deposition rates can be much higher than other arc processes. SAW is mostly used for joining thick sections.

Disadvantages

It is difficult to weld unless the joint is horizontal in order to prevent the flux from falling off due to gravity. The high heat input can lead to distortion of the workpiece.

Arc welding hazards

Welding fume

There are hazardous substances in fumes created during welding. These arise from inert gases, coatings on consumables and metal vapours [1-3]. Two methods can be used to reduce and often eliminate the effects: the integration of local exhaust ventilation systems and respiratory protective equipment (RPE).

Tungsten toxicity

Pure tungsten has a high melting point, but other characteristics render it unsuitable. The addition of thoria offers improvements although various bodies have published health warnings because of the potential toxicity. Alternatives to thoriated tungsten are readily available and should be used. [4-6]

Inert gas hazards

Although argon is non-toxic, it is 38% denser than air and therefore considered a dangerous asphyxiant in closed areas. Removal of excess inert gas by extraction during welding is useful but when used more widely as a weld purging technique the risk of inhalation is increased significantly [7].

Arc eye

This is a painful condition caused by exposure of the eye to the ultraviolet radiation from an electric arc. Special glass filters are a necessary accessory to protect eyes against damage. [8]

Intense heat

Large amounts of heat are generated during arc welding and care needs to be taken to protect exposed areas of skin. The use of insulating gloves and face/ head shields is seen as essential.

M. J. Fletcher, Delta Consultants

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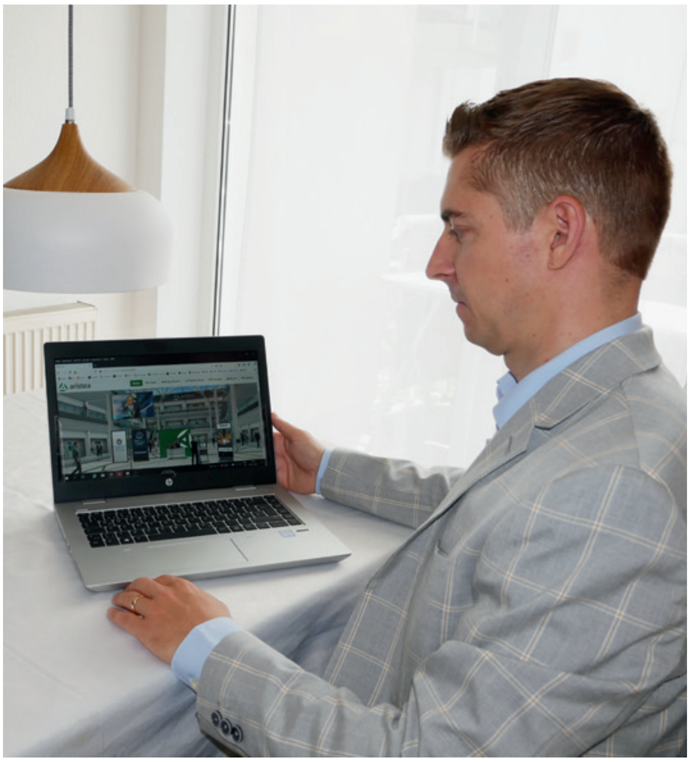
The international welding world met online: DVS took part in the "IIW On-line Annual Assembly"



Of course, DVS also took part in the "IIW On-line Annual Assembly", as here Marvin Keinert, M. Sc., technical consultant at DVS and contact person for the DVS-IIW Young Professionals. (Photo: DVS)

Presentations, discussions and interaction – this is what the "IIW On-line Annual Assembly" promised in the run-up to the event. And it kept its word: Due to the current situation, the International Institute of Welding (IIW) had invited to the virtual Annual Assembly for the first time, which was attended by over 500 delegates from 60 nations. With over 100 participants, the DVS made up the largest online delegation worldwide. Numerous DVS-IIW young professionals were also present.

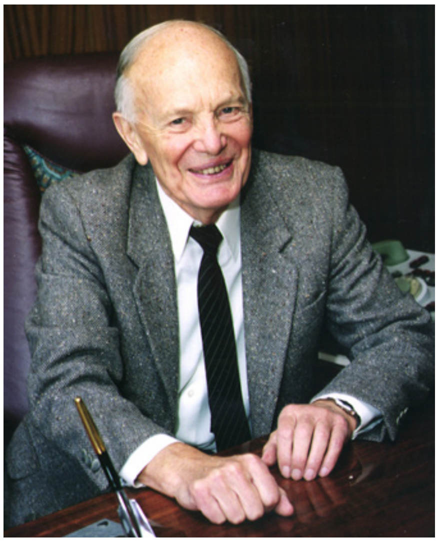
The IIW General Assembly took place on 15 July. The participants could follow the speeches and elections live. For the DVS-IIW Young Professionals, the program for students and the various working groups were of particular interest from 17 to 25 July. The young researchers were not only able to expand their knowledge digitally, but also to make international contacts online. In doing so, they took advantage of the opportunity created by the IIW "going on-line staying together virtually".

Prof. Boris E. Paton Obituary

The DVS mourns the death of Prof. Boris E. Paton, Kiev/Ukraine, who died on 19 August 2020 at the age of 101. He was the author and co-author of more than 720 inventions and of over 500 patents, as well as author and co-author of more than 1,200 published works and 20 scientific monographs. His international reputation is the result of his extensive scientific activities and his great efforts to apply the results of basic research to solve urgent social challenges. Because of his developments, Paton is considered one of the founders of the first nationwide production of high-quality large-diameter pipes, including high-performance gas pipelines.

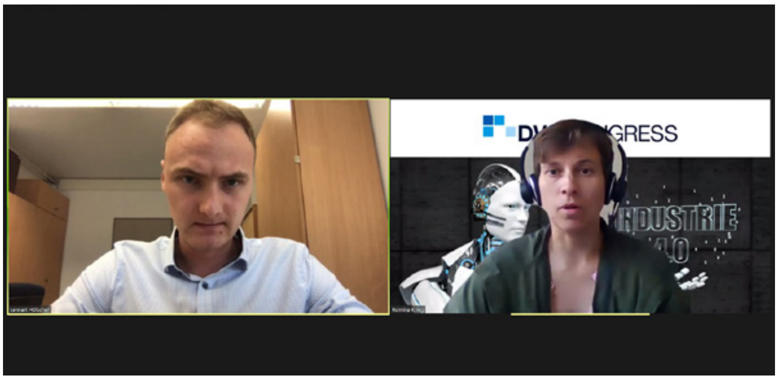
From 1953 on, he headed the globally recognised research and development center "E. O. Paton Electric Welding Institute" of the "National Academy of Sciences of Ukraine". Among other things, he built up the organisation of the institute's research activities, established business contacts with company managers, national economic councils and ministries of the Soviet Union. The USSR became a world leader in the field of welding processes, equipment, materials and technologies.

For more than 50 years he was president of the "Academy of Sciences of the Ukrainian SSR" and later of the "National Academy of Sciences of Ukraine". For his numerous merits he received honours from all over the world. The DVS, with which he maintained friendly contacts for many decades, appointed him an honorary member in 1997.



Prof. Boris E. Paton died on 19 August 2020 at the age of 101.

Successful online premiere: For five days, DVS CONGRESS 2020 informed the experts



The speaker and the moderator are discussing. (Photos: DVS)

The technical supervisor monitors the online congress.

Over 320 participants met online for the first time from 14 to 18 September 2020 for the DVS CONGRESS. Participants from Brazil and the USA also took part in the extensive technical programme on "Additive manufacturing", "Occupational health and safety", "Modern welding processes", "Surface technology" and many other topics from joining, cutting and coating technology. The DVS as the organiser was satisfied with the course of the event, the results and the thoroughly positive response.

"We were a little nervous when the first presentation of the DVS CONGRESS was held online, but we were well prepared, so that everything worked out very well," says Simone Weinreich, organiser of the event and head of the "Transfer & Network" department at DVS. Within just two months, DVS, together with its associated company DVS Media GmbH, had planned and carried out the annual congress online for the first time. The fact that this led to such a successful result is also due to the speakers of the technical lectures. Weinreich explains: "Without the large number of presentations, the DVS CONGRESS could not have taken place in this form. Special thanks therefore go to all those who prepared their presentation and answered the questions during the event in a live broadcast."

Amelie Felde, B. A., Digital Media Division at DVS Media, agrees: "The speakers recorded their presentations in just a few weeks, usually with video recording, and then joined in live to answer the questions of the platform visitors. The cooperation with them and also with the presenters and our technical support was excellent." Felde, who together with two colleagues was responsible for the technical implementation and support of the DVS CONGRESS, sees the format as a solution that could be a trend-setter for further DVS online events.

In addition to the lectures and the chat function, a discussion forum and the possibility of networking were also available online as part of the DVS CONGRESS.

The next DVS CONGRESS is planned from 14 to 17 September 2021 in connection with the international "SCHWEISSEN & SCHNEIDEN" trade fair.

Prof. Dr.-Ing. Ulrich Dilthey Obituary

Prof. Dr.-Ing. Ulrich Dilthey died on 14 August 2020 at the age of 79.

DVS mourns the death of Prof. Dr.-Ing. Ulrich Dilthey, Aachen, who died on 14 August 2020 at the age of 79. The long-standing head of the Welding and Joining Institute at the RWTH Aachen University has gained an excellent reputation in the expert world through numerous scientific publications as well as through lectures at national and international conferences. For decades, he was involved in the DVS District Branch Aachen, of which he was Honorary Chairman since 2019, and in the DVS North Rhine Federal State Branch. From 1998 to 2009 he was chairman of the DVS Technical Committee and thus a member of the DVS Presidium and Board of Directors.

With great commitment, he was involved in the committees of the International Institute of Welding (IIW) for joint work in joining technology. From 2008 to 2011, he was President of the IIW. A member of DVS since 1969, he was awarded the DVS Ring of Honour in 1996 for his extraordinary services to joint welding technology work and DVS, and in 2011 he received the DVS Plaque, the highest distinction awarded by DVS.

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The Welding Institute

NEWS

October – December 2020

THE NEWSLETTER OF THE WELDING INSTITUTE

Editorial

Q&A with Outgoing Younger Members' Committee Chair, Matthew Haslett

The Welding Institute's Younger Members' Committee (YMC) works to engage young professional engineers to encourage and assist their professional and career development. In addition, the Committee also provides science, technology, engineering, and mathematics (STEM) outreach activities around the UK to promote these subjects to school children and students of different ages.

Matthew Haslett MWeldI served as the chair of the Committee from 2013 until he stepped down in October 2020. It seemed like this was the perfect opportunity to ask Matt about his work over this time and how he has seen the Committee grow and encourage others.

Firstly, why did you decide to chair the Younger Members' Committee?
I have always had a strong interest in both promoting STEM subjects to children and young people, and supporting those in the early stages of their careers. The Chair position of the YMC was the perfect opportunity for me to shape and direct the way that the Institute delivers these activities.

What do you think the Committee provides to young engineers who are just embarking on their career paths?
The Committee provides support to young engineers directly from their peers, other engineers and scientists who have had similar experiences and can give help and advice from a first-hand perspective. I think that being able to get support from someone of a similar age and academic/work background makes it more meaningful and useful.

Of course, a lot of the work of the Committee is about encouraging children and students to look at STEM subjects – why do you think this is important?
Education outreach, in my opinion, is the most important activity of the professional engineering institutions. Children and young people need to know about the fascinating and varied careers that are available to them in STEM, and hearing and seeing those working in these areas, through school workshops, careers talks, etc, allows them to visualise what it might be like to work in this area. We need the brightest minds to take up STEM careers, and introducing children to the possibilities at an early stage of their education is vital, to allow them to make informed decisions on careers further down the line. My own interest in engineering came from local engineers visiting my school and running a STEM club, and I like to think that I am now 'giving something back' to the profession by promoting it to the next generation.

Do you have any notable, or amusing, highlights from your time as chair?
The thing that gives me a warm feeling is when I think back to the countless 'Welding with Chocolate' workshops that I have run, and the eagerness and enthusiasm of the kids participating. They really do put in a lot of effort welding up and testing the little bridges, and probably don't realise at the time, the amount of engineering theory that they have learned!

One amusing thing that occurred during one of these workshops was after one girl, during Q&A at the end, put up her hand and stated, 'I like chocolate'. This ended up with most of the rest of the class putting up their hands to state the same phrase, slightly derailing the Q&A process, and providing much hilarity to both teachers and volunteers!

What does the future hold for the Committee?
I am pleased to say that we have found the ideal candidate to take over the YMC Chair in Catherine Leahy. Catherine is enthusiastic, driven and motivated, both in her work and her passion for supporting young people, and will bring a new perspective to the role. I am looking forward to keeping some involvement on the outreach side and supporting Catherine as she continues to drive the Institute's commitment to the younger generation.

The Welding Institute would like to thank Matt for his enthusiasm, time, and effort as Chair of the Younger Members' Committee and the contribution he has given to the outreach programme over the past seven years.

Benefits of Membership for Training and Examination

The Welding Institute is a professional engineering institution with over 6,000 members.

Its main responsibility involves assessing candidates for the globally recognised registration qualifications of:

- Engineering Technician (EngTech)
- Incorporated Engineering (IEng)
- Chartered Engineer (CEng)

What else does membership offer for me?
Regardless of whether you want to gain professional registration with the Engineering Council, membership of The Welding Institute offers membership benefits to suit you:

Through completing Training and Examination courses you are already contributing to your professional development including your CPD. Membership with The Welding Institute allows you to display your professional accomplishments for employers and clients to see!

Already a Member of another Professional Engineering Institution?
Email our membership team who can advise you on the best route to becoming a Member of The Welding Institute!

Join Now!

New Professional Members (6 Aug – 5 Oct 2020)

Name	Member Grade	EngC Registration	Prev. Member Grade
SKYRME, Michael	FWeldI	CEng	SenMWeldI CEng
MWEEMBA, Martin	SenMWeldI	CEng	SenMWeldI
DHANABAL, Bharanidharan	MWeldI	CEng	
RADCLIFFE, Kevin	MWeldI	CEng	MWeldI IEng
AMSUPAN, Satanphop	MWeldI	CEng	MWeldI
CHRONOPOULOS, Konstantinos	MWeldI	IEng	AWeldI
PEIRIS, Saman Kumara	MWeldI		
DAVIES, Andrew John	MWeldI		AWeldI
CALLAGHAN, Mark	MWeldI		
BIN ABU HASAN Amirul	TechWeldI	EngTech	
BRIONES Randy	TechWeldI	EngTech	
CHHANA Kriveshin Dinesh	TechWeldI	EngTech	
DA COSTA GONCALVES Paulo Jorge	TechWeldI	EngTech	
GERAGHTY Simon Peter	TechWeldI	EngTech	
JI Xu (Michael)	TechWeldI	EngTech	
LUCAS Brian Robert	TechWeldI	EngTech	
NELSON Scott Ian	TechWeldI	EngTech	
WESTCOTT Hayley Vanessa	TechWeldI	EngTech	
CADER, Salman	TechWeldI	EngTech	0

Deceased members – October 2020

Name	Grade	Joined	Branch
Richard Raymond Roberts	FWeldI	1947	West Midlands
Robert Sandham	MWeldI CEng	1999	Highlands and Islands
Derek Patten	MWeldI IEng	1979	Eastern Counties
Peter Houldcroft	FWeldI	1954	Eastern Counties

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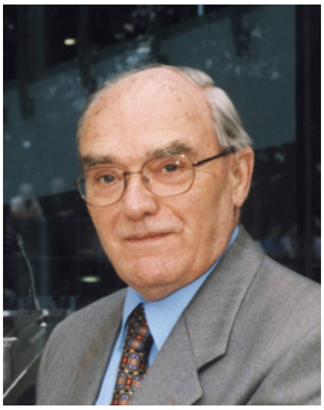
Peter Thomas Houldcroft – 1923-2020



It is with sadness that we announce the passing of Peter Thomas Houldcroft, a former Director of Research for TWI. He passed away peacefully, aged 97, on 3 August 2020, with his family rightfully announcing that "he was much loved and will be hugely missed."

As a metallurgist, Peter began his career with the aluminium producer James Booth before moving to join the research arm of The Institute of Welding, the British Welding Research Association (BWRA). He worked from the London Park Crescent office, which was where the BWRA's metallurgical research was undertaken, and worked on the welding of Al alloys. His early work focused on TIG welding behaviour before he began to research the joint properties of the newly-invented MIG welding process, which had been imported from the USA. As MIG welding became the worldwide process of choice for welding thicker Al alloys, Peter was a team member of the first UK-based demonstration project of an all-welded Al superstructure for a Thames launch.

It was around the same time that Peter developed the Fishbone test to quantify the cracking resistance of welded Mg alloys for aircraft fuel tanks and nuclear fuel canisters. He was then was at the forefront of a BWRA team developing weldable high strength Al alloys for military bridging and aircraft undercarriages.

BWRA's Engineering Department had been based at Abington near Cambridge since 1946 and, in 1956, the London-based Metallurgy Group was moved to the same location. Peter moved with the group and went on to propose that welding research activities should be separated from metallurgy and engineering research, leading to the creation of a new Welding Technology Group, which Peter headed up. By 1964, Peter had taken over from Alan Wells as Director of Research after Alan left for the Queens University of Belfast.

It was during the early 1960s that Peter developed what was possibly his greatest contribution to engineering with the creation of what would later become a multi-billion pound industry. The BWRA was working with the British Navy and the Services Electronic Research Laboratory (SERL) on the development of laser welding. Peter used his expertise in metal cutting to propose the use of coaxially delivered oxygen for the laser cutting of metals. Despite being refused a patent application by the German examining body of the time, the idea and ensuing research eventually went on to create the worldwide laser cutting industry.

This ground-breaking research was not Peter's only breakthrough at BWRA, as he also directed the build of the world's first 2kW fast axial flow CO_2 laser. This was the beginning of a new era concerned with the development of high power gas lasers for welding and cutting of metals, which was rapidly pursued worldwide.

His contributions to laser technology led to Peter being awarded the first ever UK Association of Industrial Laser Users' medal in 1997, some eleven years after his retirement. Speaking at the time, Peter announced, "It has been 30 years since I invented gas assisted laser cutting at TWI and 11 years since I retired, so I quite expected that the event would have been forgotten."

Of course, Peter's expertise in laser processes could not be easily forgotten as he remained an expert in laser welding technology and in Al alloys until he retired from TWI (as the BWRA became) in 1986.

However, his influence over the continuing work of TWI can be felt today as Peter set up the first integrated Research Board in 1966 after all of the previous Research Committees were disbanded. This programme continues to work with many of the leading names in industry to guide the direction of TWI's Core Research Programme. As part of his work with the Research Board, Peter won a succession of government grants to support a large programme of basic and applied research. Many TWI developments, which had worldwide impact, originated from this pioneering programme.

Outside of his work for TWI, Peter gave his time and support to the Institution of Metallurgists, becoming President in 1981 and then being elected to the Royal Academy of Engineering in 1985. He also authored many papers and books on welding technology, including 'Which Process?' and 'Welding and Cutting - a Guide to Fusion Welding and Associated Cutting Processes', which was co-authored with Bob John.

Following retirement, Peter wrote a 50 year history of the BWRA/TWI, which was published in 1996. The excellent book provides a detailed record of the early years of the BWRA, its staff and the formation and subsequent growth of TWI into an internationally recognised centre of excellence in joining and associated technologies.

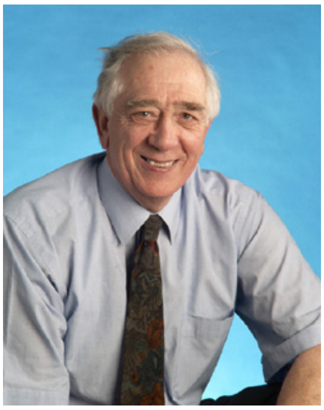
For all of his many achievements, it is perhaps the tributes paid by those who worked alongside him that demonstrate the calibre of Peter Houldcroft as a person.

Richard Dolby, himself a former TWI Director of Research and Technology, said, "In all my dealings with Peter Houldcroft, he was always polite and kind, an inherently modest man and a mentor and role model to me for many years. Looking back, we had almost identical career paths and we were both fortunate to be able to contribute to an expanding and successful engineering organisation, which was internationally recognised as a centre of excellence. Peter's contribution to laser technology worldwide has been well documented and is a wonderful legacy coming from a long and successful career."

A former colleague of Peter's from TWI, Steve Jones, revealed, "Peter was the first person I met at TWI when I arrived for interview in early 1971. He struck me as a man with wide interests - in addition to a technical discussion we spent a fair amount of time talking about Stonehenge!" He continued, "Peter's technical contributions were correspondingly wide-ranging, including working with Arthur Smith and George Salter on the development of CO_2 welding and the first development of laser cutting. I remember Peter as a supportive manager, concerned with staff welfare as well as technical excellence," adding, "In retirement he took a great interest in the history of Royston cave, publishing an analysis of its original internal structure and possible use by the Templars."

Peter Houldcroft not only impacted engineering and the work of TWI with his many years of service, but also had a profound effect on all those who met him and will be greatly missed.

Remembering Derek Patten



It is with deep regret that we have to inform you of the passing of Derek Patten, who died on the weekend of 5-6 September 2020, aged 80.

Derek and his family had a long association with TWI and The Welding Institute, having even once lived together in a cottage on the site of TWI at Abington near Cambridge. Having provided 50 years of faithful service to TWI between 1955 and 2005, he was the Supervisor of the Arc Welding Laboratory at the time of his retirement.

Of course, given his many years of loyal service to TWI, Derek was involved in a great number of innovative and important projects. One notable example came when The Flying Scotsman locomotive was undergoing refurbishment for its 75th birthday in 1998. TWI was contacted to help solve problems of wear on the boiler and it was found that there was erosion as well as pressure changes within the boiler, which was causing flexing, leading to small cracks and thinning of the wall material. Derek was heavily involved in the project as worn material was ground away before the boiler was restored to its original dimensions through the use of manual metal arc welding. Electron beam welding was also used during the repairs, making The Flying Scotsman the first steam locomotive to include an EB-welded component anywhere in the world!

When Derek wasn't helping push engineering innovations at work, he was actively involved in his local village of Abington, alongside his wife, Ros. In fact, Derek was even able to use his engineering skills to help the community when, in 1997, the Parish Council decided to build a new footbridge to celebrate the turn of the Millennium. TWI was contacted and Derek was among those who helped with the construction of the bridge, which was installed in the November of that year. This was no mean feat, since there was no vehicular access to the site, and there is a plaque on the bridge to commemorate the opening and thereby, the hard work put in by Derek and his colleagues from TWI.

Hugely respected by his peers and much loved by family and friends, Derek is a great loss to The Welding Institute. We are just proud that his many achievements continue to have an impact to this day.

UK’s First Stainless Steel Road Bridge Built in Lake District

The UK’s first stainless steel road bridge is being constructed in Cumbria to replace an original three-span 18th century structure that collapsed when Storm Desmond hit the area in 2015. The innovative new Pooley Bridge, which is composed of a mixture of steel and concrete, is being built over the River Eamont at the end of Ullswater Lake after the original bridge, built in 1764, collapsed due to the force of water from the storm.

The £5 million three-level composite structure was due to be opened in Summer 2020, but that original date was delayed with the bridge now due to open in October 2020 (at the time of writing). However, the bridge needed to meet three important factors within the design; flood resilience, compliance with Environment Agency regulations, and meeting the wishes of local residents.

Because the bridge is sited in an Area of Outstanding Natural Beauty it was important that the design did not alter the site or impact the local scenery. The project began in January this year, as the first sections of steelwork arrived, having been fabricated 190km away in Darwen, Lancashire.

The steel elements of the structure were transported to the site in two parts before being joined together and lowered into place by a crane. The next stage was to pump concrete into the formwork or the arch to support the deck, while a temporary tie bar across the bottom chord held the ends until the loads were fully transferred into the abutments.

The new bridge has at least one important difference to the original bridge in that it is single span, where the 18th century version was supported by three piers in the river. These piers were swept away as scour and erosion from the force of the water from Storm Desmond undermined the structure. This design change means that the new 40 m single-span bridge doesn’t need to undergo the same biennial checks.

The deck itself is made from a slender concrete slab, measuring 250mm in depth and between 7.5 and 9.5 metres wide. This deck fits onto a duplex stainless steel plate which is then supported by a concrete arch.

The design is intended to last at least 120 years, meaning that post-tensioning was disregarded as an option over concerns about durability. Pre-stressed bridges have had problems in the past due to corrosion and this new structure will avoid these potential difficulties.

The construction was further complicated by the quality of the ground on either bank. Due to the banks being a variable glacial till, the project could not use piled abutments to hold the span in place. Instead, steel framed backspans have been used to transfer loads from the arch and deck directly into concrete slabs that have been cast on either side of the river.

However, it is the stainless steel that is perhaps most note-worthy. Despite being two and a half times more expensive when compared to ordinary steel, its light weight and durability offers a number of advantages. This includes ease of construction as a temporary pier was not required to support the bridge, which also reduced costs.

The environmental conditions also posed a few challenges, including dealing with high winds and mixing concrete in cold weather where the water it is mixed with could freeze, expanding and damaging the concrete as it sets. Other environmental factors included how the use of steel minimised the need for concrete and reduced the carbon footprint of the new bridge.

For all of the challenges posed by the innovative construction, the local response has been positive, with brewers in the town even producing a beer to celebrate the new structure!

International Institute of Welding holds successful virtual Welded Art Exhibition

The International Institute of Welding (IIW) reacted to the COVID-19 pandemic by moving their 'Welded Art Photographic Exhibition' to a virtual, online format. The exhibition ran from 15-25 July, 2020, to highlight some amazing feats of welding art.

Welded art, like all art, can provide great benefits to improve mental health as a hobby or simply as something to enjoy as an art-lover. It is also a wonderful tool to improve the image of welding as well as providing an income for those with the appropriate artistic skills.

This year's exhibition included work from the young artist, Thomas Huisman from Australia who, now aged just 9, began welding a year ago.

The final booklet containing the digital collection has been made available online for you to view and the IIW are also now seeking feedback and ideas for new categories ahead of next year's exhibition.

The booklet is available to view at this link (https://iiw2020.online/wp-content/uploads/2020/07/WELDEDARTEXHIBITION-DEF.pdf) and you can find out more information on the proposed new categories from page 56 onwards.

Anyone with feedback or ideas for the IIW is invited to email Chris Smallbone at allbones@iinet.net.au.

Technical Group Meeting: Welding in the Railway Industry Sectors

The Welding Institute held a Structures and Infrastructure Technical Group Meeting at The Derby Conference Centre about 'Welding in the Railway Industry Sectors.'

The meeting took place just before lockdown, on 10 March 2020, and was well-attended with around 60 people present at the venue for the series of talks that began at 10am.

Eur Ing Alan Denney CEng FWeldI KD Materials Consulting Ltd, opened the event before Robert Sawdon, the director of RW Sawdon Engineers Ltd, gave a talk on rail welding.

Peter Roberts, the managing director of Collis Engineering Ltd, followed with a discussion of the challenges of joint design before a short coffee break.

The morning session continued with David Gaulthier, who works in business development for NobelClad, delivering an interesting talk on welding aluminium to steel in car body design, including innovative solutions with transition joints.

Jeff Garner, a consulting welding engineer with Manor Welding Technology, spoke next before a well-earned break for lunch during which there was plenty of opportunities to network and share ideas.

Lunch was followed by a talk on the welding of power transfer equipment courtesy of Stephen Norrish before John Hempshall, a senior engineer of rail welding at Network Rail, offered his own insights and information to the attendees.

A tea break was then followed by a discussion of standards with lead assessor Bill Mosely, who gave an introduction to BS EN 15085 as well as a comparison with ISO 3834. Over tea, some delegates recalled previous training sessions at the same venue, which was formerly a Midland Railway Training School which still retains many of its original 1930s architectural features. A very appropriate venue for this event!

Alan Denney returned to bring the informative meeting to a close and we sincerely hope it isn't too long until we can return to these interesting events in-person once more.

https://thederbyconferencecentre.com/conferences/

73rd IIW Annual Assembly: Virtual conferencing revolutionises tradition for the international welding community

The virtual conference centre for the 73rd IIW Annual Assembly.

Designing the concept

After the worldwide pandemic outbreak in February 2020, the International Institute of Welding (IIW; iiwelding.org) took the difficult decision to cancel the Annual Assembly originally planned in Singapore and instead develop the concept of an on-line Annual Assembly, to be held around the same dates of 15 to 22 July. This would be a major undertaking as the Assembly involves over 25 IIW Working Units (WUs) meeting simultaneously with a targeted participation of over 500 experts located around the world.

The IIW, supported by a professional event organiser, developed the concept of a virtual conference centre which would ensure participation experiences as close as possible to a face-to-face Assembly. This enabled the progression of all IIW activities as well as social engagement, while ensuring the safety of members participating remotely from their own homes or offices.

The concept included the following points:

- All the meetings were held between 13:00 and 16:00 CEST, to best accommodate participants' home time zones.
- Up to 10 session were offered from Monday to Saturday, allowing participants to virtually jump from one session to another and participate in different WUs.
- Opening and closing speeches as well as the IIW Awards Ceremony were available on-demand to all participants.
- Virtual booths were created for sponsors, including pre-recorded videos and presentations of products, displays of products and a live chat feature to facilitate their interact with the audience.
- A Welded Art Exhibition was included, displaying welding from around the world and explaining the artists' perspective.
- Special group registration enabled multiple participants from the same organisation at a discounted rate.

The on-line Annual Assembly project was developed over a period of three months by the new IIW Secretariat which commenced in 2020, led by Dr Luca Costa and managed by IIS, the Italian Institute of Welding. The event was supported by the following sponsors:

- Kiswel,
- Fronius International GmbH,
- Cavitar,
- Panasonic.

Registration started on 1 June and the virtual conference centre was opened for meetings on 8 July 2020.

Figures of a great success

During his opening speech at the 73rd IIW Annual Assembly, the IIW President Mr Douglas Luciani said that "Any organisation must be fluid and flexible to adjust to circumstances, and there is no better example than what we're currently dealing with under the Covid-19 pandemic". Referring to the on-line platform, he commented "This environment, although unique, I'm sure will provide us the opportunity to interact and further enhance the global welding and joining industry".

All agreed that the virtual on-line IIW Annual Assembly was a great success with the number of participants exceeding the target audience and no reduction in significant and prolific technical outputs, and:

Discussions during the on-line meeting of the IIW General Assembly.

A page of the welded art exhibition catalogue: The welded art 'Mouse' was made of metal waste, sheet material and pipes.

Mr Douglas Luciani, IIW President 2017-2020, during his inaugural speech.

- 39 countries represented
- 50 sessions of different WUs
- 150 hours of meetings in 48 sessions
- 240 scientific papers, standards and IIW position papers, best practice documents and guidelines presented, discussed and developed
- 37-180 participants in each session.

As usual, participants were grouped in delegations managed by the IIW Members, the national welding organisations from 50 countries, with 38 Members represented at the 73rd IIW Annual Assembly. The largest delegations came from Germany (101 participants), Japan (94), China (72), USA (60) and Italy (30).

Recognising excellence

During the Assembly the announcement of the 2020 IIW Prizes and Awards recognised individuals for their outstanding contributions to welding, joining and allied processes and their support for the work of the organisation:

- Walter Edström Medal, awarded to Dr Ernest Levert,
- Fellow of IIW, awarded to Prof. Yoshinori Hirata, Dr Eric M. Sjerve and Prof. Adolf F. Hobbacher,
- Arthur Smith Award, awarded to Dr Glenn Ziegenfuss,
- Chris Smallbone Award, awarded to Dr Jim Guild,
- Thomas Medal, awarded to Dr Vincent Van Der Mee,
- Yoshiaki Arata Award, awarded to Dr Stephen Liu,
- Halil Kaya Gedik Award, awarded to Prof. Zuheir Barsoum,
- Welding in the World Best Paper Award, awarded to Dr Alexis Chiocca,
- Henry Granjon Category B Award, awarded to Dr Klaus Schricker,
- Henry Granjon Category C Award, awarded to Dr Mohan Subramanian.

A booklet about the 2020 IIW Awards and the winners is available as a pdf file at: https://user-36910767433.cld.bz/IIW-Booklet-of-awards-2020.

Within the virtual Annual Assembly IIW also held the second IIW Welded Art Exhibition, with participation from 33 artists from all over the world. Special categories included "Emerging Joining Technologies", "Young Artists" and "Photography" and it is planned to expand these categories in future exhibitions. Participants ranged from world renowned artists and sculptors to hobbyists and part-time business owners. They included researchers experimenting with newer processes such as additive manufacturing, a photographer showing welding from the perspective of fine art and an up-and-coming nine year old representing the face of the next generation. A booklet presenting the artworks and artists can be viewed or downloaded here: https://iiw2020.online/wp-content/uploads/2020/07/WELDEDARTEXHIBITION-DEF.pdf

Changing IIW Presidency

In line with the IIW Constitution, Mr Douglas Luciani (Canada) ended his three-year term as IIW President with the closure of the Assembly, the position now being taken up by Mr David Landon (USA). In the absence of a physical ceremony, the handover was managed with recorded videos.

"When I look back over the last three years, it's extremely gratifying to see what we have accomplished together," said Luciani during his closing speech at the Assembly. He then highlighted some of these achievements, such as the new IIW Five-Year Strategic Plan and IIW Vision "To be the leading global community linking industry, research and education to the advancement of welding and joining for a safer and sustainable world". Also noted were the shifting of the Secretariat of the organisation to IIS in Italy after numerous years of great services delivered by the Institut de Soudure in France,


Mr David Landon, IIW President 2020-2023.

and the new five-year agreement with the European Welding Federation (EWF) for the global delivery of the IIW qualification and certification schemes.

"When future generations will look back into the history of the IIW, there's no doubt in my mind they will come back at your Presidency as being some of the most impactful through years of the IIW's history," commented Landon. He has worked for the last 28 years at Vermeer Corporation, a global manufacturer of industrial and agricultural equipment. Landon has been active in IIW since 1997 and served as a member of the IIW Board of Directors for the last four years. He is also an active member of the USA welding community, having been a member of the American Welding Society (AWS) Board of Directors and AWS President in 2015.

During his speech, he underlined that participating in IIW has provided a positive impact to his company both from a technical standpoint as well as the IIW qualification and certification products. His participation had facilitated Vermeer in finding team members and international partners and sharing in the development of welded products and technologies. He concluded "When I look at IIW and to the value proposition in participating to the IIW, I'm looking through the eyes of an end user of IIW products."

The venue for the 74th IIW Annual Assembly and International Conference in Genoa, Italy, on 20 to 25 July 2021.

The future of IIW events

With the current uncertainty associated with the Covid-19 pandemic, IIW is closely monitoring the situation in relation to the exciting calendar of IIW events planned in the following months. The experience with the virtual 73rd IIW Annual Assembly demonstrated the viability of on-line meeting technology and proved the strength and dedication of the IIW community, but also highlighted the importance of personal interactions as they were greatly missed during these unprecedented times.

The IIW is hoping to gather the welding, joining and associated processes community together again during 2021 at IIW International Congresses, Welding Research and Collaboration Colloquia and Associated Events held in cooperation with its partners, and in particular at the 74th IIW Annual Assembly and International Conference planned for Genoa, Italy on 20-25 June 2021. (According to press information from IIW)

Visitors from over 100 countries are expected to attend "wire" and "Tube" in December in Düsseldorf

From 7 to 11 December 2020 the two international trade fairs for the wire, cable and tube and pipe industries, "wire" and "Tube", will open their doors in Düsseldorf/Germany. The two leading trade fairs for these industries were originally planned for April, but then had to be postponed due to the Covid-19 pandemic. They will now be held in compliance with strict new hygiene and social distancing rules at a perfectly prepared Düsseldorf fairground.

2018 saw 71,500 trade visitors (69,000 in 2016) from 134 countries visit the exhibition halls on the Rhine river over five days to learn about innovations in their sectors and conclude business deals. For December the organisers expect stable numbers of visitors from Europe despite the tight situation in the global economy. So far, one third of visitors at both trade fairs came from Germany while two thirds were international visitors. This means that "wire" and "Tube" are among the most internationally attended trade fairs care of Messe Düsseldorf.

80% of international visitors expected to hail from Europe

80% of international visitors in December are expected to hail from Europe. Although strong producer and visitor countries such as Italy, France and Spain are seriously impacted by the consequences of the Corona crisis, these are the European countries – alongside the Netherlands, Spain, Poland, Russia, United Kingdom and Turkey – where most European trade visitors will come from to visit the two trade fairs. If the EU and national stimulus packages take effect in the European countries, then an economic recovery and increase in investment can be expected by the end of the year.

wire Düsseldorf
International Wire and Cable Trade Fair
Internationale Fachmesse Draht und Kabel

Tube Düsseldorf
International Tube and Pipe Trade Fair
Internationale Rohr-Fachmesse

Visitors to "wire" come from the wire and cable industries, the iron, steel and NF-metal industries, from automotive and construction, the chemical industry, trade and the services sector. At "wire 2020" they will be on the look-out for innovations, trends, new business partners and suppliers or seeking to deepen existing contacts. Visitors' main interests focus on machinery and equipment for wire manufacturing and finishing, as well as process technology tools, finished products, auxiliary materials, forming technology and fasteners and springs as well as wire mesh welding machinery.

At "Tube" most visitors are interested in the latest news from the fields of tubes, plant and machinery for pipe and tube processing (as well as for finishing and manufacturing pipes and tubes), raw materials, accessories, profiles and pipe and tube trading. Likewise, pipelines, OCTG (Oil Country Tubular Goods) technology and sawing as well as saw blade grinding machines meet with avid interest among visitors to "Tube 2020".

Messe Düsseldorf: Constanze Tillmann

For current information visit the Internet portals at: https://www.wire-tradefair.com/ and https://www.tube-tradefair.com/. (According to press information from Messe Düsseldorf; https://www.messe-duesseldorf.com/)

Mechanical plate edge bevelling – The key to high speed weld preparation and improved weld quality

Fig. 1

In heavy fabrication shops bevelling is one of the most critical production processes, which has historically not received its due importance. Invariably poor edge preparation is the first and the most basic cause of improper fit-ups which can lead to poor quality welds due to inaccurate 'V' joint preparations, which will result in excessive welding, higher heat input, and higher consumption of welding consumables (and extra welding man-hours). All these factors can contribute to lower productivity and have a bearing on the final weld quality.

The importance of accurate plate edge preparation can be well understood if one looks at some of the important segments in heavy fabrication, e.g. shipbuilding or fabrication of windmill tubular (WMT) towers.

The fabrication of wind mill tubular towers is comparatively not as complex as ship building, but it still must address the need of plate edge preparation of a large number of plates with consistent accuracy which goes into forming of shells for fabrication of a tower as high as 100 m or more. This application demands bevelling of at least 1,500 m in a day (three shifts) for a production level of a 'tower a day', **Fig. 1**.

Both the examples above give rise to the need to identify a fast, accurate, consistent and economical process of plate edge bevelling with a minimum or no heat input to facilitate good quality welds for carbon steels, high tensile steels, stainless steels, and also as importantly aluminium and other alloy steels.

Fig. 2

Selection of process

Selecting the most suitable process can be complex because there are many factors that must be considered. There may be a few options that could be suitable for an application; however, the final choice usually depends upon capability to economically produce the required quality bevels. Such factors may include:

- Type of material,
- Range of thickness of plates to be bevelled,
- Quality of cut required,
- Complexity of edge preparation,
- Accuracy of the cutting process,
- Number of plates/components to be prepared,
- Allowable distortion from the process.

The oxy-fuel cutting (bevelling) is the most common used process for cutting of carbon steel plates, **Fig. 2**. The equipment is low cost and can be used manually or can be mechanised.

The disadvantages of using this process could be low speeds, high thermal input, possible inaccuracies in the bevel angles (leading to excessive weld deposition), need of finishing the bevelled surface (based on the material and joint requirements). In addition, it entails significant cost of gases and other grinding consumables inclusive of inevitable wastages and manpower. If CNC oxyfuel cutting machines are used, the plates need to be fed to the machine and it entails the use of a crane, which is a time consuming and costly operation.

In contrast, Gullco International have a range of mechanical plate edge bevelling machines, which work on a rotary shear principle and are highly effective due to their portability and manoeuvrability with high speeds of bevelling ranging between 240 to 300 cm per minute, **Fig. 3.**

These bevellers can bevel 6 to 50 mm thick plates and can offer accurate and consistent "V", "K" or "X" bevel preparations. Various materials like carbon steels, alloyed steels, stainless steels, high tensile steels, and aluminium can be very successfully

Fig. 3

Fig. 4

bevelled using these machines, **Fig. 4.** Mechanical bevelling being a non-thermal process has an important metallurgical advantage of not creating a heat affected zone (HAZ) and not causing thermal distortion.

Some of the other distinct advantages of the mechanical bevelling are:

1. Noise-, pollution-, and vibration-free operation.
2. These machines can be easily brought to the job and are self-propelling types following the edge of the plate while bevelling without any help of operator.
3. Spring loaded carriage allows the machine to run on an undulating floor and negotiate the sag in the plate.
4. Easy and quick adjustment of the root face is possible.
5. Five standard bevel angles can be adjusted. Non-standard bevel angles within the min-max range are also available on request.
6. No special skills are needed to operate these machines and an operator can be trained to operate such machines in a relatively short period of time.
7. Top and bottom of the plates can be bevelled simultaneously by using two machines in tandem.

Upside down bevellers used simultaneously along with the standard bevellers can produce a double "V" preparation without turning the large plates, thereby saving on crane time, handling time and repeat process time compressing the total throughput cycle time and increasing the productivity at an optimised cost.

There is no doubt that all of these positive factors are making mechanical edge bevellers a preferred choice in the fabrication industry and are helping to deliver on the requirement of high quality edge preparation and thereby the overall final finished weld quality.

These features are also contributing to reducing the overall welding costs, and due to the simple operation of these machines reduce the need for skilled trades people to operate them.

(According to press information from Gullco International; www.gullco.com)

Refill friction stir spot welding parameter development for transport industry aluminium alloys (Technology Briefing)

Fig. 1 • RFSSW top surface.

Background

Refill friction stir spot welding (RFSSW) has several advantages compared with other mainstream single-point joining or mechanical fastening processes. Although many companies have acknowledged these advantages and benefits, further research is required to implement this technology into large-scale production and increase the current technology readiness level. This report describes the impartial gathering of baseline mechanical properties and microstructure characterisation of RFSSW welds on various transport aluminium alloys, intending to promote industrial uptake.

Objectives

- Determine the welding process window of different transport industry aluminium alloys.
- Assess the mechanical performance and characterise the microstructure of each weld condition.
- Quantify the effect of the presence of an interfacial sealant on the mechanical strength and microstructural properties of RFSSW.
- Provide a benchmark of the RFSSW properties on various transport industry aluminium alloys.

Fundamentals of the process

Refill friction stir spot welding (RFSSW) or friction spot welding (FSpW) is a relatively new variant of the friction stir spot welding process, which was patented by Schilling and dos Santos (2004). Using the same rotating tool elements as other friction stir processes, designated as shoulder and probe, the major improvement to this variant is their independent vertical movement which allows refill of the exit hole with the material displaced by the tool. The addition of an external static clamping ring enables the production of flush surface welds, as shown in **Fig. 1**, by preventing material losses in the form of flash.

The RFSSW process occurs over four stages in one continuous process as shown in **Fig. 2**. The welding cycle begins with the movement of the tool components to the surface of the top sheet to clamp the overlapped sheets. The rotating components remain at this stage for a set period to produce the initial frictional pre-heating. Stage 2, the plunging stage, initiates with the shoulder and probe moving in the opposite vertical direction to each other. Depending on the plunging tool component, the RFSSW process can be designated in one of two variants, shoulder-plunge or probe-plunge. The plunging component travels into the base material to a pre-defined depth while the retracting component moves to a pre-defined height, maintaining volume equilibrium to accommodate the displaced material. The contact between the plunging component and the base material leads to further heat generation and material softening via friction coupling. Once the plunging component reaches the pre-defined depth, the plunging and retracting components offset their positions and return to the top sheet surface, refilling the weld region with the displaced material. The extraction of the tool from the base material and unclamping the welded sheets concludes the welding cycle.

Approach

A full-factorial design of experiments (FFDoE), varying the rotation speed and plunge depth, was used to determine the

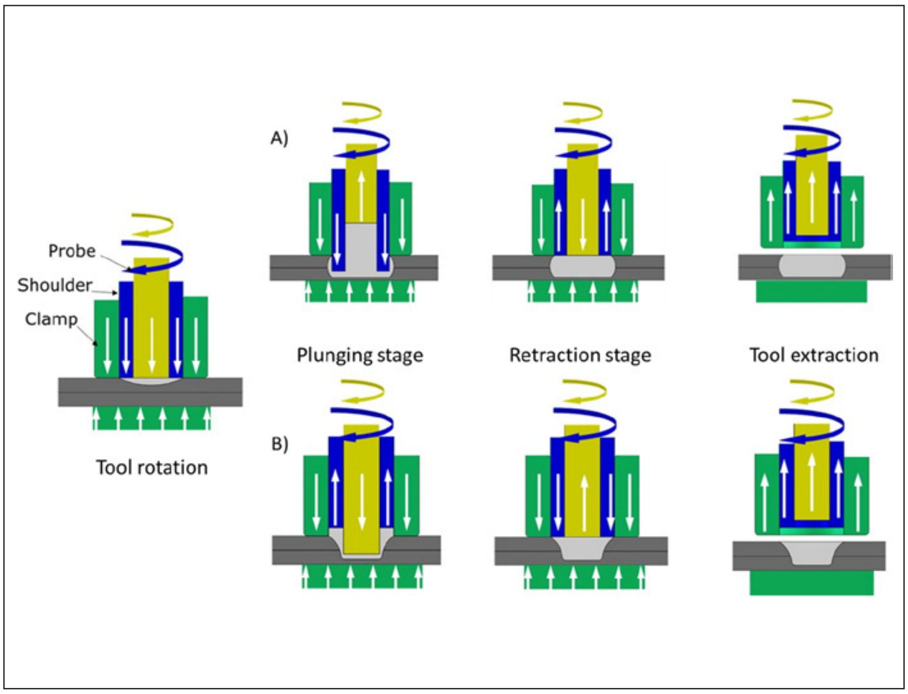


Fig. 2 • Schematic drawing of the RFSSW process (TWI, 2018): A) Shoulder-plunge variant, B) Probe-plunge variant.

RFSSW weldability range. Emphasis was placed on cross-section integrity and static mechanical properties to determine the strongest process parameter combination for various transport aluminium alloys. The fatigue life was determined, and the influence of interfacial sealant was evaluated using the strongest process parameter combination. Fracture surfaces and failure modes were investigated and described using scanning electron microscopy (SEM).

Results and discussion

Within the process parameter window explored, the welding process window was determined by either equipment limitation or process boundary. All the process parameter combinations used in this investigation surpassed the strength requirements for resistance spot welding (AWS D17.2/D17.2M:2019), one of the competing single-point joining processes. In the bare condition, the strongest process parameters for the aerospace alloys used in this investigation achieved a static strength of around 95% of the strength requirements of an equivalent sized aluminium rivet. In the presence of an interfacial aerospace sealant, an increase of around 50% of the static strength of the bare condition was observed, a novel and encouraging result for the aerospace industry sector. The fatigue life was determined for all alloys, in the bare condition and with interfacial sealant. S-N curves were plotted with a fitting coefficient higher than 95%. Specimen failure occurred before the first million cycles for the specimens in the bare condition, because stress concentration from out-of-plane bending promoted crack development at the hook. In the presence of an interfacial sealant, fatigue life improved by a factor ranging from 2 to 10 times the values obtained for the bare condition, which is believed to be due to minimised weld nugget rotation during welding.

Main conclusions

1. All the process parameter combinations used in this investigation surpassed the strength requirements for resistance spot welding, one of the competing single-point joining processes.
2. Under lap shear conditions, average strength values showed small scatter and consistent failure modes within the same parameter combination. Low rotation speed and high plunge depth values improved the mechanical performance on all alloys tested in this investigation.
3. Similar failure loads under cross tension conditions were obtained across all alloys. This was attributed to the increased stress concentration at the hook tip from this testing method, leading to early failure of the specimen.
4. Fatigue test results were used to establish an equation for the S-N curve. Acceptable fitting coefficients were found for each test condition. Failure before the first million cycles was observed for the specimens in the bare condition.
5. The presence of an interfacial sealant improved the static and fatigue strength of the alloys tested, without compromising weld integrity.

Recommendations

- Based on the results reported in the literature, the choice of interfacial sealant must consider the requirements of the application as well as the characteristics of the joining method. An incorrect choice can have a detrimental impact on the mechanical performance of the joint.
- Users wishing to assess the technology for other materials or thicknesses should be aware that results cannot be transferred directly; additional investigation to identify the optimum process is likely to be required quality.

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INFO

The full report is available to TWI members from: https://www.twi-global.com/what-we-do/research-and-technology/research-reports/industrial-member-reports/refill-friction-stir-spot-welding-of-aluminium-1137-2020

This work was supported by the Industrial Members of TWI as part of the Core Research Programme (CRP). More information about the CRP can be found at: https://www.twi-global.com/what-we-do/research-and-innovation/core-research-programme/

Multi Material Jetting – Additive manufacturing of multi-functional parts

Fig. 1 • System for Multi Material Jetting of high-performance components with combined properties or functions. (All pictures Fraunhofer IKTS)

Additive manufacturing is currently one of the most significant trends in industry. A team from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany has now developed a Multi Material Jetting system that allows different materials to be combined into a single additively manufactured part. This makes it possible to create products with combined properties or functions. The new system can be used with particularly high-performance materials such as ceramics and metal.

Additive manufacturing of multi-material parts

Additive manufacturing technologies such as 3D printing involve building up a desired product layer by layer instead of producing it from a single piece. This enables high-precision custom manufacturing with precisely defined product characteristics – and the technology is continuously being improved. Although the early years of additive manufacturing were dominated by polymers, this expanded some time ago to include metals and ceramic-based materials.

Fraunhofer IKTS has now taken another major step forward. Researchers have developed a system that enables additive manufacturing of multi-material parts based on thermoplastic binder systems. Known as Multi Material Jetting, or MMJ, this process combines different materials and their various different properties into a single product, **Fig. 1.** “Right now, we can process up to four different materials at a time,” says Uwe Scheithauer, a researcher at Fraunhofer IKTS. This opens the door to a diverse range of applications, allowing companies to produce highly integrated multi-functional components with individually defined properties.

Manufacturing products drop by drop

The new system manufactures parts in a continuous process. In the first step, the ceramic or metal powder from which the part will be made is distributed homogenously in a thermoplastic binder substance. The slurries produced this way are loaded into micro-dosing systems (MDS) in order to commence the actual manufacturing process, **Fig. 2**. These slurries are melted in the MDS at a temperature of around 100 degrees Celsius, creating a substance that can be released in very small droplets. The IKTS researchers also developed a corresponding software program to ensure precise positioning of the droplets during manufacturing. The micro-dosing systems operate in a high-precision, computer-controlled process, depositing the droplets one by one in exactly the right spot. This gradually builds up the part drop by drop at rates of up to 60 mm and 1,000 drops a second, **Fig. 3**. The system works with droplet sizes of between 300 and 1000 µm, creating deposited layers with heights of between 100 and 200 µm. The maximum size of parts that can currently be manufactured is 20 cm × 20 cm × 18 cm. “The critical factor here is the custom dosing of the metal or ceramic slurries. Getting the dosing right is key to ensuring that the additively manufactured final product takes on the required properties and functions during subsequent sintering in the furnace, including properties such as strength, thermal conductivity and electrical conductivity,” says Scheithauer.

Ceramic satellite engine with built-in ignition

The new IKTS system can be used to make highly complex parts such as the ignition system in a satellite propulsion engine made of ceramics. Satellite engine combustion chambers reach extremely high temperatures, so the ability of ceramics to withstand heat makes them an ideal choice of material. MMJ can be used to produce an ignition system that is directly integrated within the engine. This ignition system combines electrically conductive and insulating areas in a single, extremely robust component. In this case, the MMJ process requires three dosing systems: one for a support material that disintegrates during heat treatment in the furnace, a second for the electrically conductive component, and a third for the electrically insulating component. MMJ also has plenty of conceivable applications in the consumer products market – for example, a two-tone ceramic watch bezel made for an individual customer as a one-off item.

Thanks to its high precision and flexibility, the MMJ system is suitable for more than just manufacturing multi-functional components. “We could also use it to

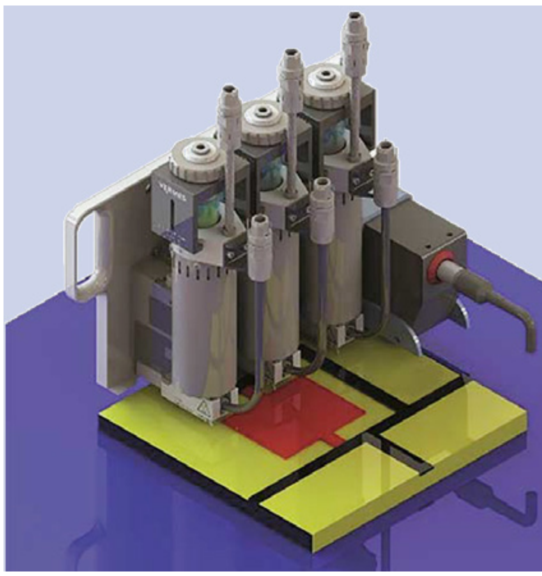


Fig. 2 • Schematic illustration of the micro-dosing systems.

make blanks for carbide parts, for example. Thanks to the tremendous precision of the dosing systems, the contours of the blanks would already be very close to those of the end product. They would therefore require very little subsequent grinding as compared to conventional methods. That is a big advantage when you are working with carbide," says Scheithauer.

Validation and commercialisation

The project at Fraunhofer IKTS has demonstrated that the technology also works in practice and is scalable. The next step is to validate the technology for industrial use. As well as supplying the hardware, Fraunhofer IKTS can also help industry customers develop the materials and software required for process monitoring and automation. Customers can therefore get everything from a single source, all tailored to their specific requirements.

(According to press information from Fraunhofer IKTS)

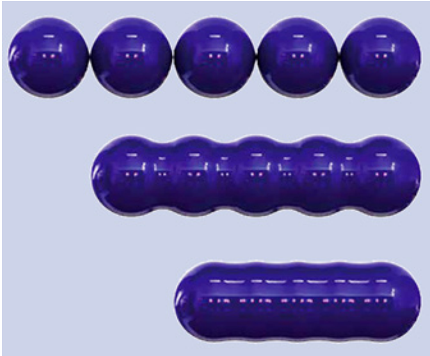


Fig. 3 • High-precision material deposition at a rate of up to 1,000 drops a second.

Influence of nitrogen in process atmospheres on the corrosion and fatigue behaviour of brazed stainless steel joints

Stainless steel components, such as heat exchangers for energy and air-conditioning technologies are commonly manufactured using nickel-based brazing fillers in vacuum furnaces or continuous furnaces. In vacuum furnaces, nitrogen is commonly used as cooling gas. In continuous furnaces, nitrogen interacts with the parts during the entire brazing process. The arising nitrogen enrichment of the braze metal and the base material can influence the corrosion behaviour as well as the fatigue behaviour of the brazed joints. Therefore, the corrosion and the fatigue behaviour of the joints were investigated with regard to the process conditions. The amount of nitrogen in the braze metal as well as in the base material was determined using the carrier gas hot extraction technique. The braze metal is more enriched with nitrogen in comparison to the base material. The corrosion measurements were carried out on the braze metal and the base material using a capillary microcell. It was determined that the joints brazed in process gas are more susceptible to corrosion attack in comparison to vacuum brazed joints. A corrosive aging was carried out in the exhaust gas condensate K1.2 at 70°C for 15 h. All joints exhibit a monotonic tensile shear strength of 185 MPa. Fatigue tests were carried out at ambient temperature on a resonance pulsator up to a number of cycles of $N = 2 \times 10^6$ used to define the endurance limit. Before and after corrosive aging, the vacuum brazed joints reached the defined maximum number of cycles at a stress amplitude of 25 MPa. The corrosion attack did not influence the fatigue behaviour of the vacuum brazed joints. In contrast, after corrosive aging, the endurance limit decreased for the joints brazed in process gas. The joints reached only 1.3×10^6 cycles at a stress amplitude of 25 MPa.

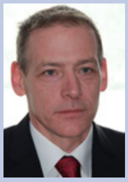
THE AUTHORS

Dipl.Ing. Vasilii Fedorov, born in 1989, is a research assistant at the Professorship for Composites and Material Compounds at Chemnitz University of Technology, Germany. He was concerned with tasks in the field of brazing as well as with the fatigue investigation of brazed mixed joints. In 2012 he defended his diploma thesis on "Characterization of the defect structure in TRIP steels using the combination of EBSD, ECCI and TEM" at the TU Bergakademie Freiberg. During his studies in Russia and at the TU Bergakademie Freiberg, he acquired extensive knowledge in the field of materials science with a focus on metal physics and materials analysis.

Dr.-Ing. Thomas Uhlig, born in 1985, is a research assistant at the Chair of Composite Materials at Chemnitz University of Technology, Germany. He works on innovative alloy concepts for brazing and coating materials. He defended his diploma thesis on the topic: "Contribution to the characterization of the melting behaviour of Fe-V-Nb-C alloys" in 2012. Already during his mechanical engineering studies with a focus on manufacturing technology and machine tool design he investigated the machinability of wear protection coatings.

Prof. Dr.-Ing. Guntram Wagner studied general mechanical engineering at the Technical University of Kaiserslautern, Germany and received his doctorate in 1996 on ultrasonic welding of glass/glass composites and glass/metal composites. From 1997 to 2014, he was head of the Joining and Ultrasonic Technology Research Department at the Department of Materials Science at Kaiserslautern Technical University, most recently as Academic Senior Councillor. In 2014 he was appointed to the Technical University of Chemnitz. His current research areas are composite materials, brazing, low-temperature joining processes and fatigue of composite materials and material composites. Furthermore, the professorship is equipped with extensive modern methods for sample preparation and analysis.

Dipl.-Chem. André Langohr, born in 1963 in Dortmund, studied chemistry at the University of Dortmund, Germany. After graduating, he continued working there in the field of physical chemistry for several years. Since 2005 he has been a research assistant at the Institute for Materials Science at Leibniz University Hannover. His main focus of activity is the development of brazing alloys, taking into account physicochemical modelling and materialographic analysis.



Dr. rer. nat. Ulrich Holländer, born in 1965, studied Chemistry at the Dortmund University of Technology in Dortmund, Germany. The subject of his doctorate was the investigation of the thermodynamic properties of liquid sodium/antimony alloys. Then, he worked as a Scientific Employee at the Professorship of Materials Technology (LWT) at the University of Dortmund and, since 2001, has been responsible for the management of the Specialist Group "Brazing and Thermal Process Engineering" in the IW-FORTIS Division at the Institute of Materials Science (IW) at the Leibniz University of Hanover/Germany.

Prof. Dr.-Ing. Hans Jürgen Maier, born in 1960, studied Materials Sciences in Erlangen, Germany and, in 1990, obtained his doctorate on the subject of the influence of ambient media on the fatigue behaviour of steels. Thereafter, he assumed responsibility for the management of the Electron Microscopy Working Group and moved to the University of Siegen as a Senior Engineer in 1993. After stations in the USA and at the University of Paderborn, he has been the Director of the Institute of Materials Science at the Leibniz University of Hanover since 2012.

1 Introduction

Brazing of stainless steels is commonly carried out using nickel-based brazing fillers, which provide a high corrosion and oxidation resistance of the resulting joints [1-3]. These brazed stainless steel joints are mostly used for the manufacturing of heat exchangers for energy and air conditioning technologies. The alloying with the elements silicon, boron and phosphorus lead to a reduction of the melting temperature of the nickel or the nickel-chromium alloy. Hence, brazing temperatures between 1000°C to 1200°C are possible. Moreover, the brazing fillers feature excellent flowing and wetting properties, because they are able to eliminate the oxide film on the surface of the base materials. However, the alloying elements adversely affect the microstructure and the mechanical properties of the joints when the gap size exceeds 50 µm [4]. The processing, structure and properties of the resulting brazed joints have been extensively studied, e.g. [5-7]. These joints are commonly brazed in vacuum furnaces or continuous furnaces. In vacuum furnaces, nitrogen (N_2) is often added during the cooling process. N_2 or mixtures of nitrogen and hydrogen (N_2+H_2) are typically used as process gases in continuous furnaces. Consequently, a nitrogen enrichment can take place in the braze metal and in the near-surface area of the base material. In previous work [8], the influence of the process parameters holding time and N_2 content in the process gas on the N_2 contents of the base material and the braze metal of the joints, brazed using different nickel-based brazing fillers, was investigated. The brazing process in the conveyor belt furnace was carried out using different holding times of 5 min and 10 min and different process gases, 100% N_2 and 50% N_2/50% H_2.

It was found out that the process parameters holding time and N_2 content in the process gas do not have a significant influence on the N_2 contents of base material and the braze metal. However, the results show that the nitrogen enrichment of the braze metal and the base material has a significant influence on the corrosion behaviour of the brazed joints [8]. This can be critical as the joints often need to endure high pressures in a corrosive environment during application. Therefore, the influence of the nitrogen enrichment in combination with a corrosive attack on the fatigue behaviour of the joints must be considered. In the present study, the influence of nitrogen in process atmospheres on the fatigue behaviour of brazed stainless steel joints before and after corrosive attack was investigated. The nitrogen content in the braze metal as well as in the base material was determined using the carrier gas hot extraction technique (CGHE). A corrosive aging was carried out in the exhaust gas condensate K1.2 according to VDA 230-214 [9]. The fatigue behaviour of corrosively affected and unaffected brazed joints was investigated. Fatigue tests were carried out at ambient temperature on a RUMUL resonance pulsator under load-controlled conditions with a load ratio of R = 0.1. The microstructure of the brazed joints and the fracture surfaces of the tested samples were investigated by scanning electron microscopy (SEM) using a backscattered electron detector (BSD). The fatigue behaviour of the joints without and after corrosion attack was compared.

2 Experimental procedure

Austenitic stainless steel (AISI 304) was used as the base material. The components to be brazed (circular and semicircular blanks with a diameter of 30 mm) were sectioned from finely rolled sheets by laser cutting, which led to burr-free and distortion-free samples. The brazing filler Ni60CrPSi, a nickel-based brazing alloy with 30 wt.% chromium, 6 wt.% phosphorous and 4 wt.% silicon, was applied onto the base material as powder. The thickness of the produced brazed joint was set to 50 µm using inserted spacer foils. The quantity of applied filler was the same for all samples and was dimensioned so that a joint thickness of at least 50 µm was ensured. The use of binder was avoided to eliminate carbon residues and their consequences, for example, the formation of chromium carbide in the braze metal.

The brazed single lap samples, used for the analysis of the nitrogen enrichment were produced at 1125°C in a vacuum furnace and a conveyor belt furnace with process gas. To induce the maximum effect of the nitrogen enrichment in the base material as well as in the braze metal, a N_2 content of 100% N_2 and a holding time of 10 min were used. The brazing temperature was recorded by a trailing thermocouple attached just below the sample surface. A brazing process in a vacuum furnace using free cooling was carried out as a reference. The heating and cooling rates were set to 50 K/min in both furnaces. The quantitative determination of the nitrogen enrichment in the braze metal as well as in the base material was carried out using CGHE according to previous work [8].

3 Microstructure of brazed joint

In **Fig. 1**, the microstructure of a joint, brazed in vacuum using Ni60CrPSi, is shown. The microstructures of joints, brazed in process gas, were similar. Due to the diffusion of Fe into the braze metal, Fe-enriched Ni-Cr-Si solid solutions (1) are formed at the interface to the stainless steel and inside the braze metal. Additionally, the resulting braze metal consists of Cr-enriched Ni-P intermetallics (2) and chromium phosphides (3).

4 Analysis of the nitrogen enrichment

In previous work [8], low nitrogen contents of 0.04 wt.% in the brazing filler Ni60CrPSi and 0.07 wt.% in the base material AISI 304 were determined for the as-received condition. As expected, the vacuum brazing process did not influence the N_2 contents of the base

KEYWORDS

strength, corrosion, brazing, nickel, nickel alloys, material questions

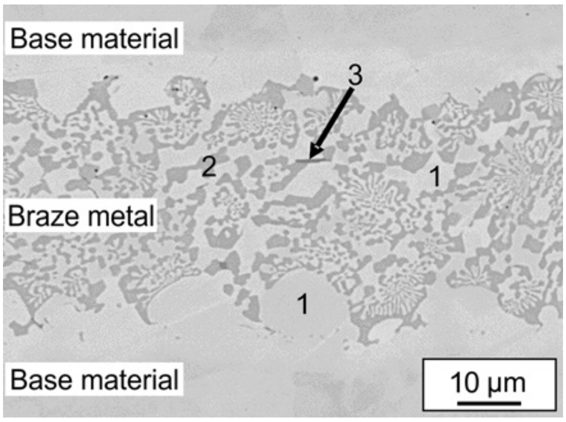


Fig. 1 • Microstructure in BSD contrast of the vacuum brazed joint: 1 – Fe-enriched Ni-Cr-Si solid solution, 2 – Cr-enriched Ni-P intermetallic, 3 – chromium phosphide.

material and the braze metal in comparison to the as-received condition. After vacuum brazing, N_2 contents of 0.04 wt.% in the braze metal and 0.07 wt.% in the base material were determined. In contrast, the nitrogen content in samples brazed in a conveyor belt furnace, was strongly affected by the process gas. The N_2 content in the braze metal increased to 1.14 wt.% while the base material was enriched by N_2 to a value of 0.4 wt.%. In comparison to the as-received condition, the N_2 contents of the base material and the braze metal increased significantly. The enhanced diffusion of nitrogen atoms into the braze metal and the base material is caused by the high brazing temperature as well known from nitriding processes of steels [10]. Additionally, it can be seen that the braze metal was more intensively enriched with N_2 in comparison to the base material. During the brazing process, the braze metal is liquid and can absorb a higher amount of N_2 in comparison to the base material in its solid state.

5 Corrosive aging

The results reported in [8] show that the nitrogen enrichment has a significant influence on the corrosion behaviour of the brazed joints. As many brazed components experience cyclic loads as well, the fatigue behaviour of corrosively affected brazed joints was studied. The corrosive aging was performed in the model exhaust gas condensate K1.2 at a temperature of 70°C for 15 h according to [11]. The selected condensate is essentially a chloride-containing, mineral acid solution with a pH of 1.2 [9].

The fatigue behaviour was determined before and after corrosion attack. In **Fig. 2**, cross-sections of the brazed samples after corrosion attack are presented. It can be seen that the vacuum brazed joints are not visibly affected by corrosion, **Fig. 2a**. In contrast, the joint brazed in process gas demonstrates significant corrosion. The damage due to corrosion occurs in the braze fillet as well as in the base material, **Fig. 2b**.

6 Fatigue tests

To evaluate the mechanical properties and the fatigue behaviour of the joints, monotonic tensile tests as well as fatigue tests at ambient temperature were carried out. Single lap samples with a joining area of 6 mm × 5 mm were used for mechanical testing. The tensile tests were conducted in a Zwick Allround-Line 20 kN material testing machine. For all joints brazed with Ni60CrPSi, a monotonic tensile shear strength of 185 MPa was determined. The fatigue tests were carried out on a RUMUL resonance pulsator under load-controlled condition with a load ratio of R = 0.1 and resonance frequency of 100 Hz. Three samples per stress level were tested for the joints brazed in vacuum and in process gas. The fatigue tests were carried out in the high-cycle fatigue (HCF) range up to $N = 2 \times 10^6$ cycles. Three stress levels (70, 50 and 30%) were set based on the measured tensile shear strength of the brazed joints. In **Fig. 3**, the results of the fatigue tests of the investigated brazed joints before and after corrosion testing are presented. For the vacuum brazed joints, the comparison of the S-N data shows that similar numbers of cycles were reached at all stress levels employed. At the highest stress level (58 MPa), which corresponds to 70% of the monotonic tensile shear strength, failure occurred at 5×10^4 cycles. At a lower stress level of 37.5 MPa, which corresponds to 50% of the monotonic tensile shear strength, the number of cycles to failure increases to 5×10^5. At the lowest stress

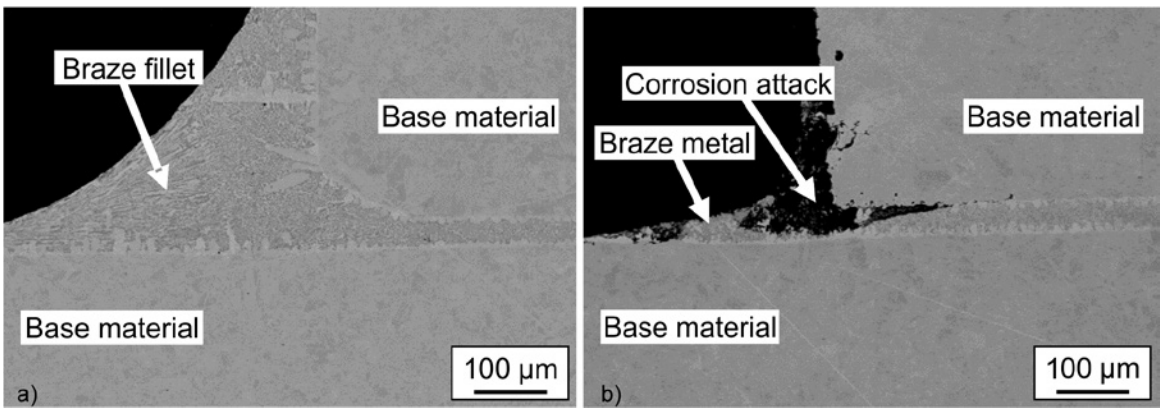


Fig. 2 • Cross-sections of samples brazed in: a) vacuum, b) process gas (BSD) after exposure to the model exhaust gas condensate K1.2; see main text for details.

level, which corresponds to 30% of the monotonic tensile shear strength, the samples reached the set limit of 2×10^6 cycles at a stress amplitude of 25 MPa in both cases. In essence, the corrosive aging did not influence the fatigue behaviour of the vacuum brazed joints.

In contrast, the endurable number of cycles decreased at all stress levels for the joints brazed in process gas due to the corrosion attack. Without corrosive aging, the joints reached the same numbers of cycles as the vacuum brazed joints. After corrosion aging, at the highest stress level of 58 MPa, the number of cycles to failure decreased from 5×10^4 to 1.5×10^4 cycles, which corresponds to a 70% decrease. At the lower stress level of 37.5 MPa, the number of cycles to failure decreased to 2.6×10^5, which corresponds to a 48% decrease. At the lowest stress level of 25 MPa, these joints did not reach the set limit of 2×10^6 cycles. The number of cycles to failure decreased to 1.3×10^6, which corresponds to a 35% decrease. Clearly, the nitrogen enrichment results in significant corrosion fatigue susceptibility for these joints.

7 Fractography

In order to determine the damage mechanisms for the fatigue tested joints without corrosive aging and after corrosive aging, the fracture surfaces were investigated by SEM. In **Fig. 4** and **Fig. 5**, cross-sections of the fracture surfaces of the fatigue tested samples are presented. It turned out that the fatigue tested joints without (**Fig. 4**) and after (**Fig. 5**) corrosive aging show the same fracture mechanism at all stress levels employed.

It can be seen that the cracks occur in the Cr-enriched Ni-P intermetallics in the eutectic and run through the braze metal. This is caused by the high hardness of these intermetallics with small grain size. The same fracture mechanism occurs during micro-hardness measurements. In **Fig. 6**, an indent in the eutectic of the braze metal is shown. During the hardness measurements, the cracks arise in the hard and brittle Cr-enriched Ni-P intermetallics, while the Fe enriched Ni-Cr-Si solid solution shows a ductile behaviour. The actual micro-hardness values were not evaluated due to the small size of the intermetallics,

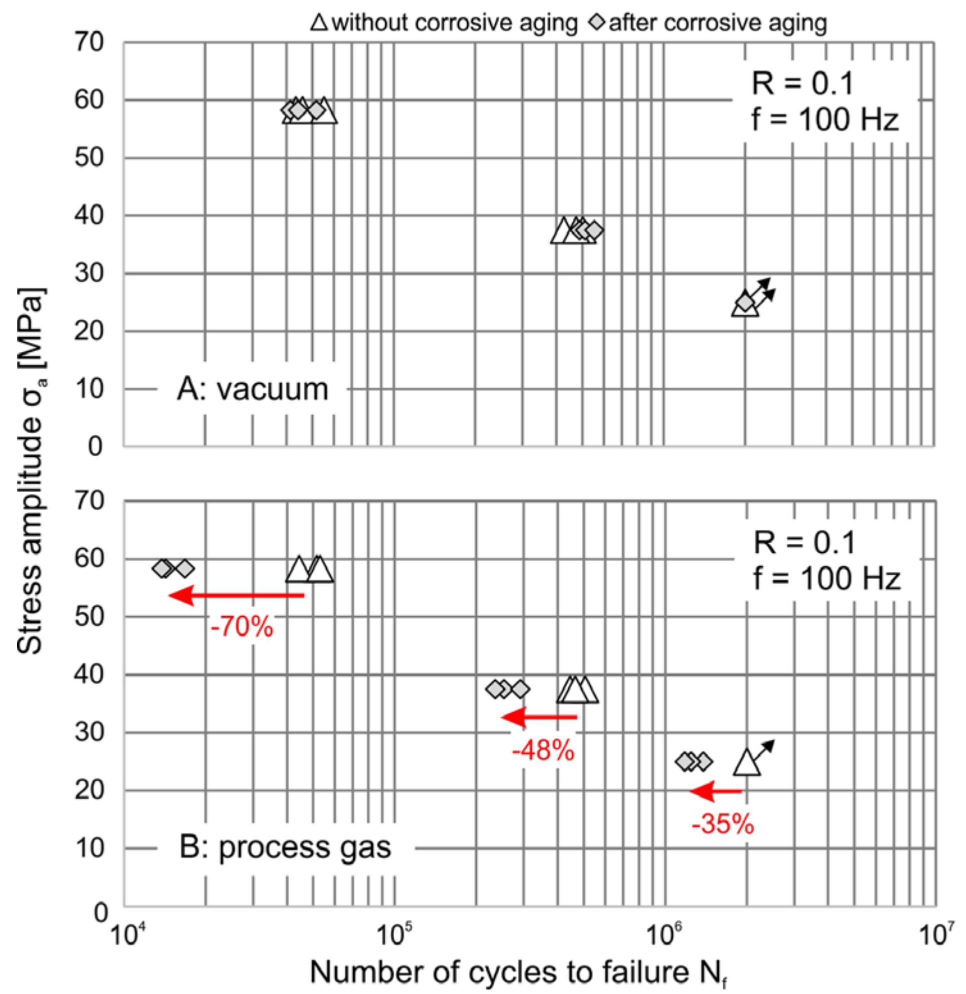


Fig. 3 • S-N data demonstrating the difference in corrosion fatigue behaviour of the stainless steel joints brazed in: a) vacuum, b) process gas.

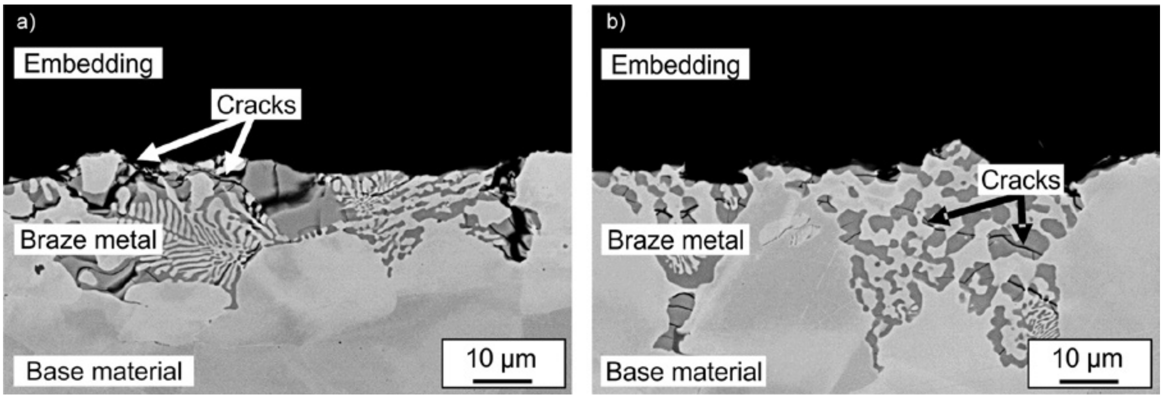


Fig. 4 • Cross-sections of the fracture surface of fatigue tested samples brazed in: a) vacuum (σ_a = 37.5 MPa, N = 5 × 10^4), b) process gas (σ_a = 37.5 MPa, N = 5 × 10^4) without corrosive aging (BSD contrast).

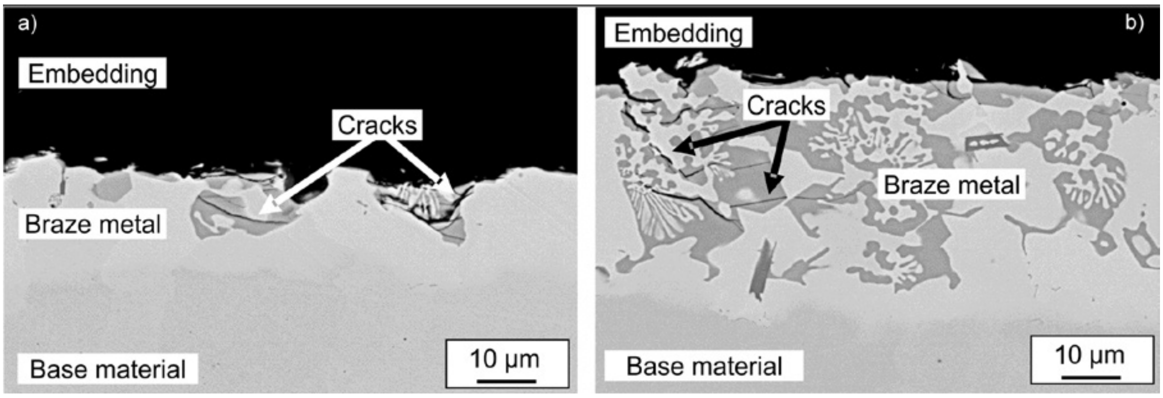


Fig. 5 • Cross-sections of the fracture surface of fatigue tested samples brazed in: a) vacuum (σ_a = 37.5 MPa, N = 5 × 10^4), b) process gas (σ_a = 37.5 MPa, N = 1.5 × 10^4) after corrosive aging (BSD contrast).

which are smaller than the indents. Apparently, the main trigger for fatigue crack initiation in stainless steel joints, brazed with the Ni60CrPSi filler, is the difference in the hardness of solid solution and intermetallics.

8 Conclusions

Brazed specimen made of austenitic stainless steel (AISI 304) and a nickel-chromium based filler metal (Ni60CrPSi) were produced at 1125°C in a vacuum furnace and in a conveyor belt furnace applying nitrogen containing process gases. The nitrogen content in the braze fillets and brazed seams, respectively, as well as in the base material was determined by carrier gas hot extraction. It was determined that the braze metal is more intensively enriched with nitrogen in comparison to the base material. The results of the corrosive aging show that the joints brazed in nitrogen containing process gas are more susceptible to corrosion attack than the vacuum brazed joints. For all joints brazed with Ni60CrPSi, a monotonic tensile shear strength of 185 MPa was determined. In addition, it was observed that without corrosive attack, the fatigue behaviour of joints brazed in vacuum and process gas is similar. The fatigue endurance limit defined at 2 × 10^6 cycles was around 25 MPa. After corrosion attack, the vacuum brazed joints reached the same numbers of cycles to failure at all stress levels as without corrosion attack. Consequently, the corrosive environment did not influence the fatigue behaviour of the vacuum brazed joints significantly. In contrast, the number of cycles to failure decreased at all stress levels for the joints brazed in process gas. At the lowest stress amplitude of 25 MPa, these joints reached only 1.3 × 10^6 cycles. Consequently, the nitrogen enrichment results in significant susceptibility to corrosion fatigue of these joints.

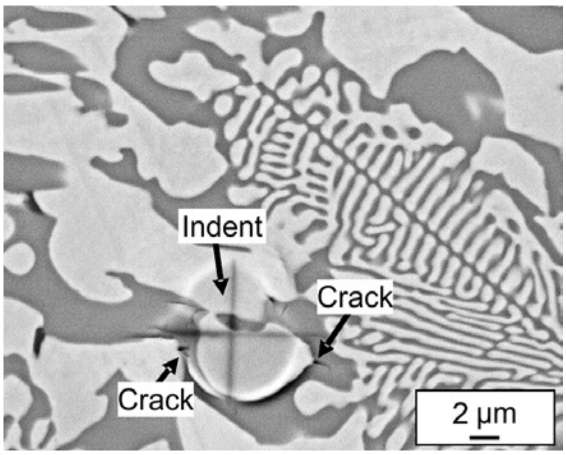


Fig. 6 • Indent in the eutectic consisting of Fe-enriched Ni-Cr-Si solid solution and the Cr-enriched Ni-P intermetallic resulting in crack formation (BSD contrast).

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on the basis of a decision by the German Bundestag

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Development and evaluation of alternative materials for friction stir welding of steel

During the friction stir welding process (FSW) of steel, the tool is subjected to extremely high temperatures of approximately 1200°C and corrosive and abrasive wear. Therefore, the requirements for mechanical, chemical and tribological resistance at high temperatures demand material systems with outstanding properties. Thus, occurring stresses of the tool and its interaction with the workpiece to be welded is of particular importance. The article reports about development and evaluation of ceramic tools for the FSW.

Introduction

Friction Stir Welding (FSW) was developed in 1991 at The Welding Institute (TWI) in the UK and has become a widely used method of welding aluminium and copper structures. The method is based on a simultaneous application of pressure and friction which generates heat that leads to the softening of the join parts to be welded. Due to stirring the tool in the softened metal the connection of the components is ensured, as shown in **Fig. 1**. Besides the resulting high quality of the welds, FSW offers a multitude of advantages such as the ability to join materials that are difficult to fusion weld, for example aluminium alloys, magnesium and copper, and a good suitability for automation and adaptability for robot use. Due to low distortion and shrinkage even in long welds, excellent mechanical properties in fatigue, tensile and bend strengths can be achieved. In contrast to conventional processes, no arcs or fumes are produced, which is beneficial for health and environmental protection aspects. The welding process also shows benefits due to the lack of need for welding consumables and auxiliaries along with high potential for saving resources and energy. From an environmental point of view, it can be noted that FSW produces less waste in the form of slag, weld residue, pre-treatment, as compared to molten welding processes, and thus does not result in environmental stress from contained alloying elements, i.e. expensive recycling processes are not required [1, 2].

As a potential group of users, in particular shipbuilding, vehicle construction and general steel construction

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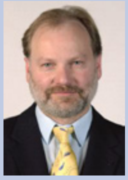
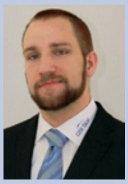
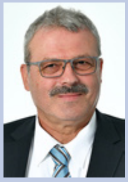
Dr.-Ing. Markus Zwick worked from 2016 to 03.2020 as the managing director of Forschungsinstitut für Anorganische Werkstoffe -Glas /Keramik- GmbH.



Ralf Boywitt, born in 1961 in Neustad /Dosse, Germany, has been employed at GSI mbH, NL SLV Berlin-Brandenburg since 1999. He is a group leader of the department of research and development which is mainly concerned with friction stir welding. Ralf Boywitt is a state-certified technician for mechanical engineering and construction as well as European Welding Specialist. He is co-owner of application patents, national and international publications about friction stir welding.



Dipl.-Ing. Steffen Risse completed his studies of mechanical engineering with a specialisation in design at the HTW Berlin – University of Applied Sciences. After his studies he qualified as a welding engineer and is employed at the SLV Berlin-Brandenburg in the field of research and development. In 2015 he successfully completed his Master (M.Sc.) in mechanical engineering and lightweight construction.



Dr.-Ing. Matthias Pöge is head of branch office GSI mbH, NL SLV Berlin-Brandenburg. He is International Welding Engineer; chairman of the working group IIW IAB 2a/2b; chairman of the GSI and DVS (German Welding Society) group Education and Training; Specialist for welding processes; DVS examiner for welding (including plastic welding).

KEYWORDS

friction stir welding

can be seen, in which long welds of large-area components and structures are prefabricated in assembly halls. Through the use of friction stir welding, the production costs of welds due to the shorter joint preparation and post-processing times, and faster welding speeds can be drastically reduced, and thus competitiveness is increased.

Numerous investigations have already examined the transferability of FSW to the welding of steel structures. Besides conventional construction steels, the principle of weldability has been demonstrated on various steel systems as austenitic steels, dual phase steels and stainless steels. Here the sheet thicknesses that could have been welded amounted to up to 20 mm in a single-layer process. [3-13]

During the welding process of steel, the tool is subjected to extremely high temperatures of approximately 1200°C and corrosive and abrasive wear. Therefore, the requirements for mechanical, chemical and tribological resistance at high temperatures demand material systems with outstanding properties. Thus, occurring stresses of the tool and its interaction with the workpiece to be welded is of particular importance. The current standard is, in addition to special alloys (e.g. tungsten-rhenium, tantalum base materials) and solid carbides, the use of pcBN tools (polycrystalline cubic boron nitride). While metallic tools do not show sufficient wear resistance, pcBN, due to its atomic structure, has a very high hardness and excellent wear resistance, but also shows the brittleness that is common for ceramic hard materials, increasing the risk of fractures during use under overload. Moreover, as a consequence of high raw material and production costs and a limited number of manufacturers, the availability of tools for the FSW of steels is insufficient. [14, 15]

Hence, in course of the present work, common ceramic materials are to be tested, in order to find a more economical and adequate replacement for pcBN-tools. Ceramic material systems have already proven their application potential and in particular their cost-effectiveness in many areas of steel production and processing. From the materials used in the field of smelting metallurgy in the lining of blast furnaces and casting machines to high-performance cutting tools, the performance of ceramic materials in interaction with steel has been demonstrated.

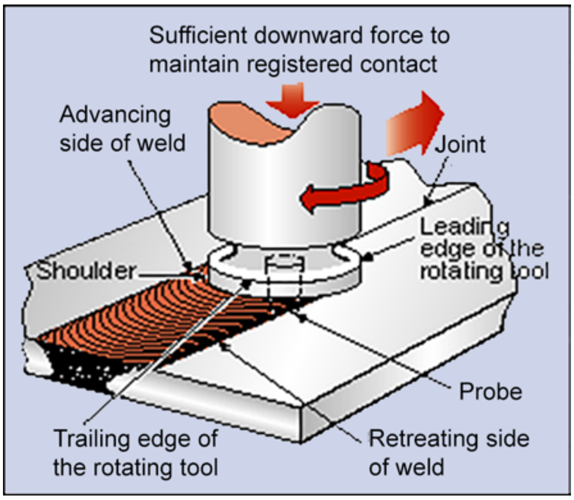


Fig. 1 • Scheme of the operating principle of FSW.

Experimental results

For the experimental setup the following materials were used as tool material: Al_2O_3, ZrO_2 (both BCE Special Ceramic GmbH, Germany) SiC and Si_3N_4 (both FCT Ingenieurkeramik GmbH, Germany). The respective material properties can be found in **Tab. 1**. In case of tested steels, the unalloyed steel S235JR / 1.0038 as well as the austenitic stainless steel X5CrNi18-10 /1.4301 were used.

For the determination of the wear resistance of the respective tool material against steel, a tribology test stand, equipped with a steel disk with a diameter of 200 mm, a rotating speed of appr. 120 rpm and a contact force of 10 N was used. The contact time between steel and ceramic material amounted to 2 h, in order to overcome the detection limit. For the quantification of wear, an optical profilometer, based on a chromatic white light

Table 1 • Material properties of the tested ceramics.

Material property	Al_2O_3	ZrO_2	Si_3N_4	SiC
Fracture toughness [MPa·√m]	4,3	7	6	3,5
Hardness [MPa]	1800	1200	1600	2600
Bending strength [MPa]	340	500	990	400
Poisson number [-]	0,22	0,3	0,26	0,15
Young´s modulus [GPa]	380	200	320	400
CTE RT-1000 °C [10^{-6} K^{-1}]	8,5	10,5	3,0	4,5
Thermal conductivity [W/mK]	30	2	30	140
Thermal shock parameter R2 [W/m]	0,0025	0,0003	0,0229	0,0264

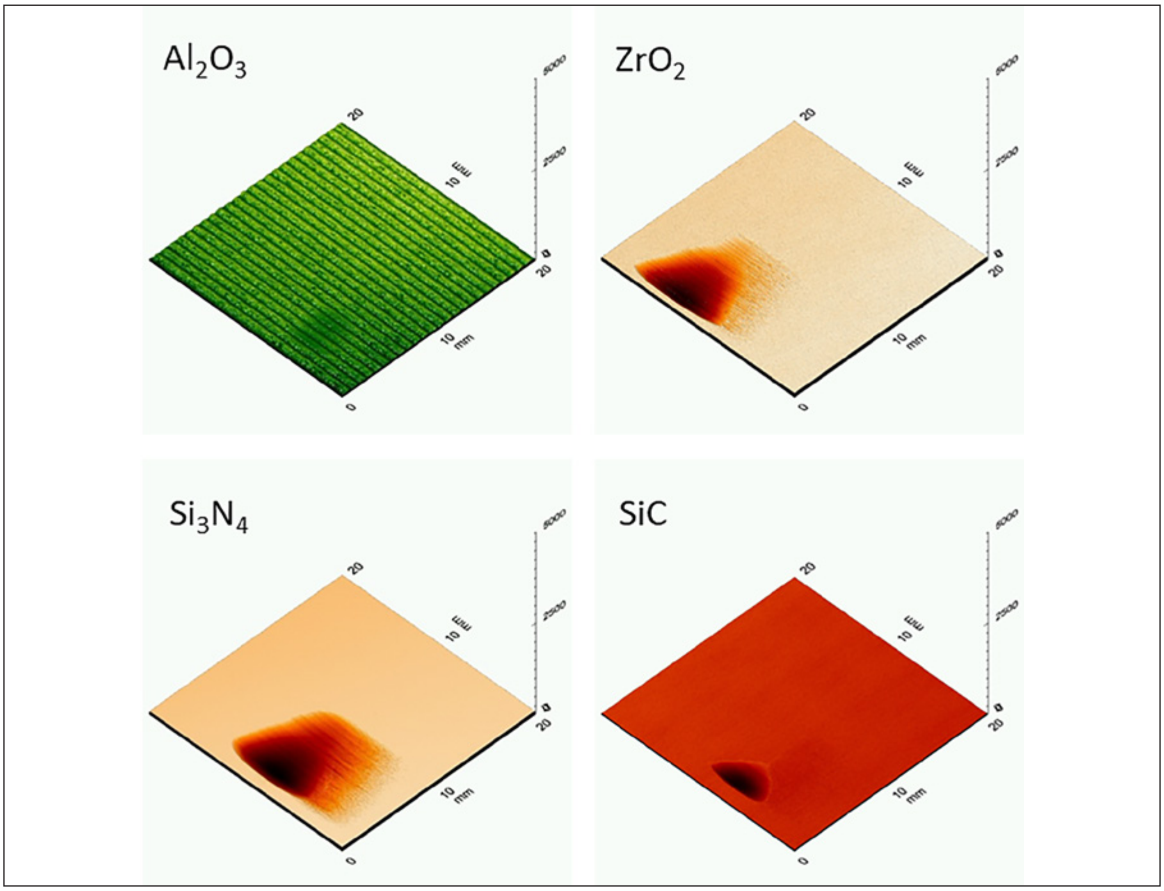


Fig. 2 • Determination of the wear resistance of the respective ceramic materials against steel.

measurement, was used. The results of the tribology test can be seen in **Fig. 2**.

It shows that in good agreement with e.g. the hardness, the materials are subject to different wear. Hence, alumina as well as silicon carbide show a promising resistance towards wear, due to steel. In contrast, the less hard zirconia and silicon nitride show more pronounced tribologically related effects. During FSW process the tool suffers from, besides those tribological stresses, thermally induced damage. Therefore, the determination of the resistance of the ceramics against steel at elevated temperatures took place at 1100°C, 1200°C or 1300°C, respectively. The different steel and ceramic combinations we realized by putting them on top of each other without the application of any additional forces within the furnace. Under oxidizing atmosphere, the dwell time amounted to 5 h. The influence of the temperature on the thermo-chemical resistance of ceramic tool materials against steel at the example of Si_3N_4 and construction steel S235JR is depicted in **Fig. 3**. It shows that the reactivity between steel (solid state) and the respective ceramic materials increases with increasing temperature. This trend could be observed in case of every combination, irrespective of the kind of steel as well as of ceramic material. **Fig. 4** indicates the great influence of the ceramic material on the thermo-chemical resistance against steel. As can be clearly seen, the reaction zone is much less pronounced in case of oxidic tool materials. In contrast, the silicon nitride shows deep penetration zones, favouring thermo-mechanical wear of the tool during operation. The SiC sample led to the formation of silicides and the reduction of the melting point of the steel already at 1200°C and therefore proved to be inadequate.

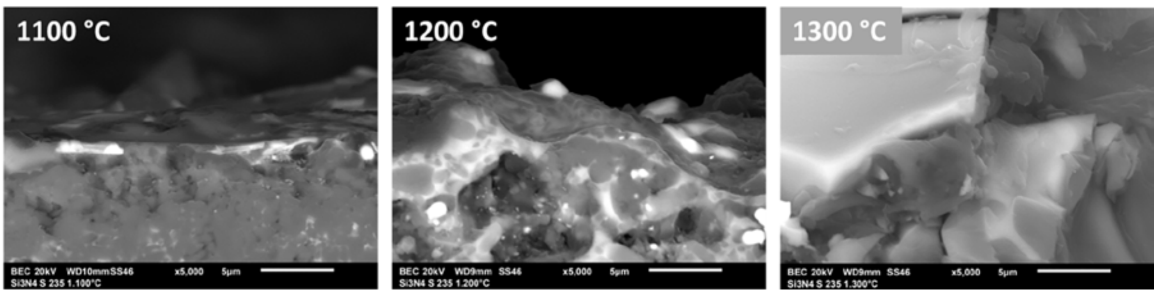


Fig. 3 • Influence of the temperature on the thermo-chemical resistance of ceramic tool materials against steel at the example of Si_3N_4 and construction steel S235JR.

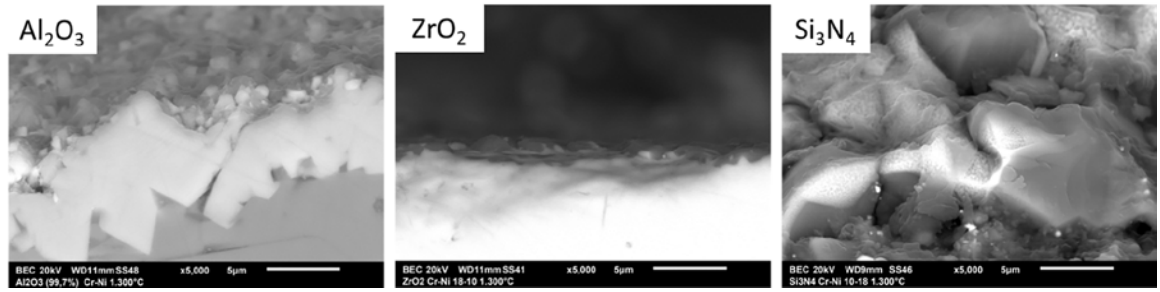


Fig. 4 • Influence of the ceramic material on the thermo-chemical resistance against steel at the example of 1300°C and austenitic stainless steel X5CrNi18-10.

Fig. 5 • Experimental set-up for test under realistic conditions with FSW-machine from HLR Systems, Germany (left), tool holder including Si_3N_4-tool (middle), test route (right).

After the pre-evaluation, the respective tool materials were tested under realistic conditions. Therefore, the experimental set-up, shown in **Fig. 5**, was used, which included a FSW-machine (HLR Systems, Germany), the tool holder as well as test steel sheets, made of either S235JR / 1.0038 or X5CrNi18-10 /1.4301 with a dimension of 200 mm × 200 mm × 6 mm. The welding parameters were a contact force of appr. 25 kN, number of revolutions of 670 rpm and a feed motion of 5 mm/s. A test route length of 600 mm was chosen.

Interestingly, the experiments under real conditions show exactly the opposite behaviour compared to the previous results, as can be seen in **Fig. 6**. Irrespective of the used steel grade both the alumina as well as the

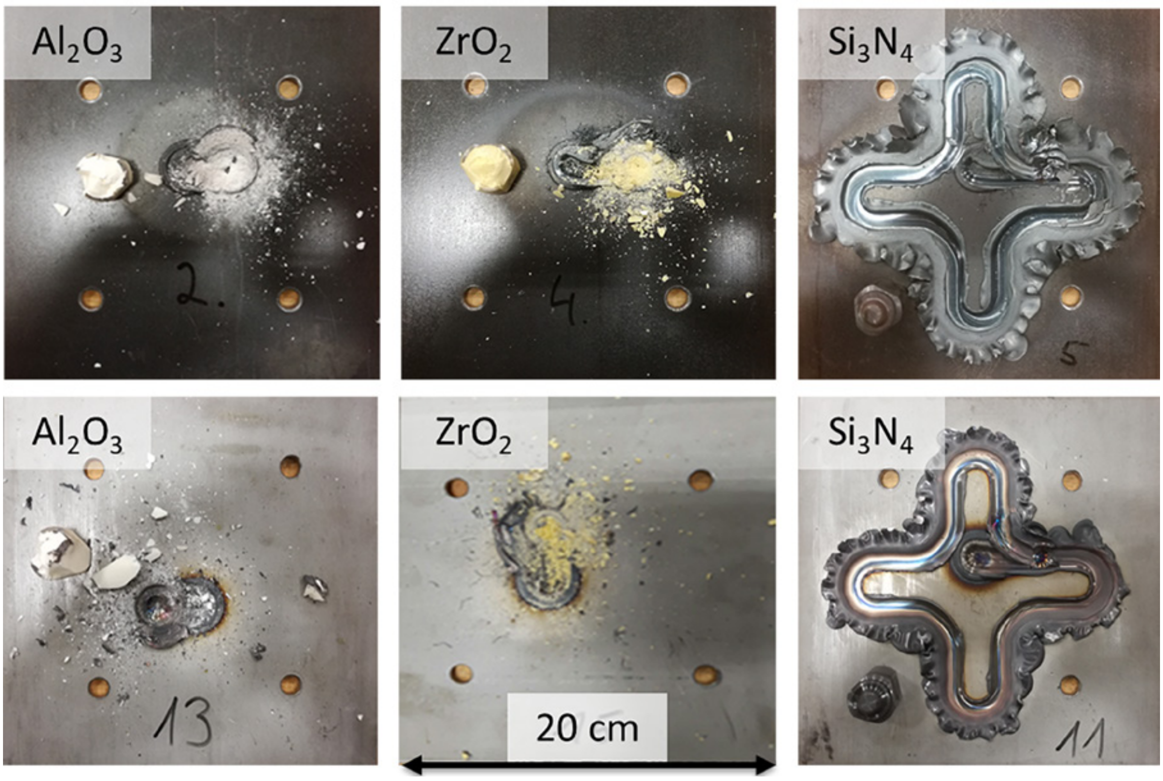


Fig. 6 • Results of the tests of oxide as well as non-oxide tools in combination with steel S235JR (top row) or X5CrNi18-10 (bottom row) under realistic conditions.

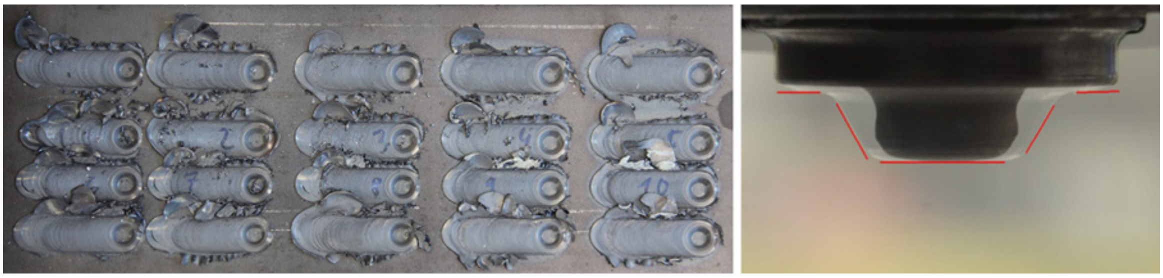


Fig. 7 • Experimental set-up for wear resistance determination (left), Si_3N_4-tool before and after 12 immersions and 9,5 m welding length (right).

zirconia tools were completely destroyed after applying the feed motion. This was preceded by a clearly audible cracking noise immediately after the shoulder, which corresponds to the largest diameter of the tool, hit the steel sheet. The tools are tested in the cold state and begin to glow red only after a few seconds after immersion, which leads to a thermal shock of the ceramic material. In case of the Si_3N_4-tools, however, no noise could be observed. As a matter of fact, the entire test route could be driven off, without the formation of defects in the tool. Taking Tab. 1 into consideration, it becomes clear that Si_3N_4 has significantly better thermal shock resistance and is therefore able to withstand the harsh conditions during welding.

In order to evaluate the wear and thus the long-term stability, a Si_3N_4-tool was immersed into a S235JR steel sheet with a thickness of 6 mm for 20 times and additionally a welding length of 9,5 m was generated. The tool was still intact even after these stresses, even though significant wear is recognizable, as depicted in **Fig. 7**. The most pronounced wear is detectable in the cross-section of the pin, which is to be traceable back to the feed motion as well as the convection of the steel.

After confirming the suitability of Si_3N_4 as material for friction stir welding, its influence on the mechanical properties of the weld had to be checked. Therefore, steel sheets (S235JR) with a thickness of 8 mm had been welded on both sides with a Si_3N_4-tool and the following parameters; contact force: 25 kN, number of revolutions: 475 rpm, and a feed motion of approx. 300 mm/min. As evident from **Fig. 8**, the fracture-causing defect and hence, the failure of the tensile test is located in the base material. As a logical consequence, the determined tensile strength equates to that of steel S235JR. This shows that despite any contamination by the FSW-tool material, no negative influence on the mechanical properties of the join parts is observed.

In order to generate tools with improved wear resistance and taking into account the previous results, the composite WC-ZrO_2 was chosen. This is due to the fact that ZrO_2 has proven itself in preliminary tests, with the exception of thermal shock resistance. WC, however, has good thermal conductivity (60 - 80 W/mK) and lower CTE (about 5×10^{-6} K^{-1}) and thus improves thermal shock resistance. Moreover, the use of WC can result in the improvement of wear resistance, due to its high hardness, and enables the component to be inductively heated. The material based on 60 vol.-% ZrO_2 and 40 vol.-% WC was initially ground using an agitator bead mill. Subsequently, drying optimizations were carried out by means of freeze dryers and drying chambers. The optimum pressing conditions were determined by creating a compression pressure curve. By varying the sintering conditions, it has finally been possible to generate a nearly dense component. For this purpose, the cold isostatically pressed green bodies were sintered at 1550°C under nitrogen atmosphere for two hours. The sintered component was finally machined by BCE (see **Fig. 9**).

Table 2 • Comparison of the failure-relevant material characteristics of the new composite material with those the standard material pcBN.

Material property	WC-ZrO_2	pcBN
Fracture toughness [MPa*$m^{1/2}$]	10,4	6
Hardness [MPa]	2285	-
Bending strength [MPa]	1139	800
Poisson number [-]	0,25	0,25
Youngs modulus [GPa]	189	400
Thermal expansion coefficient RT-1000 °C [10^{-6} K^{-1}]	7	4,9
Thermal conductivity [W/mK]	50	100
Thermal shock parameter R2* [W/m]	0,0323	0,0306

The determination of the material characteristics for the new composite material shows that it can be considered extremely promising, as shown in **Tab. 2.** Not only does it have better properties compared to the materials tested so far, but even a better performance than the costly pcBN can be expected. Friction stir welding tests have already confirmed its suitability.

Conclusions

In the course of the present work the problems of limited availability of tools and high prices were supposed to be addressed, which lead to the demand of commonly available ceramic alternatives. In this regard oxides show good tribological and thermo-chemical resistance towards steel, in contrast to non-oxides. However, tests under realistic conditions have shown that the thermal shock resistance as well as the fracture toughness of the tool materials is of great importance. Here, on the one hand, the Si_3N_4 possesses the best stability. On the other hand, the wear resistance is still in need of improvement, even though possible contaminations resulting from tool abrasion do not affect the mechanical properties of the weld negatively. Therefore, a new composite tool ($WC\text{-}ZrO_2$) has been developed that has outstanding properties and, consequently, can be classified as very promising.

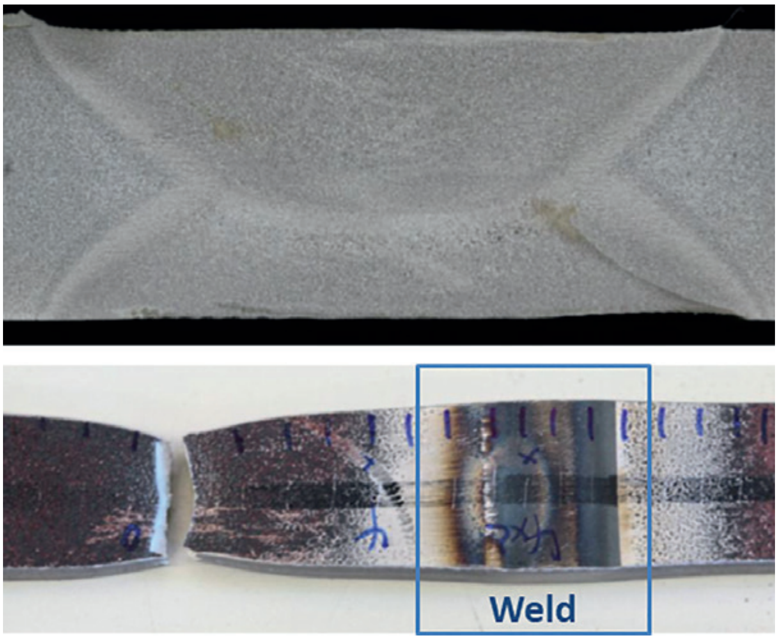


Fig. 8 • Steel sheets (S235JR) after welding on both sides (top), and after determination of the tensile strength (bottom).

Fig. 9 • First produced FSW tool made of $WC\text{-}ZrO_2$.

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E-Mail: info@otc-daihen.de
Internet: www.otc-daihen.de

Panasonic Industry Europe GmbH
Jagenbergstraße 11a, 41468 Neuss
☎ +49 2131 60899-0 🖷 +49 2131 60899-200
E-Mail: robots@eu.panasonic.com
Internet: www.panasonicrobotics.eu

SBI Produktion technischer Anlagen GmbH & Co. KG
Kaplanstraße 12, A-2020 Hollabrunn
☎ +43 2952 34 139-0 🖷 +43 2952 34 139-10
E-Mail: office@sbi.at
Internet: www.sbi.at

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

▼ Plasma welding 280

Bergmann & Steffen GmbH
Raiffeisenstraße 176, D-32139 Spenge
☎ +49 5225 8786-0 🖷 +49 5225 8786-27
E-Mail: info@bergmann-steffen.de
Internet: www.bergmann-steffen.de

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

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

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

MIG·O·MAT Mikrofügetechnik GmbH
Werkstraße 20, D-57299 Burbach
☎ +49 27 36 41 54-0 🖷 +49 27 36 41 54-99
E-Mail: info@mig-o-mat.com
Internet: www.mig-o-mat.com

Migatronic Schweißmaschinen GmbH
Sandusweg 12, 35435 Wettenberg
☎ +49 641 98 284-0 🖷 +49 641 98 284-50
E-Mail: info@migatronic.de
Internet: www.migatronic.de

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Internet: www.sbi.at

▼ Tandem welding 360

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Internet: www.fronius.de

igm Robotersysteme AG
Industriezentrum
Niederösterreich Süd, Straße 2, A-2355 Wiener Neudorf
☎ +43 22 36 6-706 🖷 +43 22 36 6-1576
E-Mail: office@igm-group.com
Internet: www.igm.at

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☎ +49 2131 60899-0 🖷 +49 2131 60899-200
E-Mail: robots@eu.panasonic.com
Internet: www.panasonicrobotics.eu

▼ Resistance spot welding 410

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Raiffeisenstraße 176, D-32139 Spenge
☎ +49 5225 8786-0 🖷 +49 5225 8786-27
E-Mail: info@bergmann-steffen.de
Internet: www.bergmann-steffen.de

▼ TIG (GTA) welding 420

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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

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Inelco Grinders A/S
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☎ +45 9650 62-33 🖷 +45 9650 62-32
E-Mail: info@inelco-grinders.com
Internet: www.inelco-grinders.com

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

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☎ +49 71 91 503-0 🖷 +49 71 91 503-199
E-Mail: info@lorch.eu
Internet: www.lorch.eu

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

Migatronic Schweißmaschinen GmbH
Sandusweg 12, 35435 Wettenberg
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Internet: www.migatronic.de

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Internet: www.orbitalum.com

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Internet: www.otc-daihen.de

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Ottostraße 2, D-73066 Uhingen
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E-Mail: rehm@rehm-online.de
Internet: www.rehm-online.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 and equipment, including automation, mechanization and industrial robots, for weld surfacing and cladding

▼ Laser cladding 450

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Kaplanstraße 12, A-2020 Hollabrunn
☎ +43 2952 34 139-0 🖷 +43 2952 34 139-10
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Internet: www.sbi.at

▼ Plasma cladding 460

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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 shielded arc cladding 490

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☎ +49 2680 181-0 🖷 +49 2680 181-244
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Lothar Spahn
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Internet: www.valkwelding.com

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

▼ Submerged arc cladding 500

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Internet: www.welding-alloys.com

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

▼ Arc brazing 600

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E-Mail: info@de.sks-welding.com
Internet: www.sks-welding.com

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

Köster & Co. GmbH Bolzenschweißtechnik
Spreeler Weg 32, D-58256 Ennepetal
☎ +49 23 33 83 06-0 🖷 +49 23 33 83 06-38
E-Mail: koeco@bolzenschweisstechnik.de
Internet: www.bolzenschweisstechnik.de

Heinz Soyer Bolzenschweißtechnik GmbH
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☎ +49 81 53 885-0 🖷 +49 81 53 885-221
E-Mail: export@soyer.de
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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☎ +49 2773 71133 🖷 +49 2773 2701
E-Mail: info@j-thielmann.de
Internet: www.j-thielmann.de

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

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

▼ Production equipment and production lines 1030

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
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E-Mail: contact@dodek.de
Internet: www.dodek.de

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

▼ Orbital welding equipment 1040

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Orbitalum Tools GmbH
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☎ +49 7731 792-0 🖷 +49 7731 792-500
E-Mail: tools@orbitalum.com
Internet: www.orbitalum.com

7 Services

▼ Leasing of welding plant and welding Equipment 1091

MSS Magdeburger Schweißtechnik GmbH
An der Sülze 6, D-39179 Barleben
☎ +49 392 03 75 19-3 🖷 +49 392 03 75 19-40
E-Mail: info@mss-schweisstechnik.de
Internet: www.mss-schweisstechnik.de

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

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

▼ 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

Orbitalum Tools GmbH
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☎ +49 7731 792-0 🖷 +49 7731 792-500
E-Mail: tools@orbitalum.com
Internet: www.orbitalum.com

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

Orbitalum Tools GmbH
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PROTEM GmbH
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☎ +49 7247 9393-0
E-Mail: info@protem-gmbh.de
Internet: www.protem.fr/de

▼ Cutting (e.g. plate shearing), slamping, nibbling 1330

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☎ +49 7731 792-0 🖷 +49 7731 792-500
E-Mail: tools@orbitalum.com
Internet: www.orbitalum.com

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

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Borker Straße 96, 45731 Waltrop
☎ +49 2309 784763 🖷 +49 2309 784765
E-Mail: mail@absaugtechnik-kalkhof.de
Internet: www.absaugtechnik-kalkhof.de

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Internet: www.demmeler.com

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

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E-Mail: info@siegmund.com
Internet: www.siegmund.com

TEKA Absaug- und Entsorgungstechnologie GmbH
Industriestraße 13, D-46342 Velen
☎ +49 2863 9282-0 🖷 +49 2863 9282-72
E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Heat recovery systems 1400

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E-Mail: contact@dodek.de
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▼ Soldering fume filters 1430

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

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E-Mail: mail@absaugtechnik-kalkhof.de
Internet: www.absaugtechnik-kalkhof.de

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Internet: www.fuechtenkoetter.de

HPS Filtertechnische Anlagen GmbH
Angerstraße 7, 99625 Kölleda
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Internet: www.hps-filtertechnik.de

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Internet: www.plymovent.de

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E-Mail: info@teka.eu
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▼ Sound absorbing materials, soundproof chambers 1460

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▼ Welding booths 1480

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▼ Welding curtains 1490

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▼ Protective screens 1500

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▼ Weld fume filters and filtration systems 1510

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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

TEKA Absaug- und Entsorgungstechnologie GmbH
Industriestraße 13, D-46342 Velen
☎ +49 2863 9282-0 🖷 +49 2863 9282-72
E-Mail: info@teka.eu
Internet: www.teka.eu

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

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

▼ Stationary vacuum cleaners for industrial use 1540

HPS Filtertechnische Anlagen GmbH
Angerstraße 7, 99625 Kölleda
☎ +49 3635 4762-0 🖷 +49 3635 4762-47
E-Mail: kontakt@hps-filtertechnik.de
Internet: www.hps-filtertechnik.de

▼ Exhaust and ventilation systems 1550

HPS Filtertechnische Anlagen GmbH
Angerstraße 7, 99625 Kölleda
☎ +49 3635 4762-0 🖷 +49 3635 4762-47
E-Mail: kontakt@hps-filtertechnik.de
Internet: www.hps-filtertechnik.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

4 Health and safety (personal protective equipment)

▼ Laser protection 1650

TEKA Absaug- und Entsorgungstechnologie GmbH
Industriestraße 13, D-46342 Velen
☎ +49 2863 9282-0 🖷 +49 2863 9282-72
E-Mail: info@teka.eu
Internet: www.teka.eu

▼ Protective clothing (helmets, aprons, garments, shoes, gloves) 1660

Weldas Europe B.V.
De Poort 77, 4411 PB Rilland, NIEDERLANDE
☎ +31 1135 511-55 🖷 +31 1135 511-56
E-Mail: europe@weldas.com
Internet: www.weldaseurope.com

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

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

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
Postfach: 51, 87751 Heimertingen
☎ +49 8335 9859-0 🖷 +49 8335 9859-27
E-Mail: info@demmeler.com
Internet: www.demmeler.com

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

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

▼ 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

Orbitalum Tools GmbH
Josef-Schüttler-Straße 17, D-78224 Singen
☎ +49 7731 792-0 🖷 +49 7731 792-500
E-Mail: tools@orbitalum.com
Internet: www.orbitalum.com

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

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 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

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

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

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 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

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

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Dr.-Günter-Henle-Straße 8, D-56271 Mündersbach
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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

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
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

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

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

▼ 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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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

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

TECHNOLIT GmbH
Industriestr. 8, 36137 Großenlüder
☎ +49 66 48 69 - 0 🖷 +49 66 48 69 - 569
E-Mail: info@technolit.de
Internet: www.technolit.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

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

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

▼ Flux cored wires and strips 2280

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

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

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
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

▼ Tubular stick electrodes 2290

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 fluxes 2300

Bavaria Schweißtechnik GmbH
Wiesenweg 23, D-85716 Unterschleißheim
☎ +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

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

▼ TIG (GTA) welding rods 2320

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

▼ 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
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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

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☎ +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

▼ Platinum containing brazing fillers 2620

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▼ Silver brazing fillers 2630

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Internet: www.pfarr.de

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E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Other brazing fillers 2650

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13 Forms of solders and brazing filler

▼ Flux cored rods 2660

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▼ Flux coated rods 2670

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▼ Brazing and soldering wires, rods and strips 2680

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▼ Preforms and foils 2690

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E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Brazing and soldering pastes 2700

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E-Mail: info@matthey.com
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▼ Filler precoated plates 2710

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

▼ Brazing and soldering powders 2720

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▼ Stranded rods 2730

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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
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Lothar Spahn
Konstruktionsbüro
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Internet: www.spahn-konstruktion.de

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☎ +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

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E-Mail: zentrale@ptr-ebeam.com
Internet: www.ptr-ebeam.com

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

▼ Plasma cutting 2860

Carl Cloos Schweißtechnik GmbH
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Internet: www.cloos.de

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Internet: www.dodek.de

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Internet: www.jaeckleess.com

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E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

2 Plant for production of filler materials

▼ Gas manufacturing and liquefying plants 2900

DWT GmbH
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☎ +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

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Internet: www.ewm-group.com

SKS Welding Systems GmbH
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☎ +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

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▼ Programs (software) 3010

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Internet: www.simufact.de

SKS Welding Systems GmbH
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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
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E-Mail: zentrale@ptr-ebeam.com
Internet: www.ptr-ebeam.com

10 Other consumables

▼ Pickling pastes 3830

Chemetall GmbH
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E-Mail: chemetall.schweiz@basf.com
Internet: www.chemetall.com

▼ Brazing and soldering fluxes 3890

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Solvay Fluor GmbH
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E-Mail: werner.schmitt@solvay.com
Internet: www.solvay.de

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E-Mail: info@hpwirth.com
Internet: www.hpwirth.com

▼ Solder masks and resists 3960

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11 Measurement and sensor technology

▼ Throughput and flow-rate measurement 4150

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☎ +49 345 68 309-0 🖷 +49 345 68 309-49
E-Mail: info@hks-prozesstechnik.de
Internet: www.hks-prozesstechnik.de

▼ 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
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☎ +49 2680 181-0 🖷 +49 2680 181-244
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E-Mail: info@valkwelding.com
Internet: www.valkwelding.com

▼ Calibration 4220

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E-Mail: info@hks-prozesstechnik.de
Internet: www.hks-prozesstechnik.de

▼ Measuring devices for resistance welding (pulses, periods, current and voltage) and Rogovski belts 4310

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

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Internet: www.karldeutsch.de

▼ Monitoring devices for arc welding 4440

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E-Mail: info@valkwelding.com
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▼ Monitoring devices for resistance welding 4450

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12 Testing Technology – Non-Destructive Testing

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

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Internet: www.bialek-ing.de

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

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▼ Leak testing 4670

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▼ Radiographic testing 4710

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▼ Dye-penetration testing 4820

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▼ Design and analysis of welded structures 4905

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▼ Magnetic testing 5110

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

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▼ Miscellaneous non-destructive testing procedures 5580

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▼ Ultrasonic testing 5730

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▼ ultraviolet lamps 5755

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15 Testing Technology – Testing Procedures/ Testing Facilities

▼ Test tables 6125

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V Contract work and services for joining, separating and coating

2 Sub-contracting – Processing of specific materials

▼ Coated and plated materials 7050

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Carl-Friedrich-Benz-Straße 7, D-47877 Willich
☎ +49 21 54 48 37-0 🖷 +49 21 54 48 37-78
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Internet: www.durmat.com

VAUTID GmbH
Pioneering Wear Protection
Brunnwiesenstraße 5, D-73760 Ostfildern
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E-Mail: vautid@vautid.de
Internet: www.vautid.com

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☎ +49 2836 9119-0 🖷 +49 2836 9119-18
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Internet: www.welding-alloys.com

▼ Platinum, gold, silver 7320

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▼ Superalloys (hot isostatic pressure) 7390

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

▼ Surfacing 7710

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Pioneering Wear Protection
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Internet: www.vautid.com

Welding Alloys Deutschland GmbH
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Internet: www.welding-alloys.com

▼ Electron, laser beam welding 7770

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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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▼ Metal spraying 7890

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▼ Robot welding TIG/MIG/MAG 7940

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▼ Friction stir welding 7960

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▼ Maintenance, servicing, repair 8070

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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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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

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
❒ 3500 Characterisation of adhesives
❒ 3510 Plant construction (plasma equipment)
❒ 3520 Paint/lacquer technology
❒ 3530 Fibre reinforced plastic technology
❒ 3540 Adhesive application
❒ 3550 Integration into the production (production planning)
❒ 3560 Surface analysis
❒ 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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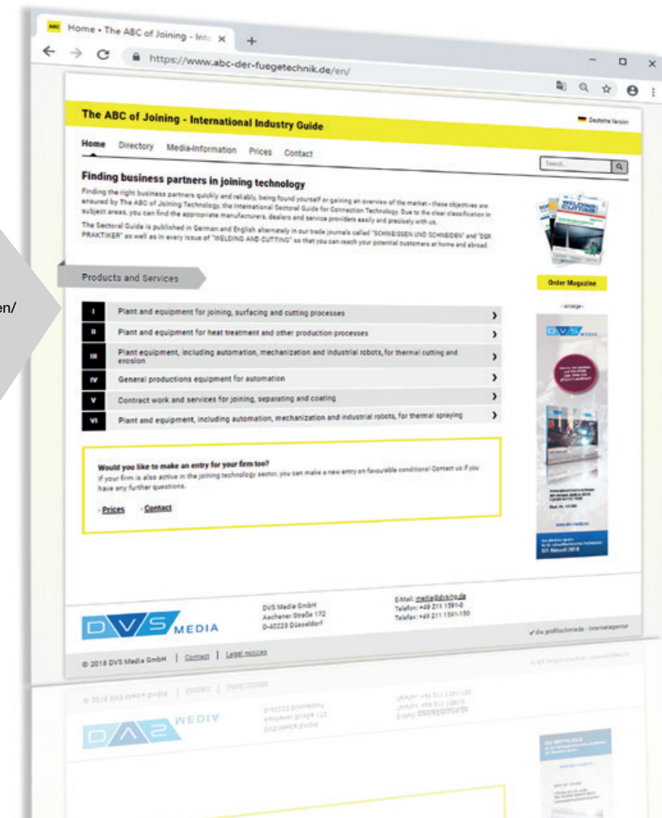

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