AFRICAN FUSION

SAIW

AUGUST 2017

Journal of the Southern African Institute of Welding

South African National Accreditation System

ACREDITATION OF CERTIFICATION BODIES OF FUSION WELDING OF METALLIC MATERIALS

The South African National Accreditation System (SANAS) is the sole national body mandated through the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006) to carry out accreditations in respect of conformity assessment. SANAS is recognised internationally by the International Laboratory Accreditation Cooperation (ILAC) and International Accreditation Forum (IAF) as equivalent to other accreditation bodies that are signatory to the ILAC and IAF.

As the sole accreditation body of the Republic of South Africa, SANAS provides formal recognition of conformity assessment bodies' (CABs) technical competence to perform certification functions as per their scope of accreditation. Accreditation is internationally and nationally recognised as a reliable and transparent method of recognising the technical competence of conformity assessment bodies (CABs) such as certification bodies.

Accreditation has proven to reduce the risk and enhance public confidence in the results that are produced from the CABs that are accredited. SANAS will be providing third party attestation of the certification bodies' technical competence that will certify manufacturer's fusion welding management system in accordance to ISO 3834.

SANAS launched a new accreditation programme for Fusion Welding of Metallic Material certification in accordance with ISO 3834. Section 3 (3), of the Pressure Equipment Regulations (PER), R 734 that was promulgated on 15th July 2009 by the Department of Labour, makes provision that all pressure equipments for use in the Republic of South Africa (RSA) shall be categorized and subjected to the applicable conformity assessment procedures contained in the SANS 347 in addition to the requirements of the relevant health and safety standard incorporated into the PER. The PER further makes provision that manufacturers have an obligation to ensure that all equipment designed and manufactured for use in the Republic of South Africa shall conform to the relevant module requirements applicable in accordance to SANS 347 categorisation. Under section 7.1.9 of SANS 347, ISO 3834 fusion welding of metallic materials is stated as one of the acceptable quality management system that can be adopted and implemented by manufactures in the fusion welding.

These pressure equipment regulation provisions, created a need for SANAS to develop the accreditation programme for the certification of manufacturers to the requirements of ISO 3834 parts.

For more information on the accreditation programme for certification bodies of fusion welding of metallic materials, please contact SANAS Projects Manager, Tumelo Ledimo on tumelol@sanas.co.za.

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New electroslag strip cladding (ESSC) solutions for the single layer cladding of Alloy 625 have now been developed. They enable the deposition of single layers with reduced thickness and allow industry Fe dilution requirements to be met in one single layer, where two layers would normally be necessary

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August 2017

FEATURES

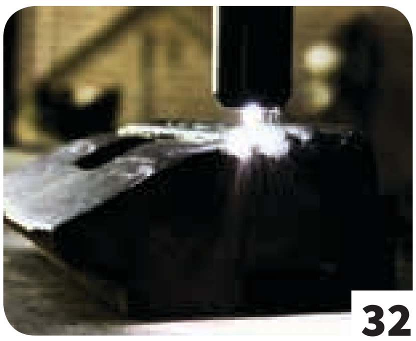
REGULARS


4


10


16


22


32

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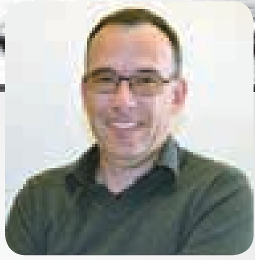


Since publication of the last issue of *African Fusion*, Morris Maroga, Jim Guild, Harold Jansen, Herman Potgieter and I have attended a very busy week in Shanghai, China. Several welding related events were staged, starting with the IIW Annual Assembly and International Conference.

Jim Guild ended his term as IAB chairperson and member of the IIW board of directors during this Annual Assembly and, on behalf of SAIW, I extend our gratitude to him for his commitment and dedication, to both SAIW and IIW.

Coinciding with the IIW events, the Beijing Essen Welding Fair was staged, an annual exhibition that has been held in China for 22 years. This year involved 977 exhibitors from 28 countries and regions, housed in seven halls with 100 000 m^2 of exhibition space – all dedicated to welding. The magnitude of the event was overwhelming.

What was immediately apparent was the level of automation. Even in China, which has massive numbers of low-cost labourers, manufacturing and fabrication is moving rapidly in the direction of automation. It made me feel that we may be lagging in this regard.

The Arc Cup Welding competition was also held to coincide with these two events in Shanghai. I am thrilled to be able to report that Samukelo Mbambani, our South African contestant, won first prize in the Student Welder Project category. This only goes to show that we do have skilled welders in South Africa. Thanks to merSETA for sponsoring Samukelo's participation.

Reinforcing the automation theme of the event, the Arc Cup also has a Robotic Welding category. At SAIW, we have already developed a welding automation course and we have been talking to local robotic service providers to support the programme. But we need to establish welding automation as a popular and thriving welding career choice.

The UK chose to adopt a service-based economy many years ago, mostly via financial services. Now they are realising that the economy needs to be more diversified and a strong focus is back on manufacturing again. Here in South Africa, we need to employ far more people. To do that, I believe, we have to ensure that we improve and grow our manufacturing sector.

For growth, manufacturing must be cost efficient and productive, which is where new technologies and automation come in. Superficially, it is believed that automation takes away jobs, but it is a known fact that it creates new opportunities at higher income levels. We should not be frightened about adopting new technologies in welding. Welding is an enabling technology that has the ability to improve quality of life – and the jobs will come.

We are also pleased with the progress Philippus Terblanche is making in preparation for the World Skills Welding contest in Dubai. Welding is not an easy skill. Like golf, it is difficult to master because it involves muscle memory and high levels of consistency and repeatability. Anyone at the top of their golf or welding game has spent hundreds of hours practising and honing their skill. We are sure Philippus will make South Africa proud.

Back at home, we look forward to opening the LIV Village Welding School in Durban next month, which is an Afrox initiative that we are supporting in terms of curriculum development and training solutions.

And please remember our annual dinners: in Johannesburg on October 29th at Emperors Palace and in Cape Town on October 27th.

Sean Blake

SA goes for **World Skills Welding gold**

On August 4 at Lincoln Electric SA's Weld Tech Centre in Midrand, the Chemical Industries Education and Training Authority (CHIETA) held an event to send off South Africa's welding champion to the 2017 World Skills International Competition. *African Fusion* reports.

Philippus Terblanche.

Having won gold in Durban earlier this year at the World Skills South Africa (WSSA) contest, Philippus Terblanche will put his skills against the world's best welders in the 2017 World Skills International event in Abu Dhabi from October 14 to 19.

Etienne Nell, South Africa's National Expert for World Skills Welding, who has played a central role in the organisation and running of the SAIW Young Welder of the Year – now the SAIW Youth Challenge and the precursor to the WSSA competition – believes that Terblanche's chances of medalling for South Africa are good. "During the finals of the SAIW Youth Challenge last year, the top three welders were separated by only 1.7 points out of the 100. That's competitive," he says.

Since then, the runner up in the SAIW Youth Challenge and the bronze medallist in the WSSA Welding competition, Samukelo Mbambani, has gone on to win a gold medal in the Student category at the International Arc Cup Welding Competition in Shanghai. Over to you, Philippus!

Following Philippus' SAIW Youth Challenge win last year, Nell describes how he went to visit him and the Terblanche family to discuss preparations for the national WSSA and World Skills contests. When Nell suggested a training and supervision programme, Philippus asked "Why? I have already won. My welding is obviously good."

Philippus Terblanche in the welding bay set up by Lincoln Electric SA at is Weld Tech Centre in Midrand. Inset: Through his personal trainer Eduan Terblanche, Philippus' aluminium welding has improved significantly.

"No! Not good enough," said Nell.

Reflecting on the incident, Philippus says that, although he was surprised and annoyed, Etienne was 100% right. "When I look back at the welding I did back then compared to what I can produce now, I know that my welding wasn't that good when this process started," he admits.

Supported by CHIETA, SAIW, DoE, ArcelorMittal and Lincoln Electric, Philippus Terblanche has been on an intensive welder training programme in preparation for the World Skills contest. Lincoln Electric, which is the global partner of the World Skills Welding event, has set up a welding booth at its Weld Tech Centre in Midrand that is identical to the one Philippus will have to use in Abu Dhabi.

Through Benoit Lamotte, Josef Henning and Thulani Mngomezulu from Lincoln Electric SA, Philippus has become very familiar with the Lincoln Power Wave multi-process welding machine he will be using. "Lincoln has top range welding equipment that makes it easier to weld, once you know how to set the machines up and what they can do. And thanks to guys from Lincoln for teaching me how to get the best out of this machine," he says.

Through an additional CHIETA sponsorship, Philippus has been allocated a personal welding trainer, Eduan Terblanche, for the push towards a medal. Terblanche runs a welding consultancy called Onsite Projects, which has a special focus on welder skills training. He is particularly renowned for his aluminium welding expertise, but his skills encompass the full set of welding processes, materials and positions.

Philippus' chances? "This morning, when Etienne Nell saw some of his most recent welding, he said that if he welds like that in the competition, he will finish in the top three – and Etienne should

Etienne Nell.

Tshidi Magonare.

Benoit Lamotte.

know, he has been involved in this competition for over 10 years," Terblanche tells *African Fusion*.

"Worlds Skills is a lovely platform for youngsters to be inspired and to learn about welding. Hats off to CHIETA and to Lincoln Electric for putting the money in and making these world-class facilities available to us to make our candidate successful," he continues.

"With welding, its not only about practice. Welders have to figure out what suits them in order to produce the quality required. Philippus has a lot of insight and a very consistent and steady hand. I believe he will do great. As I tell him, all he has to do is to weld the projects to consistently score above eight – and he can weld to that standard," says Terblanche.

Following personal training from Eduan Terblanche, which started in June, Philippus will be flying to Cleveland in the USA in September for a further few weeks of coaching from a previous World Skills Welding contestant from Lincoln Electric. "This is all going to be very good for him, whether he wins a medal or not," he suggests.

Speaking for Lincoln Electric at the event, Benoit Lamotte says: " I am happy and excited to be partnering with CHIETA and SAIW to train and send Philippus to World Skills. There is a huge need in education and training colleges for more and better welding skills development and, through our global expertise and experience, we at Lincoln are striving to find ways to address these needs in South Africa.

"All over the world, we train welders for industry and we have developed numerous technologies and strategies – such as our Virtual Welder and RealWeld coaching systems, and our U-Link online welding instructor course material – to help training schools to produce more welders with higher level skills," he says.

"As the equipment sponsor for World Skills Welding, we wish Philippus well and look forward to seeing the medal," he adds.

Addressing Philippus, Tshidi Magonare, the WSSA CHIETA project manager says: "World Skills is the Olympic Games for industry, where competition is at the highest level. You are our champion. Go make us proud – and bring us a medal."

In his thank you, Philippus opened with the words: "My name is Philippus Terblanche and I am a welder." This proud attitude to his profession speaks volumes about the value of supporting Worlds Skills and his participation.

Historic win for merSETA-sponsored SA welder

Osbourne Samukelo Mbambani from ArcelorMittal has won first prize in the Student category at the 5th International Arc Cup Welding Competition in Shanghai, China, which was held from 24 to 28 June, 2017. In total 16 countries participated in the event with Russia alone entering 26 competitors in all categories!

"This is an absolutely amazing result," says Etienne Nell, SAIW business development manager, SA team leader and senior category judge.

"Samukelo simply blew everyone away with his attitude, skill and application. Given the facts that he had never even been on an overseas trip before; that he competed against dozens of the best young welders in the world in a strange country; and that the marking was amongst the strictest of any world competition, what he achieved was nothing short of miraculous," Nell says.

He adds that Samukelo's relaxed, humorous and easy-going approach was matched by an incredible discipline and willingness to give of his best. "He was the perfect competitor and was a credit to himself, the SAIW and South Africa."

The Student Welder category of the competition is for welders no older than 22 and competitors first weld a plate, pipe and fillet weld using a specific process – GMAW in the case of Samukelo.

Then they enter the Finished Welding category where they assemble and weld, in all positions, a carbon steel project using four processes: GTAW, GMAW, SMAW and FCAW.

Nell says that the story of Samukelo getting to China is in itself quite bizarre. "He wasn't meant to go at all. SAIW Welding Challenge second-placed Angel Mathebula was originally supposed to participate in the Student Category but had to withdraw for personal reasons. So, we decided to take a chance on Samukelo who was placed third in the WorldSkills SA Nationals in Durban earlier this year. The rest is history … in the truest sense of the word," says Nell.

Samukelo was over the moon with his achievement. "China and the Arc Cup was an incredible experience. I never expected to win but it goes to show that one can only do one's best and hope that it's enough. This time it was! I must thank Etienne, the sponsors and the whole team for their support," he said.

SAIW's expanded technical services

African Fusion visits SAIW's Material Testing Laboratory and talks to the Institute's new technical services manager, Riaan Loots.

SAIW's technical services team, from left: Surekha Krishnan, project manager; Confidence Lekoane, welding consultant; Riaan Loots, technical services manager; Nicoline Kgoedi, material laboratory assistant; and Kegomoditswe Letlole, materials laboratory technician.

Born and bred in Pretoria, South Africa, Riaan Loots studied metallurgical engineering at the University of Pretoria and graduated with a BEng in 1997 and an MEng in 2003. "I started specialising in welding during my MEng, which involved research for Eskom on creep resistant materials for power stations: ½Cr ½Mo ¼V; 2¼Cr 1Mo; X20; and P91. I looked at aspects of welding these materials, more specifically, at the post-weld heat treatment procedures to overcome concerns with respect to reheat cracking," he informs *African Fusion*.

Between 2000 and 2003, Loots spent some years with Philip Doubell at Eskom's Rosherville Research and Innovation Centre and, after a short period away from welding, he returned as a contractor to do replica evaluation work – analysing etchings of microstructures lifted from *in-situ* pipe surfaces for creep damage.

"In 2008, I joined Zwane Inspections, a replication lifting and NDT company, and in 2012, I completed an honours degree at Tukkies and received the IWE diploma. From 2013 to 2016, I worked as a lecturer at the University, first under Madeleine du Toit and then under current head, Pieter Pistorius," he says.

Loots joined SAIW in August 2016 as a senior welding consultant in technical services and he was appointed to his current post as technical services manager in April 2017.

SAIW's technical services offering

Through the technical services department, the full range of technical skills at SAIW's disposal – welding; material and NDT testing; weld inspection; and all of the engineering analysis and investigation skills – are made available to members and non-members for productivity and quality improvement, problem solving and research and development work. "We offer consultancy services in several specialist areas, which include: failure analysis, welding related research and development, welding consumable evaluation, weld procedure qualification, welder qualification, post weld heat treatment and positive material identification," Loots notes.

The SAIW Technology centre is equipped to produce consumable samples using any process, to test welders and to machine the samples necessary for mechanical and metallurgical testing.

In addition, SAIW now has its own fully equipped materials testing laboratory, which is SANAS accredited to ISO 17025. "We can now offer full-circle services to clients. For welding procedure qualification, for example, we can witness the welding required at a clients premises and bring the samples back to our own laboratory, where we can do all of the required mechanical and metallurgical testing and analysis. We can cut and prepare samples, perform the mechanical tests required by the standard, prepare and analyse micrographs, perform diffusible hydrogen tests and fully record and report all the results needed for a procedure qualification record (PQR) or consumable verification," he tells *African Fusion*. "Along with the welding parameters and other critical variables, the test results are compiled into a full PQR document, which, within the range of the parameters used, is used to compile a welding procedure specification (WPS)," he explains.

"As a starting point for this process, we like to engage with welders on the practical side of producing a weld, so that we know that the developed procedure will be easy to implement in practice. In this regard, we also have skilled welders here to call upon," he says.

"Performance testing is another one of our routine offerings," he continues, "testing welders according to a given

WPS for code approvals. After witnessing the welders following the procedure, we take the test plate, cut the test pieces required and then perform the qualification tests. Also, because we have welding facilities onsite, we are able to bring welders into SAIW, where we perform all aspects of the performance tests," he suggests.

SAIW technical services is also doing more and more consumables testing. "When a consumable arrives from the manufacturer, it comes with a 3.1 certificate, which certifies as-manufactured composition and compliance to consumable standards such as AWS A5. Many companies such as Sasol, however, require additional verification, which involves retesting a consumable sample from each batch and producing a 3.2 verification certificate.

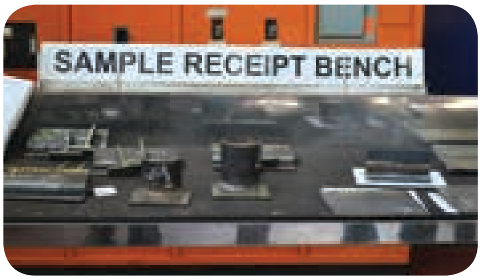
"Consumable testing involves a lot of welding, because mechanical test pieces must be cut from the weld-metal only, so even if a consumable is only going to be used for a root weld, weld metal as thick as the test specimen has to be deposited," Loots explains. "Our advantage is that we can do all of this work in-house. We have the skilled welders; the machines and operators to cut the test pieces; the mechanical testing equipment, including tensile, Charpy toughness and hardness testers; the equipment needed to produce micrographs; as well people skilled in micrographic analysis," he adds.

On the consultancy side, Loots says: "Few people are aware that we can assist with failure analysis and complicated repair procedures. We can offer fitness for service and remaining life analysis as well as feasibility studies and cost analysis of repair procedures, which are often complex because they are not directly covered by any of the construction codes, and acceptance criteria do not apply in quite the same way as for new-build fabrication," Loots points out.

He describes some current consulting work being done to reduce reject rates on an ongoing site construction project. "We hope to find a way to optimise the onsite welding operations so as to achieve lower reject/rework rates and better first-time quality.

"This might involve, for example, identifying some welders that need better training, or adjusting the welding procedure to make it easier for welders to achieve flaw-free welds. We can do this by analysing the data already being collected through the quality and NDT testing processes. All we need is enough data from the client to analyse for causal trends," he explains.

Above: SAIW's fully automated MTS Criterion tensile testing machine.



Right: The sample receipt bench outside of the SAIW weld test laboratory.

"We believe we are ideally resourced to offer short-term contract research and problem solving services such as these," Loots adds.

He says that more and more fabricators are adopting ISO 3834 certification to raise their welded-product quality and to improve global competitiveness. Meeting ISO 3834 requirements, however, requires proof that WPSs, consumables and welders are qualified to meet the minimum standards required.

At the same time, cost pressures and the increased availability of lower cost imported consumables and equipment is creating increased levels of uncertainty with regard to the validity of the certificates being issued by the 'middlemen'. "The issue is easily resolved by getting a batch tested and a 3.2 verification certificate issued – and this can be a very cost effective options if a low cost consumable proves adequate," he notes

"At the end of the day, our members are the life blood of SAIW and we are always striving to improve our service to them. We want to know what our members would find useful, so that we can tailor our service to best meet their needs.

"We are happy to consider offering new services that we cannot yet accommodate, even if we have to employ outside consultants to get started," he concludes.

Service	Equipment available
Mechanical testing	
Tensile & Bend testing	MTS Criterion 64.305 (300 kN)
Charpy V notch Impact testing	450 joule SANS Charpy impact test machine
Vickers hardness testing	emcoTEST Durascan 70 (10 grams to 10 kg load)
Rockwell hardness testing	Wilson Rockwell hardness tester
Chemical Testing	
Spectrographic analysis	Bruker Q2 Ion spectrometer
X-Ray Fluorescence analysis (XRF) & positive material identification	Bruker S1 Titan XRF analyser
Diffusible hydrogen analysis	Bruker G4 Phoenix diffusible hydrogen analyser
Microstructural evaluation and reporting	Nikon microscope Eclipse MA-200
All equipment needed for test sample preparation is available in house.	

The testing services available from SAIW's Material Testing Laboratory.

SAIW and Jomele form training partnership

Jomele Training and Placements, in association with Hydra-Arc, is partnering SAIW for the delivery of IIW IWIP (International Welding Inspection Personnel) – Basic inspection training programmes in Secunda.

"We have entered into an agreement with Jomele for our welding Inspection training programmes to be delivered as complementary services to the welder training and other programmes they already offer," says Sean Blake, SAIW executive director.

"There is an increasing need for qualified personnel to meet the requirements for supervisors and inspectors specified by quality systems such as ISO 3834 and ISO 15085," he says, adding, "while Mpumalanga has an acute need for personnel with these qualifications, this is an internationally recognised course, so it also broadens career prospects for the local trainees well beyond the provincial borders."

Secunda-based Bethuel Mabiletsa, CEO of Jomele Training and Placements says: "The new welding inspection training course offers local youth a golden opportunity to advance their careers in welding. We already have 90 students on the IIW IWIP – Basic level course and these students have already completed 12 months of practical training in our Mshiniwami Artisan Academy," he informs *African Fusion*.

Photographed outside Sky Hill Heavy Engineering after signing a partnership agreement for the delivery of IWIP-basic welding Inspection courses are: Henry Meiring, GM of the Mshiniwami Artisan Academy; Bethuel Mabiletsa, Jomele's CEO, and Sean Blake SAIW executive director.

A further 110 trainees that are currently doing practical training have been identified as potential candidates for the programme, which is being funded by the Mpumalanga Provincial Government.

South Africa now part of IASDBR welding alliance

South Africa, through the SAIW, is now part of a powerful international welding alliance – The International Alliance for Skills Development including BRICS (IASDBR) – which aims to incorporate all the countries in this region in a cooperative initiative to provide welding training to the youth.

"The training will align with the International Institute of Welding (IIW) standards and will help to boost employment in the welding industry throughout the alliance countries," says SAIW business manager Etienne Nell.

He adds that throughout the world welding is an excellent career choice for young people even in more challenging economic conditions. "With so many powerful countries pulling together, the opportunities for young people to develop a job-providing skill will grow exponentially," he says.

South Africa became a member of the alliance when Nell signed the agreement on behalf of the SAIW at the opening ceremony of the ARC Cup, which was held recently in Shanghai, China.

Some of the countries that will be working closely together are: South Africa, China, Russia, India, Ukraine, Singapore, Philippines, Cameroon, Ghana, Nigeria and others.

Demand for 3834 Certification continues

The demand keeps on growing for ISO 3834 certification. This is according to Herman Potgieter, CEO of SAIW Certification, which manages the ISO 3834 certification process. "Sometimes people support something only because they see so many other people doing it. But this is not the case in our industry because we think about things carefully before we do anything," he says.

"In simple terms the demand is growing because ISO 3834 certification is so very important," believes Potgieter. "It's the basic stamp of quality in the welding fabrication business and it is a considerable boost to one's business potential."

He adds that ISO 3834 certification is for all fabricators. "I must reiterate that this is not for big companies only. It's for all companies. In fact smaller, lesser known companies could benefit more because this stamp of approval shows they're on a par with the best."

Companies certified so far during 2017 include: LHL Engineering; Lead EPC; Murray and Roberts – Secunda Oil and Gas; FFS Refiners; HC Heat Exchangers; Medi-Clave; Master and Master Engineering; Vessel Fab; Steval Engineering; Clarko Piping Contractors; AWS Pipelines; and Mbali Industrial Solutions.

All these companies now have IIW Manufacturer Certification Scheme certificates that testify compliance with ISO 3834: Quality requirements for fusion welding of metallic materials.

FFS Refiners' fabrication workshop, which manufactures a wide range of plant and equipment from specialised road tankers built to SANS 1518; pressure vessels and heat exchangers made to ASME VIII; and filters, reactors, fractionation columns, stills and centrifuges, is now accredited to ISO 3834 Part 2.

SAIW joins Arc Cup organising committee

At the recently held Arc Cup in Shanghai, China the Institute was asked to become a member of the Arc Cup organising committee and the SAIW readily agreed!

"Not only is this a wonderful honour for the Institute but it also makes sense as this competition is becoming increasingly central to our international welding activities," says SAIW's Etienne Nell, referring to the SAIW recently having become a signatory to the International Alliance for Skills Development (IASDBR).

He says that this puts the SAIW on centre stage in terms of welding in the developing world.

"We will be upping the ante in terms finding South African youth to participate in the Arc Cup. Obviously we will be using our own Youth Challenge competitions as a source and we also hope to host a series of mini competitions throughout the country specifically for the Arc Cup, which would have the dual effect of training young people, through international experience, to do well in the SAIW Youth Challenge," Nell concludes.

High-quality electroslag strip cladding for alloy 625

Global voestalpine Böhler Welding specialists for cladding, petrochemical and chemical processing, M Decherf, R Demuzere and F Ciccomascolo, present an advanced electroslag strip cladding process that enables thin single layer Alloy 625 deposits to be achieved that meet the iron (Fe) content requirements for the oil & gas and chemical processing industries.

One of the most interesting features of the electroslag strip cladding process (ESSC) is that it can achieve the desired chemical composition in only one layer for almost all alloys used in the process industry. Among them, Alloy 625 is of course widely used in the oil & gas and chemical processing industry.

For this alloy, new thin single layer solutions have been developed with the aim of reducing the overlay thickness in order to save material and improve productivity, while meeting the deposited metal industry requirements, which are very demanding in many cases.

Controlling the dilution from the parent material and balancing the chemistry by means of new flux features, it has been possible to achieve high quality results with single layers thinner than 4.0 mm, with the iron content below 10% as per the requirement. An iron content requirement below 7% can also be met in a single layer, while two layers are necessary with conventional solutions available in the market.

This article gives an overview of the relevant specifications, followed by details on the applied welding conditions and the quantitative results achieved, which show the benefits in terms of material saving and productivity increases compared with conventional strip cladding. Chemical composition and mechanical properties obtained with the newly developed solutions are also presented. Finally, results achieved in relevant corrosion tests are discussed.

Above: Cladding using voestalpine Böhler Welding's advanced strip cladding process enables thin layer Aloy 625 deposits that meet iron (Fe) content requirements.

Introduction

For decades, electroslag strip cladding has been the most widely applied process to create corrosion-resistant overlays on the surfaces of medium to large vessels in non- or low-alloyed steel. It provides a cost-efficient solution over using components in full stainless steel or nickel alloys. Many applications are found in, for example, the chemical,

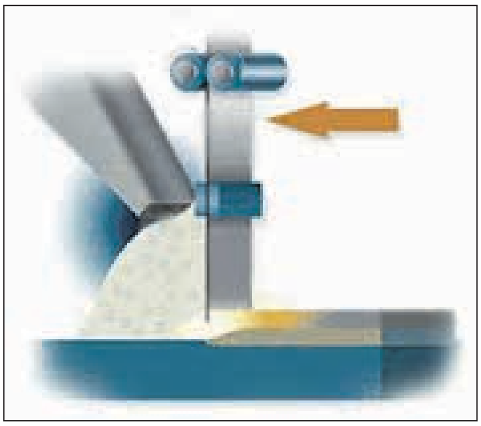


Figure 1: The electroslag strip cladding (ESSC) process. In the ESSC process, the heat needed to melt the strip and the parent metal surface is generated by the electrical resistance of the molten flux. There is no arc and therefore dilution with the parent metal and weld penetration is much lower than with arc processes such as SAW cladding.

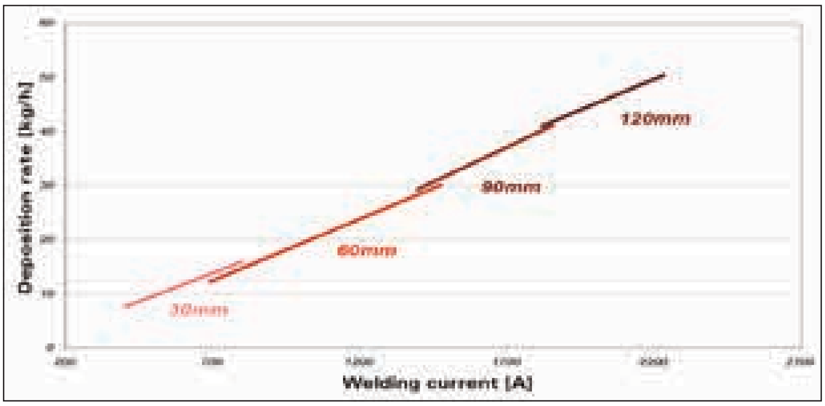


Figure 2: The deposition rate of the ESSC process in kg/ h or covered surface in h/m² increases proportionally with the strip width. Increasing the strip width may require additional investments in power sources and welding heads.

Strip	C	Mn	Si	Cr	Ni	Mo	Nb+Ta	Al	Fe	Cu	Ti	Other
Alloy 625 E NiCrMo-3	≤0.10	≤1.0	≤0.75	20.0-23.0	≥55.0	8.0-10.0	3.15-4.15	≤0.4	≤7.0	<0.50	≤0.40	≤0.50

Table 1: Chemical composition requirements Alloy 625 according ASME IIC SFA 5.11: ENiCrMo3.

Strip	C	Mn	Si	Cr	Ni	Mo	Nb	Al	Fe	Cu	Ti	N
SOUDOTAPE 625 SFA 5.14: EQ NiCrMo-3	0.01	0.01	0.06	22.1	Bal.	8.5	3.4	0.14	0.14	<0.01	0.15	-

Table 2: Chemical composition of the strip, wt. %. Strip size: 60×0.5 mm.

Item	C	Mn	Si	Cr	Ni	Mo	Fe
S355	0.164	1.32	0.2	0.018	0.01	0.004	bal.

Table 3: Chemical composition of the S355 base material, wt. %.

petrochemical, nuclear and paper and pulp industries. The process has a number of distinct advantages:

- High deposition rate.
- High travel speed.
- Low dilution.
- Low and uniform penetration.
- Flat surface.
- Homogeneous weld metal.
- Weld chemistry obtainable in one layer.

The low dilution with the parent metal is an important advantage in the sense that the desired chemical composition can be reached in just one layer, whereas arc processes used for cladding require two or more layers. The productivity in square metres per hour can be further increased by using a larger strip. Strip dimensions are typically 30×, 60× or 90×0.5 mm, but there is an increasing interest in 120 mm wide strip, when allowed by the dimensions of the component to be clad.

Staying with the same strip size, without making additional investments in heavier equipment, there are new possibilities to increase the productivity, making use of innovative ESSC fluxes with excellent weldability that have come onto the market only very recently. They have been developed with two objectives in mind, while obtaining a homogeneous Alloy 625 chemical composition in a single layer:

- To increase the economy of the ESSC process through reduced strip consumption due to thinner single layers, in the case of the Fe <10% requirement.
- To increase the economy of the ESSC process through both reduced strip consumption and reduced overlay time by providing a single layer solution instead of a two-layer solution, in the case of the Fe <7% requirement.

Alloy 625 is often used for cladding carbon steel, such as ASME SA516 Grades 60, 65 and 70. Important applications are found in gas-oil separators, slug catchers, valves and various heat exchangers. Requirements for clad metal are generally specified in ASME II Part C SFA 5.11 [2], ASME IX [3]. The required corrosion testing depends on the corrosive medium and is therefore defined in agreement with the equipment purchaser. However, as components are often subject to pitting and/or intergranular corrosion due to reducing media, the most commonly selected corrosion methods are ASTM G48 Method A [6], and ASTM G28 Method B [7].

Important to mention in relation to Alloy 625 is the iron content. For base materials a maximum of 5% Fe is allowed, whereas for clad weld metal a maximum of 7% is often stipulated in agreement with ASME II part. C SFA 5.11[2], even though this standard is valid for shielded metal arc welding only. To enable the deposition of Alloy 625 composition in one layer with traditional ESSC solutions, this limit is often further increased to maximum allowable limit of 10% Fe.

The new flux for Alloy 625 enables the deposition of matching composition weld metal with an iron content Fe <7% in a single layer, where traditional ESSC requires two layers. Alternatively, an iron content of Fe <10% can be reached in a thin single layer, where traditional cladding requires a thicker layer. It accounts for major savings on strip consumption and welding time.

The newly developed flux has passed all relevant mechanical and corrosion testing in accordance with mentioned standards and latest industry requirements and has been extensively field-tested.

Experimental scope

Tests were performed to reproduce typical industry conditions for a very common application, the cladding of S355 carbon steel plates with Alloy 625.

In the test programme, innovative thin layer solutions were compared to two of the most commonly used conventional strip/flux combinations: for single layers: SOUDOTAPE 625/RECORD EST 625-1 and for two layers: SOUDOTAPE 625/RECORD EST 201. The objective was to investigate advantages and soundness of the new solutions.

The chemical composition of strips and base material used in this research project are shown respectively in Table 2 and Table 3.

Test programme

Alloy 625 – sample preparation

The chemical composition of Soudotape

Strip cladding combination	Layer	Parent material	I (A)	U (V)	Travel speed [cm/min]
Soudotape 625 / RECORD EST 625-1	1	S355	1250	24	20
Soudotape 625 / RECORD EST 625-1 LD	1	S355	900	24	18

Table 4. Welding parameters for Alloy 625 ESSC with target Fe < 10%.

Strip cladding combination	Layer	Parent material	I (A)	U (V)	Travel speed [cm/min]
Soudotape 625 / RECORD EST 201	2	S355	1100	24	16
Soudotape 625 / RECORD EST 625-1 LD	1	S355	1150	24	16

Table 5: Welding parameters for alloy 625 ESSC with target Fe < 7%.

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625 matches the Alloy 625 analysis and has a very low Fe content. RECORD EST 625-1 is an alloying flux, adding chemical elements to the weld metal to compensate for dilution with the parent material. RECORD EST 201 is a neutral flux as such compensation is not necessary in the case of two layers.

The new flux for Alloy 625 is called RECORD EST 625-1 LD – also an alloying flux using the same Soudotape 625 strip but with a completely new formula to enable thinner layers. Two targets were selected for Alloy 625 cladding; Fe <7.0%, as required in ASME II part. C SFA 5.11[2] and Fe <10% which is a typical industry requirement that can be seen as a deviation from the code. Welding parameters used for the Alloy 625 sample preparation are given in Tables 4 and 5.

Samples were prepared in both the as-welded and PWHT condition. The heating rate was 85 °C/h from 300 °C, with a PWHT temperature of 620 to 675 °C and a holding time of one to 24 hours.

Specimen position	
Sample thickness	10 mm
Bending angle	180°
Mandrel diameter	40 mm

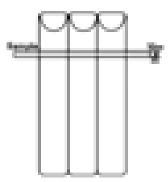

Table 6: Side bend tests conditions and Figure 3: the area of extraction for the bend test sample.

Corrosion test programme

A corrosion test programme was conducted for the Fe < 7% target, comparing the properties of single layer claddings produced with the conventional flux RECORD EST 625-1 and the new flux RECORD 625-1 LD. The following tests were performed:

- Pitting corrosion detection according to ASTM G48 Method A [6] with samples exposed for 72 hours at 50 °C.
- Pitting corrosion detection according to ASTM G48 Method A [6] in order to determine the Critical Pitting Temperature (CPT).
- Intergranular corrosion detection in the presence of reducing media, according to ASTM G28 Method A [7], with a sensitisation treatment of 675 °C for one hour and 120 hours exposure time. Samples were taken in the BSM position (sample taken in the middle of the bead) and BSL position (sample taken between two beads containing a bead overlap).

Bend test

Additionally, side bend tests were performed in both as-welded and post-weld heat-treated conditions according to ASTM E190. Testing conditions are shown in Table 7. Specimen thickness was 10 mm and was extracted as per Figure 1.

Results

Chemical composition

Tables 7 and 8 show the chemical composition measured at the surface of claddings made with the conventional flux RECORD EST 625-1 and the new flux RECORD EST 625-1 LD respectively, for the Fe <10% and Fe <7% targets. The deposit thickness from the base material to surface is also indicated.

In the Fe <10% scenario, the typical Alloy 625 analysis was achieved with both combinations. The deposit

Figure 4: Side bend test. Cladding deposit produced with RECORD EST 625-1 after PWHT at 670 °C for 24 hours.

Figure 5: Side bend test. Cladding deposit produced with RECORD EST 625-1 LD after PWHT at 670 °C for 24 hours.

ESSC combination	C	Mn	Si	Cr	Ni	Nb	Mo	Fe	N	Total clad layer thickness
Soudotape 625 / RECORD EST 625-1	0.025	0.2	0.3	21.5	Bal.	3.5	9.0	7.9	0.006	5.0 mm
Soudotape 625 / RECORD EST 625-1 LD	0.022	0.12	0.35	22.4	Bal.	3.6	9.7	8.0	0.006	3.6 mm

Table 7: Top surface analysis for ESSC of Alloy 625 with Fe < 10% target, wt. %.

ESSC combination	C	Mn	Si	Cr	Ni	Nb	Mo	Fe	N	Total overthickness
Soudotape 625 / RECORD EST 201*	0.020	0.10	0.3	21.5	Bal.	3.0	8.8	2.5	0.007	8.4mm
Soudotape 625 / RECORD EST 625-1 LD	0.019	0.12	0.32	22.3	Bal.	3.6	9.6	6.1	0.007	4.8mm

*Table 8: Top surface analysis for ESSC of alloy 625 with Fe < 7% target, wt. %. *Two layers.*

Strip cladding combination	ASTM G48 A (72h @ 50°C) Corrosion rate [mm/yr]	ASTM G48 A (72h) C.P.T. [°C]	ASTM G28 A (120h) Corrosion rate BSL* [mm/yr]	ASTM G28 A (120h) Corrosion rate BSM** [mm/yr]
Soudotape 625 / RECORD EST 201	0	82	0.650	0.680
Soudotape 625 / RECORD EST 625-1 LD	0	84	0.420	0.529

*Table 9: Corrosion test results for alloy 625 – corrosion rates in mm per year. *BSM: sample taken between two beads in the overlap; **BSL: sample taken in the middle of the bead.*

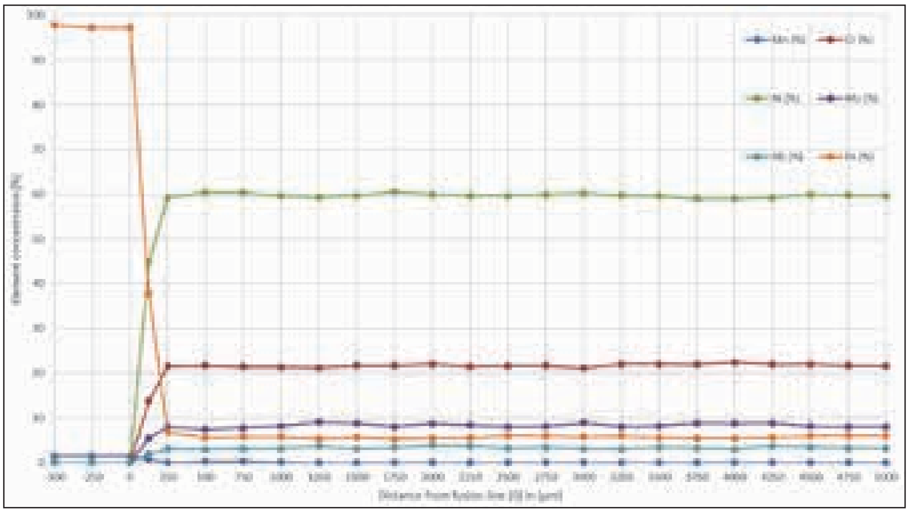

Figure 6: Chemical analysis survey from base material to top surface of cladding with RECORD EST 625-1 LD, <7% Fe scenario.

Figure 7: Bead profile of cladding with RECORD EST 625-1 LD, with Fe < 7% scenario.

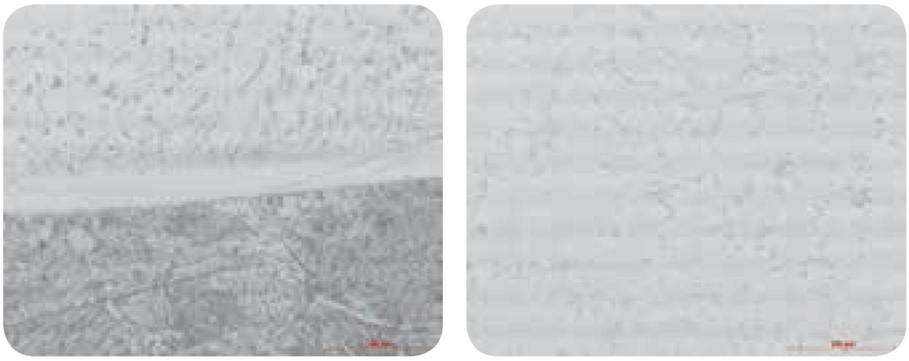

Figure 8: Micrographs. RECORD EST 625-1 LD cladding as welded. From left to right: fusion line area, middle of the bead.

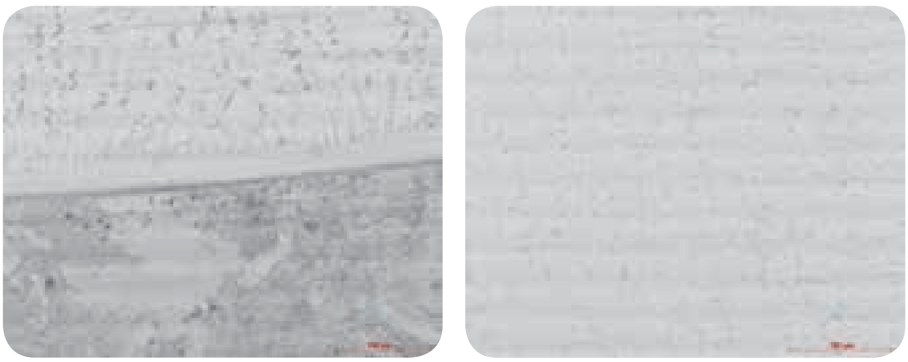

Figure 9: Micrographs. RECORD EST 625-1 LD cladding after PWHT at 670 ºC for 24 hours. From left to right: fusion line area, middle of the bead.

obtained with RECORD EST 625-1 LD shows a slightly higher percentage of Cr and Mo, resulting in a higher Pitting Resistance Equivalent Number (PREN), (54.5 versus 51.3). Important to note is the difference in thickness between the two deposits (3.6 mm against 5.0 mm) which leads to a deposit saving of 28% as strip consumption was 30.4 kg/m^2 compared with 42.2 kg/m^2

In the Fe <7% scenario, two layers were necessary to achieve the desired Fe content with the conventional solution, resulting in almost double the welding time. In terms of time to cover a surface, only 1.6 h/m^2 was needed with the new solution compared with 3.1 h/m^2 with the conventional one. Also in this case, a higher PREN was reported (54.1 compared with 50.7). Because of the smaller layer thickness, the saving on deposited metal obtained with RECORD EST 625-1 LD is about 40%, with a strip consumption of 40.5 kg/m^2 compared with 70.9 kg/m^2.

Corrosion tests

Corrosion tests results for the traditional and new strip/flux combination are reviewed in Table 9, where corrosion rates are reported. Results are fully satisfactory and meet the industry requirements.

Side bend tests

In the side bend tests, no cracks were found with the cladding deposits realised with RECORD EST 625-1 LD, both in the as welded condition and after severe PWHT at 670 °C for 24 hours, showing soundness and integrity of the weld overlay (Figures 4 and 5).

Through thickness analyses

To assess the homogeneity of weld deposits produced with RECORD EST 625-1 LD with the Fe <7% target, a complete chemical analysis survey from base material to top surface of the cladding was carried out. The chemical composition was measured transversally through-thickness in steps of 250 µm.

The through-thickness analysis is shown in Figure 10 where the main chemical elements in weight % are reported from the fusion line to top surface. As it can be expected with the ESSC process, the chemical analysis is already quite stable from 250 µm from the fusion line, resulting in more than 4.4 mm of deposit with the desired chemistry (see Figure 6).

Macro and microscopic examination

Figure 7 shows a macrograph of the bead profile. The fusion line is flat and free of defects. The total thickness (including

Figure 10: Advanced electroslag cladding with RECORD EST 625-1 LD showing the self-releasing slag.

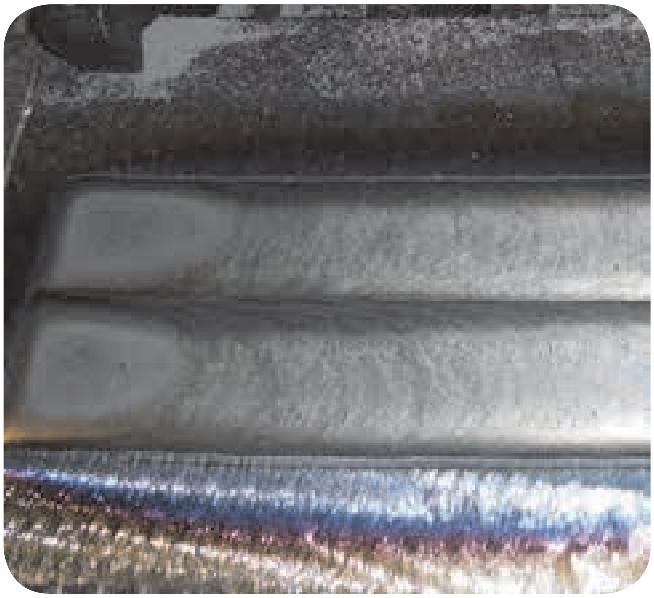

Figure 11: Cladding with RECORD EST 625-1 LD: flat beads, straight edges, no slag adherences.

penetration) is around 5.16 mm. The ratio of penetration : total thickness equates to a geometrical dilution of 5.8% matching with 6.0% Fe.

Microstructure analysis reveals a smooth transition from the ferritic non-alloyed base material to the austenitic nickel-base structure with some Mo precipitates, which are typical for Alloy 625. All the micrographs were subjected to electrolytic etching 10% Cr_2O_3. (Figures 8 and 9).

Weldability

The flux RECORD EST 625-1 LD has excellent weldability. Slag detachability is fully satisfactory, with self-lifting slag without remainders, and the deposit features flat beads and straight edges, (Figures 3 & 4). These qualities have been confirmed by field tests in the cladding of reactors shells under industrial conditions (Figures 5-7).

Figures 12: Field tests. Cladding of a reactor shell with RECORD EST 625-1 LD.

Conclusion

New ESSC solutions for the single layer cladding of Alloy 625 have now been developed. They enable the deposition of single layers with reduced thickness and allow industry Fe dilution requirements to be met in one single layer, where two layers would normally be necessary.

Alloy 625 layer composition with Fe < 10% can be realised in a single layer with reduced thickness compared with traditional industry solutions, while Alloy 625 layer composition with Fe <7% can be deposited in a single layer, where two layers are needed when using the traditional technique.

The new ESSC strip/flux solutions account for major time savings in terms of clad surface deposition rates in metres/hour as well as savings in strip material and flux consumption. The new strip/flux combination satisfies all mechanical and corrosion requirements laid down in various standards relevant to the industry.

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Welding techniques and quality evaluation on zirconium-steel clad plates for large-scale reactors

L Wu, J Cui, HB Zhang, KJ Song, and PS Du

This paper from the proceedings of the IIW 2017 International Conference in Shanghai, China, describes the development of successful welding techniques for zirconium-clad pressure vessels and reactors using narrow gap submerged arc welding, gas tungsten arc welding and some shielded metal arc welding.

Zirconium has excellent corrosion resistance to acid, alkali and a variety of metal fluids. It has superior corrosion resistance to niobium, titanium and some other metals in certain corrosive mediums, which makes it suitable for corrosive media where titanium is not. [1]

Zirconium has, therefore, found more and more application in modern petroleum and chemical industries. However, zirconium is among the more expensive metals, which means the cost of pressure vessel manufacturing using full-thickness zirconium plate would be extremely high, especially for large scale high temperature and pressure equipment, prohibiting its widespread use.

On the other hand, zirconium-steel composite plate becomes an economically viable material for the manufacturing of such pressure equipment.

In this paper, welding technology and inspection characteristics of the core equipment – the reactor used for the synthesis of acetic acid by the method of methanol carbonylation – are briefly introduced. Moreover, some details that should be taken into consideration in the fabrication of the zirconium-steel composite plate equipment are briefly described.

Technical parameters of the reactor

The main technical parameters of the reactor are shown in Table 1, while the dimensions of the reactor structure are shown in Figure 1.

The main body is made of zirconium-steel composite plate (SA516Gr55 and R60700). The material and dimension of the top and bottom spherical vessel head are SR1653×(32+4.76), and the cylinder has dimensions of ∅3 300×460×(60+4.76) with the stirring part as internal components.

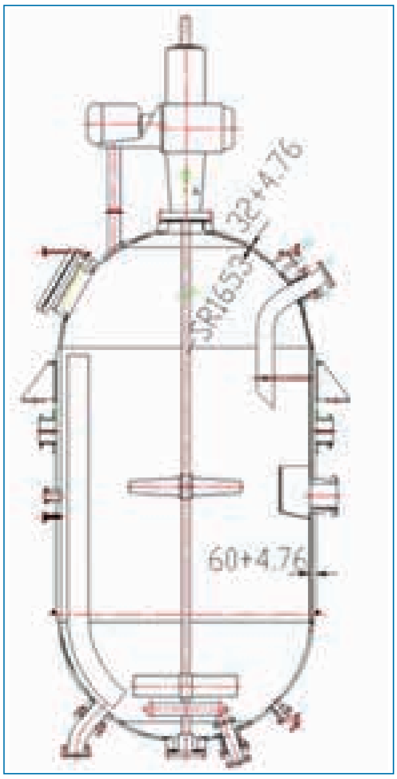

Figure 1. The dimensions of the reactor structure.

Welded joint design

Fusion welding is not suitable between zirconium and steel due to a series of brittle intermetallic compounds that will form in the welded joint. As a highly active metal, zirconium is easily embrittled by impure elements at high temperature, especially nitrogen, oxygen, hydrogen and carbon. Hence, it is difficult to obtain a sound welded joint directly by fusion welding [2].

At present, the zirconium-steel composite plates are widely joined by fusion welding of the steel base layer and the zirconium composite layer respectively, this to prevent any mutual fusion between the two layers. Firstly, the steel base layer is welded. After the post-weld inspection, the zirconium composite layer is welded independently.

Longitudinal and circular welding seam on the backing plate and cover plate

The welding of zirconium and steel composite plate is prepared as follows.

Dual side protection is applied during welding of the longitudinal and circular seam of the composite layer. Firstly, welding is performed on the steel base layer. Afterwards, the welded seam on the base layer is ground until flush with the base layer and an inspection is performed on the welded seam.

Sequentially, the zirconium backing plate, which is also the cover layer, is placed, with the bottom surface firmly covering the top surface of the composite layer (in the middle), as shown in Figure 2. Welding on the composite layer and sequential inspection is then performed.

Parameters	Value
Design pressure	3.3 ±0.1 MPa
Design temperature	210 ±12 °C
Operating pressure	2.9-3.1 MPa
Operating temperature	185-195 °C
Medium	CO, methyl alcohol, acetic acid, catalyst
The body material	SA516Gr55 and SB551 R60700
Weld joint factor	1.0
Corrosion allowance	0 mm
Hydraulic test pressure	4.2 MPa
Net weight	~46 396 kg
Equipment volume	~58.1 m^3
Equipment water weight	~104 496 kg
Container categories	III
Motor capacity	55 kW
Tool speed	88 rpm
Pin tool diameter	101.6 mm
Tool material	R60702, R60705

Table 1: The technical parameters of the zirconium clad reactor vessel.

Lastly, the zirconium cover layer is welded. It is worth noting leak detection pipe can be used as the gas flow tunnel for the welding of zirconium cover and composite layer. Also, it can be designed as the leak protection system for the manufacturing of the equipment.

Connecting pipe, head and cylinder

Figure 3 shows the welding scheme for the small diameter connecting pipe (∅<219 mm) and the cylinder, both of which are made of the zirconium-steel composite plate. Such a structure is simple and practical and is flexible for assembly and welding. However, the large stress concentration is formed in the joint corner of the connecting pipe. It is therefore recommended that connecting pipes of small diameters are not used in high temperature and high-pressure zones.

Figure 4 shows the welding scheme for the connecting pipe of the larger diameter (∅≥219mm) and the cylinder, both of which are also made of the zirconium-steel composite plate. This structure can avoid the problem of stress concentration at the corner of the connecting pipe (as shown in Figure 3), and has a good sealing effect.

However, this structure requires careful grinding of the joint of the carbon steel flanges and zirconium flanging, and the zirconium flanging requires special processing, which increases the manufacturing cost.

Welding experiments

During the manufacturing process of the reactor, five welding methods including manual gas tungsten arc (GTAW), electrode/shielded metal arc welding (SMAW), submerged arc welding (SAW), and plasma arc welding are used with consideration of the material, heat input and lateral shrinkage.

Welding of base layer

The base layer is made of SA516Gr55, which is a low carbon steel that has good weldability. The conventional welding methods and processes are suitable for this steel. However, due to the specialty of the structure and material of the zirconium-steel composite plate, it is an important requirement that the heat input of the base layer during welding, especially for the joint that is adacent to the composite plate, should not be too high.

In the manufacturing process, the welding preparations of the longitudinal and circular welding seams are prepared using bevelling machine. The backing GTAW welding pass is initiated from the inner side, following by two or three fill layers using shielded metal arc welding. The remaining layers are filled from the outside using narrow-gap submerged arc welding. With this method, the welding heat input is assured to be low and the cleaning of the root weld pass with gas gouging is not necessary. Moreover, the lamination of the joint is not badly affected.

The welding parameters of the steel base layer are listed in Table 2.

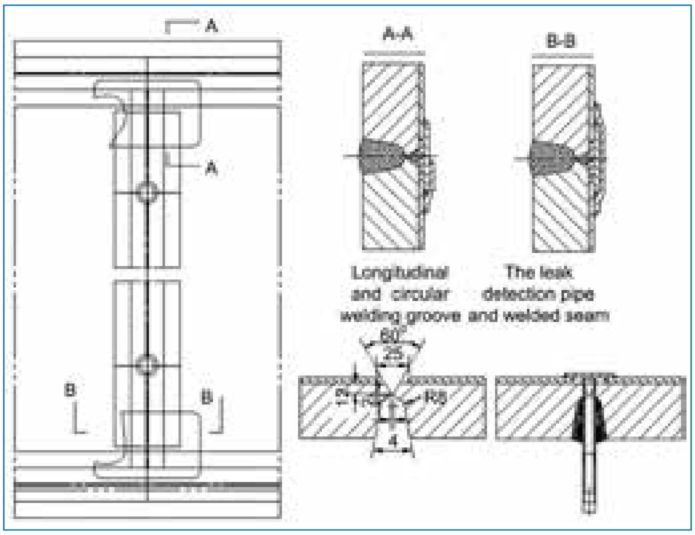

Figure 2: The welding of the zirconium and steel composite plate.

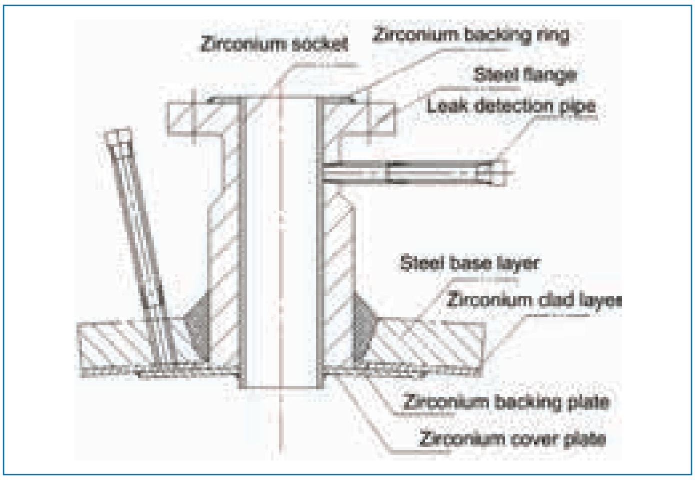

Figure 3: The welding scheme for the connecting pipe of small diameter to the cylinder.

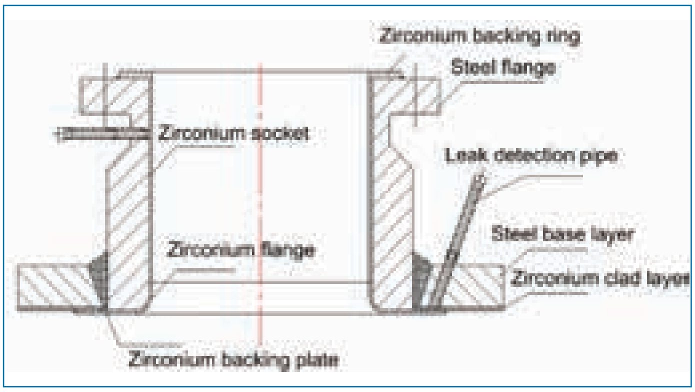

Figure 4: The welding scheme of the connecting pipe of large diameter to the cylinder.

Weld position	Weld layer	Weld method	Weld metal	Specification	Welding current A	Welding voltage V	Welding velocity cm/min
Welding seam on the circular	Root pass (inner)	GTAW	ER50-6	∅2.5	110-140	11~13	8~15
	2~3 (inner)	SMAW	J427	∅4.0	140-180	24~28	15~25
	Other (outer)	NSAW	H08MnA+SJ101	∅4.0/1800~300 µm	520-620	31~33	35~55
Connecting pipe and cylinder	Root pass (inner)	GTAW	ER50-6	∅2.5	110-140	11~13	8~15
	Other (outer)	SMAW	J427	∅4.0	140-180	24~28	15~25

Table 2: Welding parameters for the steel base layer.

Position	Layer	Method	Weld metal	Wire	Current (A)	Voltage (V)	Speed	Gas flow (ℓ/min)
Long & circ welds on backing plate & comp layer	1	GTAW	ERZr2	∅2.4	120~160	11~13	8~15	Main 8~12; Side 30~50; Back 3~5
Long & circ welds on root cover and composite passes	root	GTAW	ERZr2	∅2.4	110~150	11~13	8~15	Main 8~12; Side 30~50; Back 3~5
-	cover	GTAW	ERZr2	∅3.2	140~180	11~13	8~15	
Long weld on the zirconium cylinder	1	PAW	ERZr2	∅1.2	150~160	26~28	20~22	Ionic gas 8; Tail 30~50; Back 25~45;
Connecting pipe backing & comp layer backing ring	root	GTAW	ERZr2	∅2.4	110~150	11~13	8~15	Main 8~12; Side 30~50; Back 2~3
-	cover	GTAW	ERZr2	∅3.2	140~180	11~13	8~15	
Steel & zirconium	1	GTAW	AG	∅2.0	90~120	11~13	8~15	Main 10~15

Table 3. Welding parameters for zirconium composite layer, cover plate, connecting pipe and cylinder on the reactor.

The welding bevels for connecting pipes on the cylinder are machined using floor type boring and milling machine. The root pass is finished by manual GTAW with subsequent passes being completed using SMAW. The process is not complex. After welding of the base layer, X-ray and ultrasonic inspection are performed on the welding joint. The entire weldment is then transferred into the furnace for heat treatment.

The high temperature during heat treatment reduces the peel strength of the composite plate and the surface of the composite layer gets over-oxidised. With the design and related specification being required, the holding temperature should be low and the holding time should be as short as possible.

Also, the inner should be cleaned before the heat treatment, and at least two layers of titanium-based high temperature coating are necessary on the inner wall. The heat treatment specification for the reactor is 580 °C for three hours.

Welding of composite layer

The inner composite layer is commonly made of ZR 700, R60700, while the backing plate and cover plate are still made of R60702. Compared with R60702, R60700 has the similar welding ability and corrosion resistance but the oxygen content and the strength are slightly lower. It can be directly explosion welded with low carbon steel. The titanium is usually added as the interlayer between R60702 and carbon steel to produce the zirconium-steel composite plate [3]. Zirconium is very active at high temperature and a series of brittle intermetallic compounds will form in the welded joint due to air absorption, especially due to oxygen. The welded joint will be embrittled.

The corrosion resistance and the machining property can also be affected. Therefore, in order to prevent gas pollution during welding, it is necessary to shield the weld joint using purging devices. Pure argon (99.99%) is used in the high temperature zone (≥400 °C) of the weld joint and the weld seam is rapidly cooled. The impure elements, especially carbon, can greatly affect the corrosion resistance of the weld seam. When there is a small amount of carbon (>0.05%), the corrosion resistance will be drastically reduced. Therefore, it is necessary to clean the oil and other contaminants on the surface of the welding part, to prevent contamination [4].

The welding parameters for the zirconium composite layer, cover plate, connecting pipe and cylinder on the reactor are shown in Table 3. The welding quality of the zirconium composite layer is related to the long-term safe operation of the equipment. The welding processes are introduced as per Table 3.

While welding between the backing plate and composite layer, welding gaps should be as even as possible and must be between 1.0 and 2.0 mm. If it is smaller than 1.0 mm, it cannot guarantee the design requirements of the welding depth of 2.0 mm. Otherwise the base metal will melt and cause hot cracking in the weld seam. If it is difficult to control the welding gap precisely, it is better to let the welding gap be as small as possible. Meanwhile, a 1.0 mm ×45° groove is machined into the backing plate so that the reinforcement of welding between the backing plate and the composite layer is small. This can also ensure welding penetration of 2.0 mm according to the design requirements.

For the welding between cover plate and composite layer, there is always misalignment in the longitudinal and circumferential welding seam in the cylinder. Hence the gap between the welding seam of the cover plate and the composite layer is different. When the pair of cover plates is mounted, the gap should be even and as small as possible.

Two welding passes are performed, in which the arc ignition and arc blow out locations are staggered. The first welding pass is performed using a welding wire of ∅2.4 mm. A small amount of filler wire, which assures the full penetration of weld leg, is used.

The second welding pass is performed using a welding wire of ∅3.2 mm. The weld fill is normally finished when the size of the weld leg is big enough. Figure 5 shows the welder is operating on the cover plate and composite layer and the forming quality of the weld.

It is worth noting that the high-purity argon in the leak detection pipe can replace the air at the back of weldment to prevent contamination. While

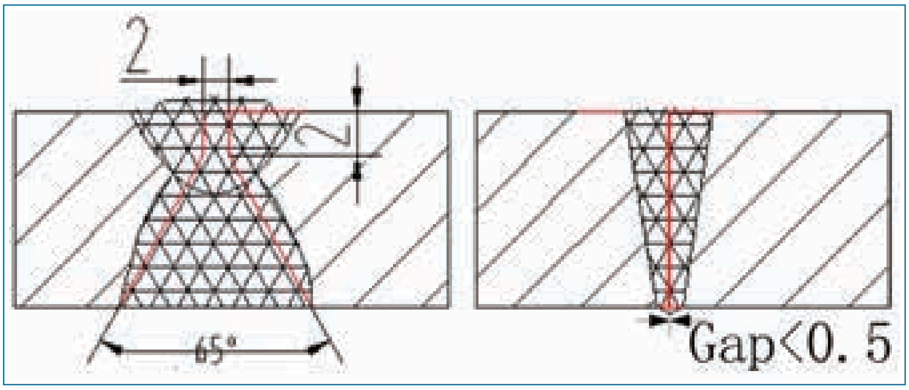

Figure 5. The welding and formation quality of the longitudinal welding seam.

Figure 6. GTAW and plasma welding being applied to the sleeve joint.

Figure 7. The welding of small diameter-connecting pipe and backing rings in the argon gas box.

welding, high temperature resistance tape is pasted in the zone that is not yet welded. With the welding continuing, the tape is torn off. With this method, a relatively closed space is formed at the back the protection area.

The zirconium sleeve of the small-diameter connecting pipe can be obtained directly by purchasing straight tube. When the diameter of the connecting pipe is larger than 273 mm, however, the zirconium sleeve will have to be coil welded from sheet. The thickness of sleeve is generally 3-4.76 mm, otherwise it is difficult to operate the coiling or obtain good weld quality. In these experiments, the thickness of the zirconium sleeve used is 4.76 mm.

Zirconium is a work hardening material and has poor ductility. To prevent cracking of the longitudinal seam during straightening, the pressure head should be machined to assure the arc of the end during the coiling of zirconium sleeve. Meanwhile, flanging (flare) can be easily formed in both ends.

In order to ensure the quality of bonding, a margin of 8.0×2.0 mm is left at both ends of the sleeve. After coil welding of sleeve, the inspection is carried out and the margin is removed if the qualified weld joint is obtained.

The gap between the zirconium sleeve and the carbon steel connecting pipe is generally required to be less than 0.5 mm. In order to ensure the dimension, the actual outer diameter of the sleeve, L is measured after the shaping of the sleeve. Afterwards, the matching inner diameter ($L/\pi+1$) of the carbon steel connecting pipe is shaped. Using this process, the matching gap of the connecting pipe and sleeve, which is difficult to control due to the lateral shrinkage caused by longitudinal welding of zirconium sleeve, is adjusted.

For the longitudinal joints of zirconium connecting pipe (t=4.76 mm), the plasma arc welding method is applied on the designed straight groove with no gap. These technological schemes can reduce the lateral shrinkage of welded joints and the residual deformation and guarantee good fitting of the sleeve with the carbon steel flange. Figure 6 shows a cross-section being welded using GTAW and plasma arc welding.

For some small diameter-connecting pipe and the backing ring, the overall temperature of the workpiece rises rapidly on starting to weld because of its small size. As a result, the weld protection is very difficult. In the production process, these small parts are welded in an argon box that offers protection and solves the problem. This is shown in Figure 7.

In order to ensure that the zirconium flange backing and the carbon steel pipe are tightly matched, the quality of carbon steel pipe grinding should be strictly controlled. In the installation, the bolts are used to tighten the parts to ensure the installation.

The inner parts are made of zirconium and are mostly structural parts. Due to the complex structure, it is difficult to protect these during welding. The corresponding protective covers are designed according to the shape of the workpiece. The requirements of the related welding quality are not as strict as that of other main parts, that is, some local welding zones may appear as blue. Still, the welding quality is very important thus the welders must carefully adhere to the welding procedure.

GTAW of the carbon steel base layer and zirconium composite layer

In order to ensure the seal space required for helium leak detection, seal welding between the carbon steel flange parts and the zirconium rings is performed. Here the sterling silver wire (99.99%) was selected and the conventional GTAW welding machine is used to perform welding. The welding processes used are listed in Table 3. After completion of the welding, a colour test is performed on all the zirconium welds and the heat affected zone.

The weld is qualified and will be processed according to the instructions in Table 4 [5]. 100% of butt welds of the composite layers are subject to the X-ray radiation and penetration testing. No pores can be found for a Grade I weld quality to be obtained. 100% of fillet welds are subject to the colouring test.

Equipment inspections

It is not enough to judge the quality of the equipment only by the non-destructive testing of the weld. It is also necessary to evaluate the quality of the equipment by means of subsequent inspection. The test methods and results used in this reactor are as follows.

Pressure and air tightness test: According to the design requirements, after the riveting of the equipment, the water pressure and air tightness test are performed. The test pressures are 4.2 MPa and 3.3 MPa. There must be no leakage, no visible deformation and no

Weld seam and HAZ	Argon protection condition	Qualified judgment	Treatment
Silvery white	Good	Qualified	Not necessary
Golden yellow (dense)	Acceptable	Qualified	Not necessary
Blue	A little bad	Only acceptable in non-critical areas	Remove the blue
Grey	Bad	Not qualified	Repair

Table 4: The colour requirements of the zirconium weld seam and HAZ.

abnormal sound during the test. The equipment can then be is qualified.

Thermal cycling test: The thermal expansion coefficient of zirconium, which is 5.3×10^{-6} per °C, is much lower than that of low carbon steel, which is 11.12×10^{-6} per °C. As the temperature of the reactor rises, the zirconium composite layer will bear large tensile thermal stress.

The welds on the zirconium composite layer are mostly overlapped fillet welds with low load carrying capacity. Thermal cycling tests can test the thermal stress-bearing capacity of zirconium composite welds under the non-corrosive media at designed temperature and pressure [6]. The reactor was subjected to a thermal cycle test with a pressure of 3.3 MPa and a temperature of 210 °C in an electric furnace with compressed air as a medium after the water pressure and air tightness test. Testing temperature and pressure are shown in Figure 8. As the testing pressure and temperature are reached, the equipment is held in the testing conditions for four hours. If there is no leakage and abnormal deformation, the equipment is qualified.

Nuclear leak detection: Acetic acid, iodomethane and other reaction liquids are strong corrosive mediums for the reactor. As there is a steel layer barrier, they cannot be observed immediately once they are leaking from a weld. The strong corrosive media can, therefore, cause the corrosion of the steel base very quickly, with the possibility of serious accidents on the pressure vessel occurring.

The fillet welds on the zirconium composite layer have low carrying capacity and the weld quality is difficult to guarantee. Generally only non-destructive testing can be performed on the surface, while it is difficult to detect the flaws by using radiation or ultrasound. Pressure tests cannot ensure that the layer does not leak even if the shell does not leak. The leak tests are therefore very important [7]. During the reactor manufacturing process, two helium leak tests are performed.

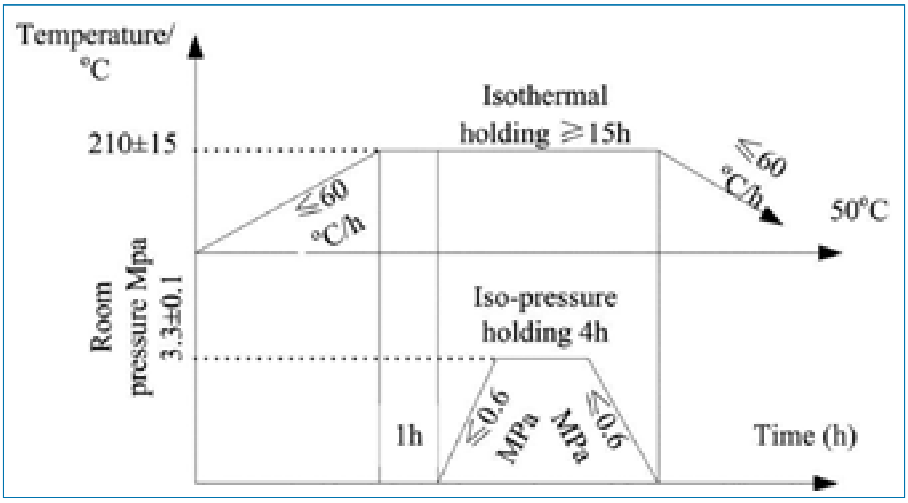

Figure 8: The thermal cycle curve.

For the first time, all zirconium-welded joints were tested with helium pressure of 0.05 MPa. The design requires that the leakage rate shall not exceed 1×10^{-5} Pa.m³/s. The experimentally measured value is 1.3×10^{-7} Pa.m³/s.

For the second test, helium leak detection was carried out after the thermal cycling test on all zirconium-welded joints with helium pressure of 0.05 MPa. The measured value of 5.6×10^{-7} Pa.m³/s was obtained,, which was much lower than the design requirement of $\leq1\times10^{-5}$ Pa.m³/s.

Conclusions

In summary, the welding difficulties of the zirconium-steel composite plate reactor that result from the complexity of the structure and material are solved. Some effective process control measures and testing methods were studied and identified and the excellent welding quality of zirconium-steel composite plate can now be obtained. The reactor studied here has been safely in service for six years.

Acknowledgements

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How to hardface: The ten-step

At an afternoon seminar at SAIW on July 26, Alain Laurent, business developer of consumables for Saf-Fro and Oerlikon, presented the companies hardfacing offering and its ten-steps approach to achieving optimum surface layer characteristics.

Surfacing operations involve a harder or tougher material being applied to a less durable base metal, begins Laurent. "The objective is it to extend the service life of equipment, avoid machine down-time and reduce production costs," he says.

Surfacing, hardfacing or cladding can be on new parts during production or on used parts to restore worn-down surfaces, with the aim to increase the wear, abrasion, erosion or corrosion resistance of contact surfaces.

Surfacing, hardfacing or cladding aims to increase the wear, abrasion, erosion and/or corrosion resistance of contact surfaces.

"Selecting the proper hardfacing alloy, does not in itself always guarantee the desired result. Base metal interactions with the surface metal, the working environment, the welding process, the welding procedure and many other factors can be equally important to get the maximum benefits from a hardfacing operation," he suggests.

Hardfacing processes are widely used in the cement, material handling, steel, sugar, railway, waste to energy, dredging and tunnelling industries, while many fabricators offer wear plate solutions for earthmoving and other plant equipment.

"All of the common welding processes can be applied for hardfacing and Oerlikon offers a wide range of consumables and solutions to meet the different applications needs," Laurent says, adding, "to achieve cost-effective and optimal results, Oerlikon has identified 10 steps that need to be followed in order to choose the appropriate surface alloy, welding process and layering procedures.

The buckets on a bucket wheel reclaimer will typically be subjected to abrasive and impact wear.

Step1: Identify the base metal

"We have to know the chemical composition of the base material before choosing a consumable," Laurent points out. For new equipment this is easier, "but if we don't know what the base material is, there are some tests that can help us to identify it.

"The majority of the base metal used for equipment is iron based and there are four broad categories: high carbon steel; low carbon steel; manganese steel; and cast iron," he adds.

The first and easiest test is to see if the material is magnetic or not. If a magnet does not stick to the base material being hardfaced, then it is likely to be an austenitic stainless steel (3xxx series), manganese steel or a non-ferrous material such as copper, aluminium or tin. Low and high carbon steels and cast irons will be highly magnetic, as will ferritic stainless, while nickel-copper alloys such as Monels and some high-ferrite duplex stainless steels will be partially magnetic.

Laurent also cites the grinding spark test: white sparks for carbon steels, yellow for cast irons; the hammer test: if the surface marks, it's a low carbon steel, if the hammer marks, it's a high carbon steel: and the stick electrode welding test, which involves using a 3.2 mm basic electrode to weld a bead onto the surface. If the HAZ metal cannot be sawn, the base metal is a hardenable low-alloy steel (<0.5% C), while if the deposit cracks or comes off, it is likely to be a difficult-to-weld cast iron that can only be hardsurfaced on top of a ferronickel buffer layer.

"The more information we can get, the better though," he suggests, and there are more accurate ways of identi-

approach

fying materials, such as the use of a PMI (positive material identification) spark analyser.

Step 2: Identify the dominant factor of wear

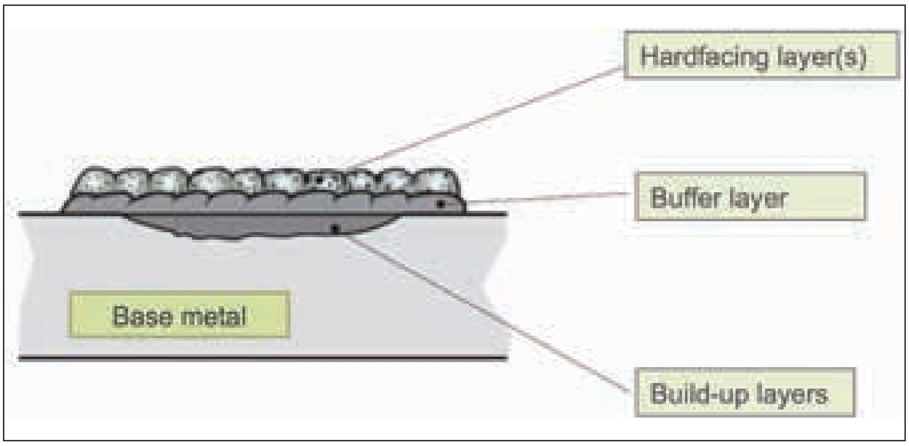
Lauren emphasises that information about the specifics of the application is vital for an appropriate hardfacing solution to be selected. Showing a diagram of how wear can occur, he says that abrasive wear is due to a gouging action of the particles with horizontal speed, while impact, which can cause denting, squashing or cracking, is due to the perpendicular impact speed. Mixed impact and abrasion is also common.

To overcome abrasion in the mining, earthmoving and materials handling context, for example, he suggests that the hardfacing process needs to be selected to suit the hardness of the specific ore being extracted or handled.

He notes several other mechanical factors with particular wear mechanisms: abrasive wear on the pressure rollers for the clinker crushing process in a cement plant; metal-to-metal friction wear on railway lines: and impact wear on crushing hammers, where the hardness, speed and weight of the impacting materials plays a vital role.

In addition, corrosion factors should be identified if using seawater or chemicals; and/or thermal factors, for furnace components and hot rolls in steel mills, for example.

"We have a lot of experience in the different hardfacing applications, though, so we can generally help to identify the wear factors involved in an application, either from a site visit or from a detailed description of the equipment's use," says Laurent.



Hardfacing involves several build-up layers: build-up to bring to the shape and dimensions; a buffer layer to reduce crack propagation and to ensure bonding; and a hardfacing layer to achieve the required wear characteristics.

Step 3: Select the hardfacing alloy and process

The better the match between the hardfacing alloy and the application, the longer the wear life of the coating is likely to be. "A first choice can be done by using ISO 17400 or the old DIN 8555 classifications, but the more information you can give us, the better," he says. "Tests are sometimes necessary to validate the choice, because the carbon percentage in the alloy, while a good indicator of abrasion resistance, is not enough. Other parameters such as the microstructure and the type of carbides that will form must also be considered," he says, adding again, "the more information you give us, the better."

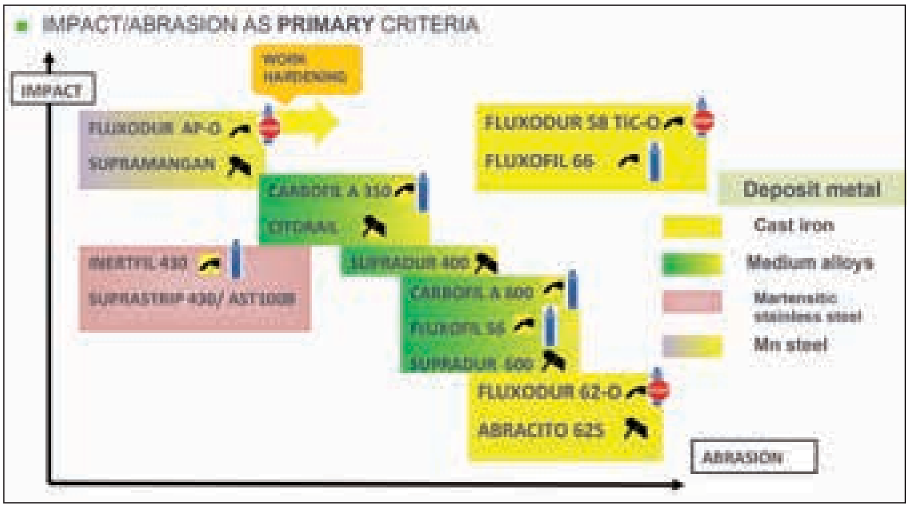
Lauren displays a summary grid of consumables organised with increasing impact resistance on the y-axis and increasing abrasion resistance on the x-axis. Several types of consumables are represented: Citorail and Supradur MMA electrodes; Carbofil A350 and A600 GMAW wires; Fluxofil 56 and 66 for gas shielded FCAW; and, for self-shielded FCAW, several Fluxodur consumables.

Cast iron, medium carbon steel alloys, martensitic stainless steel and manganese steel alloys are all represented. "And submerged arc wire, strip consumables and flux combinations as well as TIG or oxyfuel wires (Citolit CT) are also available," Laurent adds.

As an example application to show how to use the selection grid, he cites the clinker grind rolls on a crusher at a cement works, where Fluxodur 58 TiC-O or Fluxofil 66 would be chosen to cater for the high impact, high abrasion application on the pressure rolls.

On a friction application for the shafts of the grind rolls, however, a machineable Carbofil A 350 or Supradur 400 might be more suitable.

"Where impact wear dominates, such as on crusher jaws, then manganese steels such as the Fluxodur AP-O



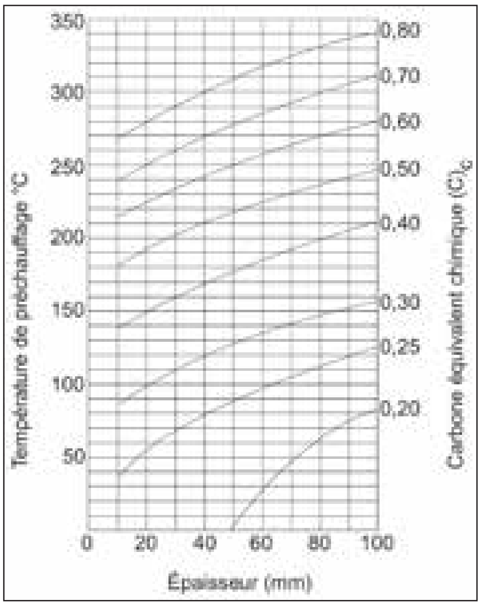
Hardfacing consumables organised in terms of their suitability for use against abrasion and impact wear combinations.

and Supramangan consumables tend to work best," Laurent says.

Temperature and corrosion resistance are taken into account as secondary criteria, and Oerlikon has developed a similar temperature versus corrosion grid to assist operators to choose appropriate consumables.

In terms of the welding process, Laurent says that each has its advantages and disadvantages. SMAW (shielded metal arc welding) is easy to implement both indoors and onsite and a comprehensive range of consumables is available, covering every segment. "Some of our best sellers include Abracito 62S, Supradur R 600 and Supramangan," he notes. The only downside for SMAW is that the productivity is lower than other more automated processes.

Solid GMAW wires offer higher deposition rates of – up to 6.0 kg/h – and are well suited to automatic or semi-automatic applications. But



To determine preheat required, Laurent suggests that the Seferian Diagram be used. For a 50 mm thick 42CD4/42CrMo4 plate with a carbon equivalent of 0.63, the preheating temperature will be above 220 °C, for example.

they require shielding gas and this can prevent them from being used outdoors. A large range of impact resistance wires exist, most notably, Carbofil A350, Carbofil A600 and Inertfil 430.

For the flux-cored process, which offers deposition rates of up to 8.0 kg/h, both open arc (gasless) and gas-shielded wires are available in the Fluxodur and Fluxofil ranges respectively.

For higher deposition welding, albeit limited to the flat (1G) position and indoors, submerged arc welding (SAW) offers high deposition rates of up to 12 kg/h using consumable combinations such as OP 122 flux with Fluxocord 52 wire.

Strip Cladding, which offers dilution rates as low as 25% at deposition rates as high as 20 kg/h is also an option for those whose cladding requirements can justify the equipment expense.

Step 4: Prepare the surface

Critical to a coatings success is the cleanliness of the surface prior to welding. All traces of dirt, grease, oil and paint needs to be removed. In addition, previous hardfacing layers usually need to be removed, especially if the deposit composition is unknown.

"Before rebuilding manganese steels, about 2.0 mm of the work-hardened surface is usually removed. Failure to do so might result in weld bead spalling," Laurent notes.

Step 5: Preheat

Preheating and interpass temperature control needs to be done while hardfacing to avoid cold cracking; allow diffusible hydrogen to escape from the weld metal; and to reduce shrinkage stress.

To determine preheat required, Laurent suggests that the Seferian Diagram be used, which relies on the carbon equivalent (C_{eq}) formula of the base metal and the thickness of the material to determine the preheat required.

By way of an example, Laurent shows that, for a 50 mm thick 42CD4/42CrMo4 plate with a carbon equivalent of 0.63, the preheating temperature will be above 220 °C.

"In the case of manganese (Mn) steels, however, preheating is forbidden and, instead, the interpass temperature must be restricted to less than 150 °C during the hard-surfacing operation.

Step 6: Rebuild

For worn components, it is always necessary to restore the original shape of the base meal surface before hardfacing. To do so, a deposit as close as possible to the original base metal composition should be sought.

Step 7: Establish a buffer layer

Once restored to its original shape, a buffer layer is often applied. Its main purpose is to prevent cracks from travelling from the hardfaced surface deposits into the base metal. This step is always necessary between surface layers containing nitrides or carbides.

"The buffer layer also ensures good bonding with base material, prevents the surface layer from sinking under high load conditions and helps overcome dilution issues," says Lauren, adding that it is important to avoid having a ductile deposit on top of hard metal. "The harder material should always be on top," he advises.

Austenitic-type consumables, generally a 307L or 312L are commonly applied for the buffer layer.

Step 8: Hard surface

"The key issue with respect to the weld deposit of the hard-surfaced layer is low dilution," says Laurent. It is important to minimise the percentage of hardening constituents lost to the buffer layer or to the base metal. This is to ensure that the top surface of the hard layer is to the exact composition required to achieve long wear life.

Target dilution should be as low as possible and is controlled using the welding parameters, such as welding speed, current and polarity settings. Parameters should be set to achieve a minimum plate penetration, which is most often associated with high welding speeds and deposition rates.

Welding direction also plays a role and smaller (stringer) beads deposited with weave can also help.

When welding manganese steel, which is austenitic and therefore susceptible to hot cracking, the beads should be narrow and convex (peaky). "If wide and flat, the risk of hot cracking increases," Laurent notes.

Low heat input, which is associated with convex welds, also gives a finer grain structure, which improves the mechanical properties.

Step 9: Post-weld heat treatment

Heat treatment is routinely applied to relieve welding stress and to minimise hardness and microstructure variations across the surface.

As with all welding procedures, post-weld heat treatments are an integral part of hardfacing procedures and need to be developed in conjunction with the hardfacing procedure development.

Advice on post-weld heat treatment requirements is readily available based on the choice of the consumable and the welding process.

Mechanical post-processing such as machining and/or oxy-fuel or plasma cutting may also be required, and this may also influence the consumable choice.

Step 10: Control the quality

"The entire hardfacing process needs to be under control at every step of the way," Lauren suggests. "Visual control of the welding can, for example, be used to identify cracks, porosity, dimensional inaccuracy, deposit rates and thickness, and to validate the correct number of layers has been applied.

In the case of hardenable alloys, the base material, due to thermal shock or contraction stresses, may exhibit cracking across large areas – and on very hard deposits, these surface cracks may be normal and acceptable.

Excessive porosity is mainly due to nitrogen (the voltage may be high) or hydrogen, perhaps due to moisture in the flux or the electrodes.

Hardness and hardness variations are usually due to changes in weld deposit chemistry and/or changes in cooling rate. Better control of the dilution, preheat and interpass temperatures may help. If high hardness is found in the heat-affected zones adjacent to welds, for example, the preheating and or interpass temperatures being used are not high enough.

The crack on the right in this hard top surface layer of Fluxodur 58 TIC-O has been stopped by a Supranox RS 307 buffer (bottom) layer.

Conclusions

Displaying his ten ticked steps, Laurent says that this approach offers the best possible assurance of achieving successful end results. And in making all of the choices required, Oerlikon and Saf Fro specialists, either directly or through its local distributors, are accessible and available to help fabricators to arrive at ideal hardfacing solutions.

Creep, cracks and fitness for service

Ronald Koenis, principal metallurgical engineer for MegChem, talks about fitness-for-service (FFS) and remaining life assessments (RLAs) of welded components that operate within the creep range and those with crack-like flaws.

MegChem's Materials and Forensic department offers expert services and failure investigations to insurance companies, law firms, manufacturers and industrial operations. "We conduct meticulous investigations of accidents and failures to establish root causes and the sequences of events leading to accidents or failures," begins Koenis. "Typically, failures can involve boiler tubes, processing and engineering components, valves and flanges, bolts, bridges, polymers, ropes, non-ferrous components and even bicycle frames," he says.

With regard to fitness-for-service (FFS) and remaining life assessments (RLAs), he says that theoretical and practical knowledge of degradation processes are combined with knowledge of materials and structural behaviour to establish if continued operation is feasible and safe.

"MegChem is well positioned and experienced with regards to FFS and RLAs. We make use of leading standards and documents such as BS 7910 and API 579-1/ASME FFS-1.

FFS assessments assure continued safe and reliable operation with reduced downtime and the elimination of unnecessary repairs. They offer additional time to plan shutdown activities and can significantly reduce costs.

An RLA, on the other hand, can be performed to establish a retirement or replacement plan for equipment nearing the end of its lifecycle or for equipment that has been in operation for longer than its original design life.

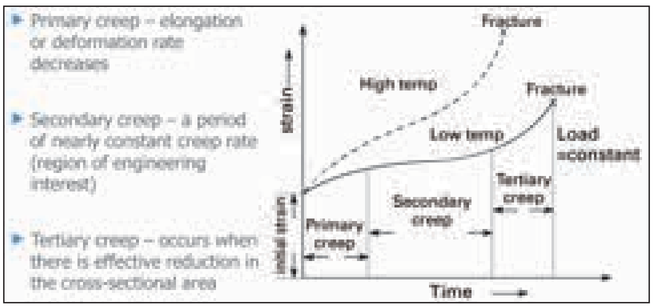
"This also applies to components with crack-like defects," Koenis says. "The safe remaining life can be estimated based on the critical crack dimensions and the rate of propagation – and the assessments will typically be supported with on-line monitoring."

Other services offered by MegChem include: metallographic assessments; material phase and tempering condition assessments; creep degradation classifications; determination of material failure modes; degree of sensitisation in stainless steel components; wall and coating thickness measurements; portable, in-situ hardness testing; and failure reconstructions.

"Our material-related services include corrosion engineering, risk-based integrity (RBI) support and auditing, personnel training on metallurgical issues, independent review of testing facilities, heat treatment facilities and optimisations and welding engineering services," he says, adding that the company also operates its own comprehensively equipped laboratory.

Introducing the concept of creep, Koenis says creep can be defined as the slow and continuous deformation of metals at high temperatures below the yield stress. "It is a time-dependent deformation of stressed components and all metals and alloys are susceptible," he notes.

The rate of creep damage accumulation is a function of material, load and temperature. "An increase of 12 °C or 15% in stress can reduce the remaining life of component by half or even more – depending on the alloy," he points out, adding: "Creep behaviour is relevant above four-tenths of the melting point (0.4 Tm) and it is often mistaken for creep embrittlement when little or no plastic deformation is discerned. In addition, increased stress due to a loss in thickness from corrosion will reduce creep life exponentially."



A typical creep curve can be split into three distinct stages: primary, secondary and tertiary creep.

Displaying a typical creep curve, he says that the creep life to failure can be split into three distinct stages: primary creep, where the elongation or deformation rate decreases with time; secondary creep, which is an extended period of nearly constant creep, which is generally the region of engineering interest for RLAs; and tertiary creep, the stage when the accumulated reduction in the cross-sectional area results in an acceleration of elongation towards failure.

While at temperatures well above the threshold limits, noticeable creep deformation or bulging may be observed, the initial stages of creep may only be identified by using SEM or optical metallography, with damage manifesting as voids at grain boundaries. The void density is indicative of the severity of the creep degradation. "Micro cracks will develop and creep cracking may occur at locations with high metal temperatures and stress," Koenis explains.

"Assessment techniques include in-service replication; dimensional monitoring and core drilling," he says before displaying the Neubauer creep classification system, a table relating observed creep indications to remedial action.

For measurement and testing, MegChem collaborates with the CSIR for the use of its extensive creep testing facilities, which has at its disposal six constant load rigs for testing to temperatures of 1 200 °C as well as Laubinger creep rigs with gas shielding.

"Accelerated creep rupture (ACR) testing at a specific stress requires testing until failure across various time orders: 10 hours, 100 hours and 1 000 hours, for example. Different rupture times are achieved by increasing or decreasing the test temperature.

"The results are used to calculate

Larson Miller Parameter (LMP) values, which can be compared to published values for identifying the relationship between stress and LMP.

"The LMP is a single value that reflects the creep rupture strength of alloys as a function of applied stress and is used for the determination of design creep curves for steels. The parameter incorporates both temperature and time effects as indicated in the equation.

$$LMP=\frac{(T+273)}{1000}(C+\log(t))$$

"We prefer to use Omega creep properties, however, which are determined by exposing the creep samples to a stress marginally greater than the operating stress and temperature to ensure approximately 2% to 5% creep strain accumulation within 1 000 hours," says Koenis.

Omega creep samples are not tested until failure, but until sufficient creep strain has been achieved within the secondary creep stage – where constant strain rate prevails.

Advantages of Omega creep testing include: much quicker availability of results – one to two months compared to three to four months for the LMP method; fewer samples are required – theoretically only one sample can be used to predict remaining creep life; and from known omega and ISR values, the creep life fraction consumed to date can be theoretically determined.

Koenis goes on to point out that other temperature related degradation mechanisms must also be looked at: Spheroidisation and/or softening, for example can occur when the unstable carbide phases in carbon steels agglomerate from their normal plate-like form to a spheroidal form, or when small finely dispersed carbides in low-alloy steels such as 1Cr-½Mo form into large agglomerated carbides.

Crack-like defects could also be considered during a fitness-for service assessment, including, for example: mechanical, corrosion and thermal fatigue cracks, due to cyclical stress; and stress corrosion cracking, caused by the interaction between tensile stress and a specific corrosive medium to which the metal is sensitive.

"FFS assessments, which are almost always coupled with RLAs, provide technically sound approaches that ensure the safety of plant personnel and the public in an environment where aging equipment continues to operated," Koenis notes. "The assessments provide inputs for decisions to continue to run as is, or to alter, repair, monitor, retire or replace the equipment," he adds.

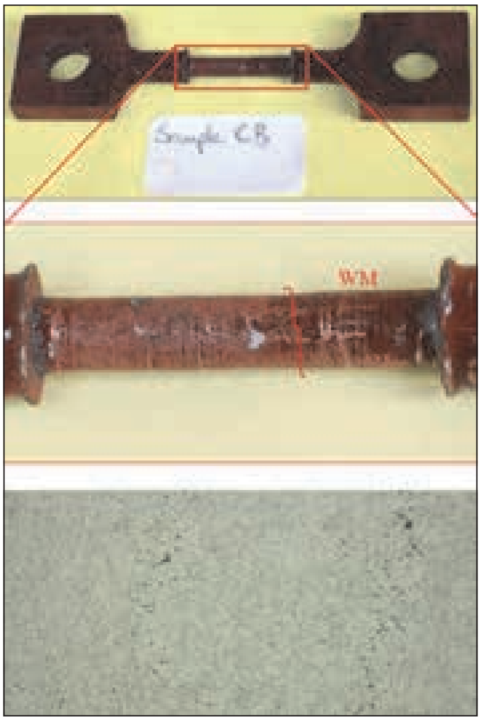
Citing some examples, he relates a creep-related Level 1 screening assessment experience based on published creep material behaviour. "A localised hotspot was identified that had been prevalent for one month (744 hours) on a vessel at a processing plant. A thermography survey showed a maximum temperature of 536 °C in the carbon steel shell and FEA calculations indicated stress at approximately 40 MPa in the affected region.

"The standard creep screening curve indicated the conditions to be acceptable and that the unit was still fit for service, provided no previous excursion had occurred," Koenis says, pointing to the creep screening curve.

With regard to Level 2 and Level 3 creep FFS and RLAs, he says that reference stress solutions can also be applied for Level 2 assessments. "FEA models that extract the peak stress values can be considered, however, due to creep strain, stress redistribution may follow, so for RLAs membrane stresses are preferred," he says.

"If actual material condition or Omega properties are ascertained during the analysis, past operation can be ignored, but future corrosion allowances and rates should be incorporated. If no actual data is available, the approach must also consider past creep damage fractions over various load or temperature periods as indicated by the histogram.

Koenis goes on to describe Level 1 and Level 2 crack-like-flaw FFS assessments as well as a leak-before-burst (LLB) assessment. "The LBB approach should not be applied when the crack growth rate could potentially be high, since when a leak occurs there should be adequate time available to detect the leak and take the necessary action," he advises.



Post Omega testing assessments: two samples + left hand micrograph (PM)Omega creep test samples after testing and a parent metal micrograph showing aligned pores that would eventually grow together to form micro cracks.

Concluding, he says that FFS assessments can provide a significant financial advantage in terms of repair and downtime. "However an FFS should preferably only be considered in situations were repair or replacement cannot be performed," he suggests.

A high level of conservatism is incorporated into the typical screening approach of Level 1 assessments, in accordance with API 579-1. Should a Level 1 assessment not confirm FFS, a Level 2 and/or Level 3 assessment may be performed, which could have a different outcome.

"Sensitivity analyses should always be included in remaining life assessments to demonstrate confidence in the calculated remaining life," Koenis concludes.

Class	Microstructural feature	Remedial action
Undamaged	No creep damage observed.	None.
Class A	Isolated cavities on grain boundaries.	Observe.
Class B	Orientated cavities i.e., the cavities are distributed so that an alignment of damaged boundaries normal to the maximum stress can be seen.	Requires inspection at fixed intervals, usually between 1½ and 3 years.
Class C	Some micro-cracks, coalescence of cavities causing the separation of grain boundaries.	Requires repair or replacement within six months.
Class D	Macro cracks.	Requires immediate replacement.

Neubauer B et al: Proceedings of the 2^{nd} international conference on creep and rupture of engineering materials and structures; Pineridge Press, Swansea, 1984, page 1226-1271.

Cost-effective welding solutions: a tiered approach

African Fusion **talks to Warwick Hogan and Anthony McGuinness of Brand Weld about welding brand choices and their approach to meeting the needs of the diverse South African market.**

Between them, Anthony McGuinness and Warwick Hogan have substantial experience as distributors of welding equipment, which, for McGuinness, goes back to 1997 with Binzel. Prior to the death in 2009 of Sydney Ellerine, McGuinness was running the Ellerine's welding businesses, Welcom Distribution and Welders Warehouse, while Hogan was running a company called TorchMaster in Australia.

"We started Brand Weld as a new and clean entity in 2009 as an importer and wholesaler of a carefully selected range of brands that we thought would be well suited to the South African market," says McGuinness. "We decided to sell only through distributors and to carry a comprehensive and complete range of popular, fast moving welding products: MMA, MIG and TIG welding machines, accessories and consumables; gas and plasma cutting equipment; and a comprehensive range of associated safety gear and accessories," he tells *African Fusion*.

"The bread and butter of the business, lies in welding consumables," he notes – flux-cored, MIG, TIG and stick consumables as well as SAW wires and fluxes – and Brand Weld has adopted a tiered approach to give users the choice between cost-effective brands, high-end certified quality and mid-tier options.

"We offer three consumable ranges: a low cost Strike Master option, which is focused on steel such as 6013 electrodes; a mid-tier Taurus range of products, which is our own registered brand of good quality but well-priced products; and the Oerlikon premium brand.

"Taurus consumables are available for the popular steel alloys, including 7018 and 7024s, as well as the common stainless steel and cast iron electrodes such as Nickel 55 and 98," McGuinness says.

For MIG welding, a full range of solid wires is available, including stainless and aluminium wires, "and we have some Taurus flux-cored wires such as the 71T1 wires, as well as silicon bronze MIG wires.

"The Taurus consumable brand is ideal for general fabrication and is ideal for small and medium sized fabricators that are under competitive pressure – but still have to produce quality products," McGuinness suggests. "And in the currently lean economic climate, we are also selling to some bigger operations for non-critical welding tasks," he adds.

"Wherever the contract price is an issue, Taurus can be a cost-effective alternative to the premium brands," Hogan suggests. "But for premium quality welding tasks, we have the full Oerlikon offering at our disposal," he continues. "We are a relatively new to Oerlikon, but Brand Weld has quickly emerged as the go-to agency for imported Oerlikon consumables. We are now the primary supplier of all Oerlikon consumables and if any direct enquiry is received in Europe, these will be referred to us," he says.

The Taurus Flama TIG 320 ac/dc pulse machine. Taurus inverter-based 380 V power sources are all factory tested to 550 V.

The quick success is largely due to a "substantial commitment" from Oerlikon to make their products work in the South African market. "Oerlikon's top technical people are accessible to us for up to one week every month to help us and our customers to make best use of this premium consumable range," Hogan assures.

While the price is higher, what Oerlikon offers is a better welding process. "The brand comes with a lot of expertise and knowledge. As a distributor, our task is to do more than sell volumes into the already competitive market. With Oerlikon, we strive to offer complete solutions that are cost effective by virtue of better productivity, higher deposition rates, less rework and higher end quality," McGuinness says.

"Through partnerships with Air Liquide Welding and its local agent, ALP, we can also offer consumable support and accessories for automation solutions that reduce labour costs and significantly increase consistency and

The Taurus Flama MIG 500f Synergic welding power source from Brand Weld is a 500 A dc inverter-based synergic double pulse and multi-process power source.

The Brand Weld offering includes specialised robotic mild steel wires for very fast welding, such as the Carbofil Elite MIG welding wire.

Parweld auto darkening respirator helmets offer cost-effective fume extraction solutions compared to mobile and permanently installed extraction systems.

quality. Initiatives such as these will often make the use of a premium quality consumables economically sensible," Hogan adds.

"In many areas, Oerlikon is the global consumable specialist," Hogan continues. "Its seamless flux-cored wires, for example, offer exciting possibilities, especially for stainless steels and hardfacing applications. We have direct access to welding procedure specifications (WPSs) and historical procedure qualification records (PQRs) for many of the applications we are asked to look at, and Oerlikon France is happy to develop procedures for us for new applications.

"Locally, we are happy to have consumables tested and certified for customers wanting to use Oerlikon consumables for niche, safety-critical or high-quality fabrication," Hogan tells *African Fusion*. "Consumable certification is routinely required by the petrochemical and the power generation industries, on high temperature steels and special stainless steels, for example," he adds.

Globally, Oerlikon has also developed specific consumables for the automotive industry, which are preferred by carmakers such as Volvo and Renault in Europe. "These are also ideal for use by second- and third-tier component manufacturers, because the components they make are also subject to similar quality requirements," Hogan suggests. The Brand Weld offering includes specialised robotic mild steel wires for very fast welding, such as the Carbofil Elite MIG welding wire.

"Hardfacing is Oerlikon's key strength, though. We are currently doing well on the Oerlikon Fluxofil 58 wire, which is an excellent product for flux-cored hardfacing for high abrasion, medium impact wear applications," continues McGuinness. "This wire is as close as you can get to a universal hardfacing solution and it is being used extensively for front-end loaders and mining buckets at our open cast coal and iron ore mines."

Hogan adds: "This is a gas-shielded flux-cored wire, which is ideal for workshop use, but Oerlikon also offers the Fluxodur 58 TiC-O, which is a self-shielded (gasless) equivalent consumable for use outdoors or where gas availability is a problem."

"A lot of MMA work is done outdoors where wind can affect shielding and cylinder handling is difficult. The use of self-shielded cored wire is an ideal substitute for MMA for people needing to improve productivity and uptime and the self-shielded FCAW process also offers improved surface quality and consistency," he adds.

Brand Weld has adopted the same tiered approach to its welding machine offering, with an entry level Strike Master machine range and a mid-tier Taurus range that offers "some fantastic features".

"All our machines are inverter-based and we have options from basic MMA machines all the way up synergic, synergic double pulse and multi-process power sources," says McGuinness.

Most notably, he says that the Taurus range has advanced input voltage protection. "All of the three-phase 380 V machines are tested to 550 V. While we don't recommend using them at higher voltages, these machines will operate accurately at up to 540 V, after which they will trip to protect the electronics. This is an important feature in Africa, where the supply can vary and it is often unreliable," he says.

On the Taurus ac/dc TIG welding machines, McGuinness says that a wireless remote foot pedal has been added. "For ac-TIG welding of aluminium, this is particularly useful as it gives the welder the current adjustment needed to control the penetration with less risk of burning through," he explains.

On the cutting side, Brand Weld offers the Harris range on the high end, along with lower cost Taurus gas cutting equipment. "We are also agents for Hypertherm plasma cutting equipment," says Hogan.

From an accessories perspective, a full range of welding safety equipment is available, including auto darkening helmets and "good quality respirator helmets that are much more cost-effective than fume extraction solutions that try to suck all of the fume out of the whole workshop".

The outlook? "From our perspective, things are looking good. We are covering the extended welding market with products from the entry level to premium and we have good support from our suppliers.

"We have recently introduced Parweld MIG torches, which have a novel design that makes consumables such as contact tips, gas shrouds and liners last longer – and their duty cycles have been extended to 80%," Hogan says.

"We also intend to bring in some new cutting equipment: small low-cost CNC plasma cutting tables, a CNC pipe cutting system and an I-beam cutting system for the construction industry. In addition, we have found a 1.0 kW entry-level fibre laser cutting system, a very low maintenance unit that does not need gas.

"Our tiered approach ensures that fabricators can source welding products that they can afford, no matter how small, large, simple or complicated their requirements," Hogan concludes.

Automatic stud welding for efficient liner mounting

Colin Maine.

With its new automatic stud-welding process, Rio-Carb is at the forefront of innovation in the application of efficient liner mounting. Stud welding is particularly beneficial where a regular ore flow is required, as there are no interruptions or recesses caused by the bolt heads on typically mounted liner plates.

A leading manufacturer of wear-resistant chromium carbide (CrC) clad liner plates for heavy materials handling applications in the mining and allied resources industries, Rio-Carb offers stud welding as a standard option on OEM equipment, unless bolts are specified by the client. "Stud welding is a quick and robust process," explains Rio-Carb director, Colin Maine.

Typically, an M16 or M20 stud is fitted to a gun/chuck, which then places the stud in a pre-determined area. A 1 200 A dc current is applied for about three-quarters of a second. The electrical arc is initiated by a match-head-sized aluminium insert in the bottom of the stud, which de-oxidises the molten weld, which is shrouded by a ceramic mould. Cooling is virtually instantaneous, achieving full strength immediately.

"It is most important that the stud is placed vertically and in the correct position, to within 0.5 mm," Maine stresses. For this, Rio-Carb has developed a mechanised jigging system whereby the stud gun and stud is held precisely perpendicular and placed on a pre-determined point to within 1.0 mm. This CAD-etched point is taken off the same plasma-cutting programme when the liners are made.

With Rio-Carb's extensive experience in the mining industry, the supply and application of a liner plate is only part of the story. The removal of conventional liner plates poses an additional issue in that, following corrosion and weathering, conventional countersunk bolts are difficult to remove.

Removing liners that have been stud-welded, however, is a simple 'one-person operation.' Also, due to the long-life of Rio-Carb's CrC liners with its MaxCS™ alloy, corrosion can be excessive. Therefore, all studs are supplied in 304 stainless steel, complete with a galvanised washer and Nyloc-nut.

Commenting on the industry misperception that stud-welded liners tend to break, Maine explains that this is caused by studs cracking off on 400 and 500 martensitic steels, which are not welded regularly. Rio-Carb liners have a weldable mild steel backing, which means zero breakages under normal usage.

"All our stud welding is certifiable according to American Welding Society (AWS) standards, which involve a sacrificial 15° minimum bend test on each batch of 100, as well as a torque test," Maine points out. Installation has to be according to the specified torque range, denoted by a plastic collar on each liner.

The location of the mounting holes in the parent chute are replicated from that chute's CAD program directly into Rio-Carb's plasma-CAD programme. "Misfits and breakages in assembly are reduced to zero," Maine says. Stud welding requires simple operator-skill levels, and is virtually fully automatic with the Rio-Carb process, which also uses pre-set parameters. "Once again, Rio-Carb is at the forefront of innovation in the application of efficient liner mounting," he notes.

"For conventional applications, we have our Rapid Removal System (RRS) of CrC 700 hard-faced galvanised countersunk bolts, with a slot at the end to prevent rotating, whilst unthreading the nut at the end of its lifecycle. This offers a simple 'one-man' dismantling operation, without harmful grinding or cutting," Maine concludes.

www.riocarb.co.za

WeldEye upgrades WPS and qualification management

Kemppi's WeldEye Welding Procedure and Qualification Management software simplifies welding management and now offers a single efficient and secure cloud solution to create and manage WPSs and qualifications. Suitable for any size and type of welding company, WeldEye is up to 85% faster for recording personnel qualifications compared to traditional methods.

Kemppi's Weldeye offers efficiency at its best for WPS and qualification management.

It has user-friendly built-in drawing tools for sketching weld joints. The tool enables sketches to be creating in just one minute, which is 95% faster than with traditional methods. Support for AWS, ASME, EN and ISO standards capitalises on the full potential of digitised welding management.

"This offers efficiency at its best for WPS and qualification management. WeldEye has been tested and proven to perform in an excellent way in the coordination of welders, operators and NDT personnel alike, regardless of the industry," says Vesa Tiilikka, product manager for Software at Kemppi Oy.

WeldEye is also an ideal choice for multisite welding management. It generates a range of EN ISO qualifications and enables convenient qualification promulgation with internal and third party signatures automatically. It has a timesaving function for copying templates, it sends automatic certificate expiry warnings to the email of responsible persons and offers an advanced search function and content filtering.

Welders' data is transferred automatically when new qualification certificates are created, which results in significant timesavings in qualification management.

In addition, when used together with the Kemppi X8 MIG welder, WeldEye enables the use of revolutionary digital WPSs.

www.weldeye.com

First Cut and NitraLife establish 'clean cut' partnership

For the laser cutting and fabrication sectors, high-purity nitrogen is essential as it is used to clear molten metal from the point of cutting. An important factor in this process is that – as an alternative to oxygen – nitrogen prevents oxidisation of the cut, allowing for a so-called 'cold' cut which gives a clean finish to the edges. This obviates the need for time-consuming, expensive deburring work.

Until now, the laser-cutting and fabrication sectors have sourced nitrogen in cylinders, a frequently costly system with some inherent challenges. That scenario is now changing, with the signing of an agreement between First Cut, a leading South African distributor of cutting consumables and capital equipment, and NitraLife, a manufacturer of nitrogen generators. In terms of the agreement, First Cut has exclusive distribution rights to NitraLife's NitraCut nitrogen generators aimed at the laser cutting and fabrication industries.

"When we first saw a NitraLife generator connected directly to a fibre laser we had recently sold, we were excited by the potential of being able to supply an uninterrupted, affordable supply of nitrogen – on-site and on-demand – to all our Bystronic laser customers," says First Cut managing director, Andrew Poole.

In 2016, the owner of a laser cutting business approached Sowry, wanting to know if a NitraLife generator would be able to supply his laser machines with nitrogen. A fit-for-purpose generator was built and tested and, once in service, was an instant success. This saw the inception of the NitraCut division of NitraLife; which now markets nitrogen generators exclusively through First Cut to the laser cutting and fabrication sectors.

"Through the agreement, NitraLife will be able to access the laser cutting and fabrication markets, leveraging First Cut's extensive knowledge of and excellent reputation in this industry as a springboard to spearhead future marketing efforts," Sowry explains.

"We have found that customers benefitting from this on-site, on-demand supply can usually recoup the generator purchase price within a year, achieving excellent return-on-investment," says Gareth Jackson, Bystronic South Africa sales director at First Cut.

Tom Sowry, sales director of NitraLife with a NitraCut nitrogen generator aimed at the laser cutting and fabrication industries.

"This will allow laser cutting shops which are remote from mainstream nitrogen gas suppliers to have their own source of nitrogen on-demand and on-site, regardless of geographical location," adds Jackson.

www.firstcut.co.za

PTA for the protection of power components

Thermal spray coating and plasma-transferred arc (PTA) cladding solutions from Thermaspray protect power generation components against corrosion and wear.

Equipment and components such as steam generators, pumps and turbines that handle steam and water in the steam cycle operate in extremely harsh environments, being subjected to high pressure steam, high temperatures and metal-to-metal wear in seating areas. "These are the main contributors of wear in steam and water valves," says Thermaspray spray shop manager, Paul Young. "These components require a variety of control, safety and shut off systems and this is where a lot of wear occurs," he adds, "Furthermore, the surfaces of valve seats and spindles need to inhibit oxidation, which can lead to adhesion damage at high temperatures.

"Our thermal spray and PTA capabilities enable us to refurbish and repair a wide range of components used by local power stations. These include fan blade and steam side spindles, servo motor and rack spindles, stator pump bearing and accumulator housings, fan blade shafts and liners, pump impellers, nose tip liners, deflector rings, control casings, sleeve and rotation plates, sleeves and bushes as well as a range of valves," Young says.

Thermal spraying provides increased resistance to high temperatures, oxidation, traction, cavitation, chemicals and corrosion as well as wear resistance from erosion, abrasion and friction.

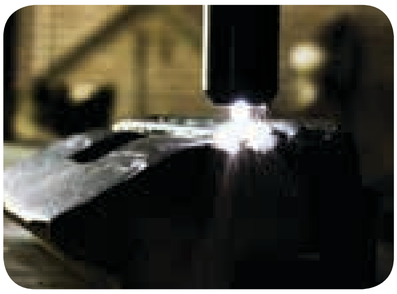
Thermal spraying is considered a 'cold method of welding' where high temperatures can be achieved in the heated spray zone while the temperature of the part itself usually remains under 100 °C. The process can restore worn components to precise original dimensions and extend component service life – "and the subsequent increased uptime and improved production translate into significant cost savings for the end-user," notes Young.

PTA clad hardfacing offers the ideal solution for applications where severe impact and corrosion are prevalent. Here, coatings that can withstand such conditions by providing the necessary protection to the substrate are required.

"This welding process is used to produce high-quality weld hardfacings of Ni, Co and Fe alloys, as well as tungsten carbide containing grades of the nickel alloy," continues Young. "The PTA hardfacings that are metallurgically bonded to the parent material, are able to handle impact, point and/or line loads that a thermal spray coating cannot tolerate."

The scope of work for various repairs and refurbishments conducted by Thermaspray at eight power stations include:

Complete refurbishment of Semple Valves, which involved stripping of the valve, pre-machining, stress relief, thermal spraying, PTA welding, NDT, final machining, final grinding, and assembly. Thermaspray also manufactured rings and bushes for the Semple valve from Mehanite material to the client's specification.



PTA clad hardfacing offers the ideal solution for applications where severe impact and corrosion are prevalent.

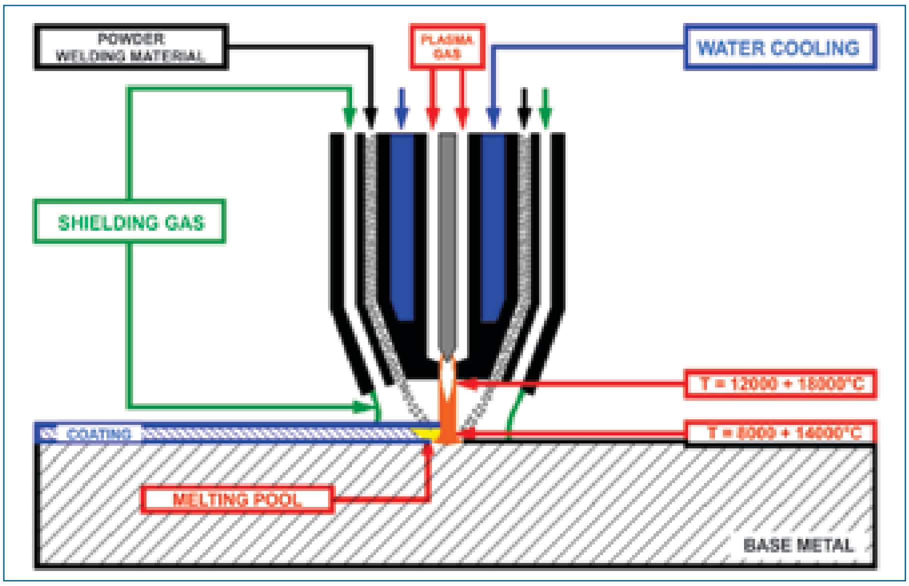
The refurbishment of valve spindles, in partnership with a business partner, included pre-grinding, thermal spray coating, final grinding and NDT (DPI) on the coating. The repair and refurbishment conducted on gland boxes demanded pre-machining, thermal spray coating, final machining and final grinding.

Refurbishment of valve seats included pre-machining, PTA welding with a cobalt alloy and machining to the required dimensions. The job included PTA welding on new seats.

Pump refurbishment, which was completed in conjunction with a business partner, included machining, grinding, thermal spray coating, and final grinding. Electrical run-outs have also been conducted on these shafts ensuring the quality required. Thermaspray also coated butterfly and ball valves to increase wear and corrosion resistance.

Thermaspray, in a joint venture with Cape Town-based Surcotec, offers an extensive portfolio of engineering and thermal spray coating solutions to assist OEM and end-user clients in reducing costs and increasing production.

www.thermaspray.co.za



A schematic of the PTA weld cladding process.

INDEX TO ADVERTISERS