Singapore Welding Society

MARCH 2016 MCI (P) 076/11/2015

WELDPOINT

Reception

NEW OFFICE & TRAINING FACILITY

Training Room

HIGHLIGHTS



SINGAPORE WELDING SOCIETY

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WELDPOINT TEAM

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SWS Newsletter is now available online
WWW.SWS.ORG.SG

PRESIDENT'S MESSAGE

Warmest Greetings!

Time flies! By the time you read this message, we have already cruised through the first quarter of the year with lots of festivities and fun during the New Year Day and Lunar New Year period. Whichever nationality or race you belong to, I am sure you've

soaked in the festive mood with celebrations across the island from the colourful 'Chingay' parade, busy seasonal markets to the loud beating drum of lion dances. The atmosphere was one of excitement and happiness with the people greeting and exchanging mandarin oranges wishing one another prosperity and good luck. In Singapore, the celebration would not be complete without everyone tossing the special Lunar New Year dish, 'Yusheng' high in the air and shouting all the good wishes.

SWS's New Home

SWS reached a very important milestone in the first quarter of 2016. Our newly acquired office at TradeHub 21 has been renovated to accommodate a simple reception counter, a cosy lounge for members and a training room for about 25 participants.

The Property Acquisition Committee (PAC) led by Mr Juerg Schweizer (JS) has done an excellent job in getting the new premises renovated in time for the 'Asian Welding Federation Constitution Review Working Group Meeting' in Singapore. The renovation was completed on schedule and within budget. This would not have been possible without JS' total commitment and astonishing dedication to oversee the completion of this project. We must salute him for a job well done.

I am sure every SWS member, including myself will feel at home and be proud when we step into the new office/training centre. We have planned to hold the next technical talk at this new place and hope to see you there. We have shown some photos of this new place in this issue of Weldpoint. This new facility truly symbolises another important milestone in the history of our society.

Education & Training

The Education and Training Committee continues their efforts in bringing new welding and plant inspection related education, training and certification programs to our members. Our Welding Engineer program offered in collaboration with the Japan Welding Engineering Society (JWES) had its inaugural run in January 2016. With more than 20 participants enrolled for this course and certification, the program was a big success. My sincere appreciation goes to the committee Chairman Mr Chow Ngai Mun and Mr Sze Thiam Siong whose committed work made this possible.

Several of our members have expressed interest in attending the Senior Welding Engineer program as well. I look forward to the continued support from all our corporate and individual members so that the Education and Training Committee can continue to offer training programs of great value.

SWS hosted AWF Working Group Meeting

SWS hosted the 'Asian Welding Federation (AWF) Constitution Review Working Group' meeting on 18 & 19 January 2016 at our new office. The AWF members comprised of twelve delegates from Malaysia, Indonesia, Philippines, Thailand, Japan and China who participated actively in this meeting. The meeting was cordial and achieved its intended objectives. It also facilitated an open exchange of opinions and ideas. Needless to say, it was a great opportunity for our council members to network and establish new friendships and to forge greater cooperation with our counterparts from the AWF.

Singapore Welding Competition 2016

A welding society cannot and should not forget our welders! We will be conducting the *'Singapore Welding Competition 2016'* from 16-17 March 2016. The previous competition held in March 2014 was a big success with the participation of about 30 top-notch welders across industries and the generous support of seven corporate members.

Now, this competition will be held for the 6th time and it promises to be an even bigger event with competitions in three welding processes. This event aims to promote welding excellence in Singapore and also provides a rare opportunity for the gathering of the best welders to exhibit their skills. The winners will be sponsored to represent Singapore at the 2016 Beijing 'ARC Cup' International Welding Competition in June 2016. Winners and Runner-ups will get $800 and $500 worth of vouchers respectively and a plaque. Commendation plaques will be awarded to the employers of the Winners and Runner ups. I wish all the competing welders a safe and successful competition. I wish to also express my gratitude to our corporate members who are generously supporting this event with their sponsorships in cash and kind. Thank you for partnering with SWS!

Resolute work by all our other committees

Our other committees on International Affairs, Publication, Standardization & Consultancy, Common Welder Qualification Scheme (CWQS), Technical Talks and Membership will continue their resolute work and will have more updates for you in the coming months. The Chairmen of the various committees will continue to evaluate and pursue programs of value to the members.

SWS Members' Night and AGM 2016

The SWS Members' Night is around the corner and the Membership Committee is busy planning this event for the annual get-together. Please look out for announcements on our Members' Night 2016 and the Annual General Meeting (AGM) which will be held on 22 April 2016 and 27 May 2016 respectively. We promise you exciting and memorable evenings to look forward to, seeing every one of you there.

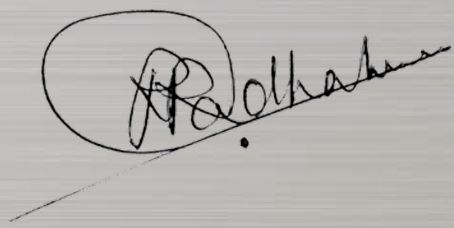
Current economic outlook and what we can do

Based on recent reports from the Ministry of Trade and Industry (MTI), Singapore's economic prospects have softened since the start of this year amid a sharp fall in oil prices and global financial market volatility. MTI however reiterated an earlier forecast for growth to come in between 1 and 3 per cent this year. According to MTI, the global economy should recover gradually this year, but manufacturing, which makes up a fifth of the Singapore economy, is expected to stay weak as demand for exports remains depressed. As a consequence, I expect the local welding and related industry that supports the manufacturing sector to face continued challenges.

Let's remind ourselves to use this slowdown to re-examine our toolbox (knowledge and skillset), identify what is lacking and act on to acquire or sharpen our tools for better years ahead. As you may already know, the Singapore Government has put in place several initiatives and programs towards having a competitive workforce with workers learning for life and advancing with skills. My humble opinion is that, for the welding and related industry to remain relevant, we should work towards better skills and enhanced productivity. In this regard, useful resources and guidance are available at the following government websites.

www.waytogo.sg	-	*Productivity at work by National Productivity Council (NPC)*
www.skillsfuture.sg	-	*SkillsFuture*
www.wda.gov.sg	-	*Singapore Workforce Development Agency (WDA)*

"Wishing all good health, happiness and prosperity in the Lunar New Year of the Red Fire Monkey!"



Perianan Radhakrishnan
President
Singapore Welding Society

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Dr. Sun Zheng	Vice President
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Mr. Yusoof Aynuddin	Chairman, Membership
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NEW MEMBERSHIP FOR NOVEMBER 2015

Fellows		
Sze Thiam Siong	General Manager	Setsco Services Pte Ltd
Full		
Saw Ping Yen	Site Manager	Clavon Engineering Pte Ltd
Palaniappan Padmanathan	Welding Supervisor	SPIE
Student		
Yan Guangxu	Ph.D	Nanyang Technological University

NEW MEMBERSHIP FOR DECEMBER 2015

Corporate		
Kean Teong Tee	Director	Kean Hong Engineering Pte Ltd

NEW MEMBERSHIP FOR JANUARY 2016

Associate		
Manivannan Prabhakaran	QA/QC Inspector	Goodwill Engineering & Inspection Pte Ltd
Full		
Sithu Sithu	Senior QA/QC Inspector	Lead Management Engineering & Construction Pte Ltd

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SWS NEW OFFICE & TRAINING FACILITY

By: Mr. Juerg Schweizer, Chairman, Property Acquisition Committee

After we successfully completed all legal transactions and took over the property in mid-December 2015, the Property Acquisition Committee (PAC) sprung into action to hold several meetings to plan and renovate the premises. Consulting the SWS Council members, it was concluded that the unit should be renovated to accommodate a simple reception, a cosy lounge for the members to meet as well as a training room for about twenty five participants.

The PAC then invited six contractors to participate and submit proposals for the renovation project. Although all the six had made the on-site check and received the work scope from us, only three contractors finally submitted their proposals. After a detailed evaluation of all the three proposals, the PAC recommended to the SWS Council to award the contract to i-Details Pte Ltd. Clarification in greater details and further negotiations were made before awarding the job. As SWS was to host the 'AWF Constitution Review Working Group' meeting during 18-19 January 2016 at the new premises, the PAC had a very tight timeline to follow. On the contrary, hosting the above meeting at a hotel would involve additional expenditure and logistical issues for SWS.

Our contractor for the renovation did a commendable job and finished the project within the budget and given timeframe. SWS occupied the renovated premises on 14 January 2016, well ahead of the target!

All this has been made possible thanks to the excellent dedication and commitment of all PAC members and SWS Council members. This new facility truly symbolises another important milestone in the history of our society.

Our secretarial office address remains the same until further notice.

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Singapore 159836


SINGAPORE WELDING SOCIETY

ADVANCES IN LINEPIPE MATERIAL AND WELDING

By: Dr. Jens P. Tronskar and Ms. Therese Vadholm

Deep Water Technology Centre, DNV GL
16 Science Park Drive, DNV Technology Centre, Singapore 118227

Paper Presented at the Offshore Pipeline Technology Asia 2015, Kuala Lumpur, 20-22 October, 2015.

Jens P. Tronskar

Jens P. Tronskar M.Sc., Ph.D., C.Eng., IWE, SenMWeldI received his M.Sc. degree in Materials' Physics / Physical Metallurgy from the Technical University of Norway (NTH) in 1980 and was conferred the degree of Doctor of Philosophy (Ph.D.) by the National University (NUS) of Singapore, Department of Mechanical Engineering in 2002. His Ph.D. thesis was titled Fracture Analysis of Structural Components in Floating Production Vessels and Ships".

Dr. Tronskar is a certified International Welding Engineer (IWE), a senior member of The Welding Institute and a UK-Engineering Council Charted Engineer (C.Eng.).

Presently, Dr. Tronskar is Vice President and Chief Technology Officer for DNV GL's Deepwater Technology Centre in Singapore. He has more than 33 years of experience of materials technology research, failure investigations and deterministic/probabilistic fracture mechanics analyses/ Fitness-For-Service analyses of structural and piping/process components and pipelines for the offshore and onshore oil & gas industry.

Dr. Tronskar has been involved in materials evaluation and testing for many North Sea field development projects since the early 80s. Since 1994, he has been based in Asia and has been involved in similar work for offshore and onshore projects in South East Asia, China, Australia and Middle East. Dr. Tronskar has been project sponsor and project manager for a large number of Root Cause Failure Investigations, FFS and repair of fixed offshore structures and floaters including mooring system, risers, pipeline and riser FFS and repair projects.

Dr. Tronskar has presented papers at international conferences in Europe, America, South America, Australia and Asia. He has published more than 70 journal articles and peer reviewed conference papers on materials technology, welding and deterministic and probabilistic fracture mechanics analyses of weldments and structural components, pipelines and risers as well as on weldability of structural and pipeline steels.

Abstract

Subsea pipelines are installed to transport oil and gas over long distances and in deep waters. Use of higher strength pipe grades is attractive from a cost perspective as thinner pipe can be used unless it is limited by the collapse and buckling capacity. Traditionally subsea pipelines have been installed using grades DNV SAWL 450 (X65) or 485 (X70). Although the DNV-OS-F101:2013 also covers SAWL 555 (X80), there are not many examples of subsea pipelines installation projects using grade 555.

For flowlines and pipelines carrying fluids containing high CO_2 in combination with H_2S corrosion resistant alloys (CRA) need to be used. Under certain environmental conditions solid 13% Cr, Duplex and Super Duplex grades have been applied for projects but more cost efficient solutions are offered by CRA clad or lined pipe.

High Temperature and High Pressure (HT/HP) wells poses challenges associated with thermal gradients that may cause pipeline lateral or upheaval buckling. At the buckle crown areas, high strain may develop and due to frequent changes in the operational conditions large cyclic strain may be imposed on the pipe and girth welds resulting from so-called pipeline walking. At high operating temperatures *i.e. 140-150ºC* partial under matching or under matching for the weld metal yield strength have been experienced in several projects using nickel base welding consumables.

Installation of pipelines and pipe-in-pipe by reeling imposes high strain to the pipeline girth welds during reeling on and off. Hence, for the mentioned conditions the strain capacity of the girth welds becomes very important and limits the choice of welding processes and consumables as well as imposes tight requirements to the detection capability and sizing performance of the AUT systems.

The present paper discusses use of high strength pipeline steels *i.e. beyond the traditional X65 and X70 grades for offshore pipelines*, use and lessons learnt about installation and service performance of CRAs and CRA clad linepipe. The challenges in selection of linepipe materials and welding consumables are discussed. Recent cases from the industry are presented to illustrate the issues. Finally the paper provides a summary of recent DNV GL Joint Industry Projects on pipeline technology.

Keywords: Materials for high strength pipelines, corrosion resistant alloys, clad pipe, strain-based design and welding requirements

Introduction

Materials for offshore pipelines have traditionally been limited to pipe material with SMYS 485 MPa *i.e. DNV SAWL or SMLS 485 and API 5L grade X70 or lower*. Although the DNV-OS-F101:2013 includes grades DNV SAWL and SMLS 555, these have not been used to any significant extent for offshore pipeline installation.

Recent challenging projects for oil and gas industry has promoted development of linepipes with enhanced performances, especially for deep and ultra-deep water with high temperatures and pressures, introducing additional materials requirements to ensure pipeline reliability in operations. This development has led to advances in linepipe material and welding including quenched and tempered (Q&T) weldable seamless pipes with heavier wall thickness, better combination of strength and toughness and high resistance to sour environments (CO_2 and H_2S) [1]. Advances in the use of strain-based design of pipelines and development of new welding procedures are to avoid unfavourable microstructures that are associated with low fracture toughness, which could cause unstable fracture during installation or in service.

There have been several projects where operators intended to qualify higher strength pipe for deep water subsea pipelines such as Petrobras [2]. However, despite the intentions of running qualification programmes the higher grade pipes were never installed by S-lay, J-lay or reeling. This is surprising since many of the world's longest large-diameter onshore gas transmission pipelines are constructed using API X80 or equivalent grades. It may be argued that the installation methods used onshore impose far lower axial strain levels than for conventional S-lay or J-lay offshore installation and certainly lower than the cyclic strain associated with reeling. However, even for onshore lines large strain may occur during service in connection with soil movement. Therefore, codes such as ASME B31.8 requires that additional axial strain caused by such factors, to be considered by the designer. In case of an axial strain of up to 2%, the designer must pay due consideration to the strain capacity of the pipe body, long seams and girth welds, according to the code. However, the ASME B31.8 code is not specific on how the improved strain capacity should be established and no specific strain-based design methodology is referred to. Presently, the most recognized procedures for tensile strain design are the DNV-OS-F101: 2013 *Appendix A* [3] and DNV-RP-F108 [4] for offshore, and CSA Z662 *Annex C (Refer to Table 1)* for onshore applications. These methodologies are useful under many circumstances but they still have limitations. There are other design codes that allow strain-based design and engineering critical assessments to establish flaw acceptance criteria. Some of the codes are listed in *Table 1*, which includes DNV-OS-F101 and CSA Z662 mentioned earlier.

High Strength C-Mn Pipeline Steels and Girth Weld Properties

There are several topics of concern when using higher grade steels in pipelines; the design, construction and operational phases. Some of these challenges include the data availability to set design criteria for engineering in reliability analyses based on design limit states, design for large strains, welding technologies, criteria for tolerability of defects in girth welds in high grade lines for high pressure, possible damage phenomena affecting the reliability of a line in operation due to mechanical effects and damages arising from pipe interaction with cathodic protection and the soil [5].

Table 1: Overview of design codes that allows for strain-based design

CODE	STRAIN-BASED DESIGN GUIDANCE INCLUDED	ECA GUIDANCE INCLUDED
ASME 31.8	Yes, provides guidance on strain-based design and limits to maximum 2% with due consideration of pipe, seam and girth weld strain capacity and ductility	Yes, allows use of ECA to assess integrity of cracks
ASME 31.4	Yes, provides guidance on strain-based design and limits to maximum 2%	Yes, allows use of ECA to assess integrity of cracks
DNV OS-F101	Yes, provides detailed guidance on strain-based design and limits strain to maximum 2.25% for pressurized and 5% for non-pressurised pipelines with use of supplementary material requirements	Yes, provides detailed guidance on use of ECA, including fracture control for lines subject to plastic strain during installation. Analytical ECA methods and flaw sizes for operating strains > 0.4% and FEA based fracture mechanics methods and materials testing for < 2.25% strain
API 1111	Yes, provides guidance on strain-based design. No strain limit cut off. Strain limit is a function of D/t ratio	Yes, allows use of ECA to assess integrity of cracks
ISO 13623	Yes, allows for strain-based design provides limited guidance	Yes, it makes no specific reference to use of ECA but does make reference to using weld imperfections to set strain criteria
CSA Z662	Yes, provides detailed guidance on strain-based design and limits strain to maximum 2.5% less any residual lay strain. Some of the technology recommended is out of date	Yes, provides detailed guidance on the use of ECA

Strain-based design (SBD) refers to pipeline design methodologies, which has a specific purpose of maintaining pipeline service and integrity under longitudinal plastic strains > 0.4% [2]. Large strain in onshore pipelines may arise due to frost heave and thaw settlements in arctic regions or seismic and landslides/soil movement/subsidence. For offshore pipelines, large strains may in addition occur during pipeline installation, reeling on and off, resulting in thermal expansion, underwater landslides, soil movement and sedimentary deposits associated with rivers for near shore pipelines. Traditional pipeline design focuses primarily on pressure containment by limiting the hoop stress to a certain percentage of the SMYS. However, to assess the structural safety and integrity of a pipeline against large strain caused by any of the above reasons, it is necessary to know the strain demand and the strain capacity. The safety is often considered against two limit states *i.e. the limit against tensile rupture and compressive buckling.*

The tensile strain capacity of a pipeline is governed by the strain capacity and fracture resistance of the girth welds. Girth welds tend to be the weakest link in a pipeline due to the possibility of the existence of weld defects and the changes in metallurgy and mechanical properties arising from the welding process [6].

With increasing water depths, the compressive yield strength, rather than the tensile yield strength, needs to be considered and the minimum wall thickness requirements need to be based on the external pressure, where the D/t-ratio is an important factor to be considered to avoid collapse. Materials used need, among other factors, higher strength, better toughness, better elongation properties and adequate strain capacity. In order for a pipeline to sustain the high plastic strains involved in offshore installation processes and for pipelines operating at high pressure and in deep waters, using higher grade materials, such as grade X80 and even X100 would be more attractive.

However, several challenges arise when using higher grade steels. Among these are the challenges in meeting the weld metal yield strength overmatch-criteria, as required in DNV-OS-F101:2013 [2] in addition to the fracture mechanics procedures being stress-based (including BS7910) and not containing specific guidelines regarding strain-based analyses.

A recent collaborative research program on the strain capacity and fracture behaviour of girth welds in seamless X80 pipes subject to displacement-controlled conditions has been performed jointly by DNV GL and Nippon Steel & Sumitomo Metal Corporation [7]. The study focused on strength mismatch and in particular, weld strength over-match combined with HAZ strength under-match/softening. As part of the joint study, full scale reeling and bending tests were carried out, where the full scale reeling test showed that the welded X80 pipes could sustain a strain level of up to 2.5% without any instability for the range of defect sizes considered. Testing was accompanied by FE-analyses, in good agreement with the obtained results.

Subsea 7 has in collaboration with Vallourec performed a qualification programme for reelable X80 linepipe using a seamless X80 pipe of 323.9mm OD x 18mm WT pipe in accordance with DNV OS F101, supplementary P requirements [8]. Other studies on X80 UOE and spiral welded pipes have also shown that these pipes might be suitable for large strain-based applications even if the pipes were not specifically designed to be used for this purpose [9].

The use of even higher strength steels, up to grade X100 and X120, for onshore pipelines has been a subject of studies over the last decade [10, 11]. However, the interest in use of higher grade materials for line pipes, like X100 is seen to be premature for large scale industrial applications [9, 5]. The chemical composition design, the steel rolling technology, strength and toughness of weld material and the effect of strain ageing are amongst several other factors important to control and investigate, to enable the use of the higher grades in the pipeline industry moving forward [10], also including large strain applications.

The microstructure of linepipe steels is dependent on the chemical composition and online accelerated cooling & rolling condition. To obtain good mechanical properties, the finish cooling temperatures before and after thermal ageing processes are of importance. Adequate tensile properties and low temperature toughness can be achieved by applying higher cooling rates and optimized cooling stop temperature for higher grade steels [12, 13]. In a recent study [14], lower finish cooling temperature in the TMCP process produced a much finer microstructure, and the yield ratios were increased and uniform elongation decreased after thermal ageing in the X100 steel investigated. Ageing properties are of special interest for pipes with anti-corrosion coatings applied, as the process usually takes place at 200-250°C for several minutes which can potentially be harmful for the fine microstructure initially obtained during controlled TMCP processes [14, 15].

Higher strength and toughness of X100 steels has been shown to stem from the structural composition, finer grain size and sub-grains [10]. In X100 steels, the high density of dislocations in acicular plates, cellular structure formed by tangled dislocations and M/A islands in acicular ferrite plates can increase the difficulty of slipping in grains and deformation between adjacent grains in the X100 material investigated. The cellular structure is also being seen as a way to further grain refinement to improve toughness of the pipes.

HAZ softening is an issue for TMCP/QT steels, especially for higher steel grades. Softening normally occurs in the 650°C-1100°C peak temperature regions of the HAZ corresponding to the subcritical, intercritical (Ac_1 -Ac_3) and fine grained austenite zones. During welding, the degree of overmatch or undermatch will to a large degree, determine the variation in yield strength across the weld and in addition, the width and actual hardness drop in the softened zone. The variation in yield strength across the weld and HAZ is not taken into account in the standards applied for fracture assessment such as BS7910, where it is assumed that the flaw tip is present in homogeneous material of uniform yield strength. In very high strength steels, the degree of weld deposit overmatch depends on the choice of welding process or consumables [16]. Therefore, measurement of softened zone HAZ toughness is an important first step in the procedure for determining the significance of flaws in pipelines susceptible to the development of such zones. In *Figure 1*, failure in the soft zone during reeling pipeline installation of a X70 pipeline is shown.

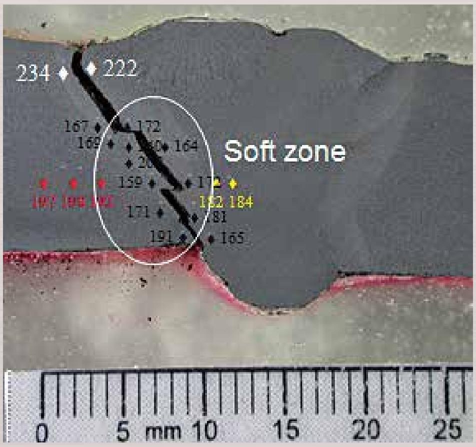


Figure 1: Example of failure of X70 pipeline in soft zone during pipeline installation

Strain-Based Design requirements

For HT/ HP pipelines whether onshore or offshore, lateral and upheaval buckling and changes in operations may cause large cyclic strain. Hence, the pipelines and the girth welds must be selected to ensure adequate strain capacity. The DNV-OS-F101 *Appendix A* ensures that the welds have sufficient strain capacity by specifying requirements to the ECA to be performed at Level 3 *i.e. requiring ductile tearing and fracture resistance curves and that the welds should overmatch the pipe strength*. However, some codes applied for pipeline construction such as API1104 only requires that the weld strength in cross weld tensile tests meets the minimum UTS, which leaves the possibility for the weld to undermatch the pipe depending on weld preparation [17]. DNV GL has experienced several cases recently of pipeline failures and HT/HP pipelines that cannot meet the strain-based design requirements, because the construction and welding practice as per API1104 requirements allows choice of welding consumables that does not meet the fracture resistance and overmatching requirements. For semi-automatic welding and typical in narrow gap weld preparations, some undermatch with a small margin may occur as the narrow weld constrains the weld deformation. This is particular true if the weld cap is not removed on the cross weld tensile specimens. However, for strain-based design, gross weld undermatching cannot be tolerated and an ideal weld overmatch of 10% should be targeted by the welding procedure development. However, with pipe strengths in the upper range for the supply and with high strength grades such as X80 or above, it may be difficult to meet this requirement and at the same time ensure good tearing resistance and maximum load behaviour of the weld fracture toughness test specimens.

Welding of pipelines subjected to large strains adds additional considerations to be addressed in design, construction, and operation. Some of the key issues to be considered when evaluating girth weld performance for strain-based design include [15]:

1) Overmatch

It is essential that the strength of the weld is higher than the strength of the pipe in strain-based design. According to DNV-OS-F101 [3], undermatching weld metal is not acceptable for pipeline girth welds and in particular those subjected to large strain. Modern, low-carbon, low alloy TMCP pipeline steels have seen significant increases in the yield strength with only minor changes in tensile strength, resulting in higher yield to tensile strength ratios. In addition to the above, the actual yield strengths of the higher grades materials may be significantly higher than the minimum specified requirement. This makes achieving the target for weld metal yield strength overmatch difficult. Overmatch levels of 15% or higher should be targeted [15]. Meeting the overmatch criteria can be challenging for pipelines with well fluids with higher reservoir temperatures [18]. A challenge in meeting the overmatch criterion may also arise for CRA clad linepipes when welding using nickel base consumables and for operating conditions involving temperatures of 140-150°C [18].

2) Strain Capacity

Linepipes subjected to large strains needs adequate strain capacity to prevent failure from occurring and to withstand brittle, unstable fracture and pop-in behaviour. Several factors are known to affect the tensile strain capacity of a linepipe. These include: linepipe material (steel composition and tensile properties in transverse and longitudinal direction (including strength level, strain hardening and the shape of the stress-strain curve)), the girth welds (weld metal tensile properties, toughness, weld bevel geometry and high-low misalignment), the interface between the linepipe and weld (HAZ toughness and softening properties), weld flaws (flaw location, orientation, size, position and interaction), pipe geometry (thickness and diameter) and the loading that the pipe is subjected to (internal pressure, accumulation of strain, loading rate).

3) Misalignment

Weld misalignment can be detrimental to the integrity of a pipeline, especially in high strain applications. A certain misalignment must be accepted during welding due to pipe-to-pipe fit-up tolerances. Axial misalignment produces a secondary bending moment across the weld that may affect the local stress range in the weld, resulting in a reduction in the weld strain capacity and fatigue life. The "hi-lo" on the inside of the pipeline is especially important to control as this will affect the probability of having defects in the root pass in which, it further reduces the weld strain capacity and fatigue life. Therefore, for strain-based design situations it is important to keep the misalignment as low as possible [19].

4) Buckling Capacity

For pipelines carrying well fluids from high temperature and high pressure (HT/HP) wells, thermal gradients can result in pipeline lateral or upheaval buckling. Therefore, it is important for a pipeline to have adequate buckling capacity in areas where buckling can be an issue. Defects in girth weld HAZ can be detrimental to the buckling capacity of a pipeline. In addition, the D/t-ratio is of great importance, especially for high strength pipelines to be used in deep-water operations. The collapse pressure of pipes is related to the D/t-ratio, where the steel grade is believed to influence the collapse properties for D/t ratios below 25, increasing with higher steel grades [7]. The probability of failure by buckling also depends on the pipeline length and property variations. Mismatch due to wall thickness variation and yield strength variation also affects the likelihood of buckling in a pipeline [20].

5) Choice of NDT Method

In order to prevent pipeline failure, it is important that the weld defects are detected by the NDT activities. The NDT technique needs to have adequate sensitivity *i.e. probability of detection (PoD) and sizing capability to detect and size flaws in the girth welds.* The use of ultrasonic detection methods should be used. Radiographic Testing (RT) has inherently lower PoD for certain types of flaws such as planar flaws [21]. Therefore, the use of other NDT methods with higher PoDs, like Phased Array Ultrasonic Testing (PAUT) techniques should be used to increase the probability of detecting planar defects that might not be detected by the radiography.

6) Clean Welds

Low tearing resistance is detrimental to pipelines designed for high strain applications using strain-based design. This becomes even more important with increasing strength of the weld metal used for welding higher grade pipes *i.e. X80 and above*. There are several factors that contribute to decreasing ductile fracture (tearing) resistance in steel weld metals. These include higher volume fraction and larger average size of non-metallic inclusions, weaker bond between non-metallic inclusions and the matrix and lower work hardening capacity of the microstructure (normally also meaning higher material strength) [6]. Consequentially, it is important to control the cleanliness of the weld and to choose a suitable weld procedure and consumables that introduces low volume fractions of non-metallic inclusions.

7) Welding Procedure Qualification

In order to ensure adequate properties for SBD pipelines the welding procedure and the welding qualification are very important as it affects the strain capacity of the welds.

As outlined above, a suitable weld procedure should produce clean welds and the choice of NDT method with the right PoD is of utmost importance to ensure overall pipeline reliability and performance in high strain applications. Softening of the HAZ is a concern for high strength steel pipes [7] and should be addressed in developing good WPS procedures with the optimized number of passes, control of the heat input and choice of filler metal to ensure mechanical properties are maintained at the adequate level, the weld metal yield overmatch criterion is met and to avoid formation of inclusions and phases LBZ/MA* detrimental to the strain capacity of the weld zone.

LBZ's and reeling

During welding, formation of local brittle zones (LBZ) can occur in the heat affected zones (HAZ). Welds in offshore structural steels are known from the early 80s introduction of low carbon-manganese micro-alloyed steels, to occasionally exhibit low fracture toughness associated with LBZ. LBZs can be described as discrete microstructural regions in a weld heat affected zone (HAZ) that exhibit significantly lower resistance to fracture initiation than the surrounding material. The brittle behaviour is caused by the presence of brittle transformation microstructures (upper bainite, martensite/austenite (M/A) constituents). Microstructures associated with LBZ are extremely brittle with critical CTOD-values down to 0.02-0.03mm.

Presence of LBZ microstructures may have a dramatic effect on the coarse grained HAZ CTOD fracture toughness properties causing unstable fracture initiation by cleavage. Investigations have shown that LBZs in multi-pass welds of ferritic steels can be formed in either the grain coarsened HAZ (GCHAZ) close to the weld fusion boundary, or in the inter-critically reheated grain coarsened HAZ (ICGCHAZ). Inter-critical reheating of the primary CGHAZ containing LBZ may add to the problem as M/A phase precipitation along prior austenite grain boundaries can occur. The LBZ behaviour is primarily dependent on steel chemistry, welding procedure, welding conditions and the fracture toughness test temperature. Therefore it is highly important to control the welding parameters and choose a WPS to avoid these brittle microstructures from forming. Changes to pipe chemistry or welding procedure may be required to avoid formation of LBZ.

During testing of pipeline girth welds for reeling, low CTOD critical fracture toughness values due to pop-ins and unstable fracture initiation in the HAZ caused by LBZs have been experienced. For reeling, the large plastic strain associated with the reeling process affects every girth weld during reeling on and off for installation, as opposed to offshore structures where there may be only a few extreme wave load and fatigue critical welds. If the weld heat affected zone contains local brittle zones, unstable fracture and brittle fracture may occur, which could lead to premature pipe failure or cracking during reeling installation. To avoid LBZs, it is vital for reeling, maximum load behaviour and large tearing capacity are required to obtain practical weld flaw acceptance criteria for AUT [22].

CRA, clad and lined pipe

For flow lines and pipelines carrying fluids containing high CO_2 in combination with H_2S corrosion resistant alloys (CRA) need to be used. Under certain environmental conditions solid 13% Cr, Duplex and Super Duplex grades have been applied for projects but more cost efficient solutions are offered by CRA clad or lined pipe. For welding of clad and lined pipes, a special welding procedure is needed.

High Temperature and High Pressure (HT/HP) wells poses challenges associated with thermal gradients causing pipeline lateral or upheaval buckling. At the buckle crown areas high strain may develop and due to frequent changes in the operational conditions, large cyclic strain may be imposed on the pipe and girth welds resulting from so-called pipeline walking. At high operating temperatures *i.e. 140-150°C* partial under matching or under matching has been seen for the weld metal of girth welds deposited using nickel base consumables *i.e. Inconel 625, 622, 686 etc.* [18]. Welds deposited using Super Duplex consumables may provide overmatching strength but other disadvantages include greater susceptibility for lack of fusion defects and hydrogen induced stress cracking (HISC) at strain levels above 0.8% and cathodic protection levels below -1050mV.

Discussion

Some of the main issues in relation to welding when considering using of higher strength pipeline steels *i.e. grade X80 and above* for offshore pipelines include formation of LBZs, HAZ softening, maintaining high tearing resistance, strain capacity of girth welds and ensuring weld metal overmatch, especially for clad and lined linepipes.

SBD Procedures and Codes

Some of the key issues to be considered when evaluating girth weld performance for strain-based design, especially when using higher steel grades, includes adequate weld metal overmatch, strain capacity, buckling capacity, weld misalignment, choice of NDT method, keeping the welds clean and weld procedure qualification methodology. When addressing these issues and designing pipelines operating in areas where large and cyclic strains must be accounted for, many of the design codes used today include varying levels of detail on SBD and ECA methods, as shown in *Table 1*. These issues need to be addressed moving forward to ensure good pipeline design and to assure pipeline integrity for the pipeline during the service life.

The development of linepipe material and welding solutions for reelable high-strength carbon steel and CRA-lined pipe are considered to be vital to enable oil and gas exploration and production in deeper waters and harsher environmental conditions moving forward. Testing and qualification of new materials and procedures for manufacturing and welding is needed and a lot of research has been and is currently being done on the matter. As an example, Subsea 7 in collaboration with Vallourec, performed a qualification programme for reelable X80 linepipe using a seamless X80 pipe of 323.9mm OD x 18mm WT pipe in accordance with DNV OS F101, supplementary P requirements. Subsea 7 developed and qualified a mechanised girth weld procedure based on the CMT/PGMAW welding process. The procedure qualification was successfully performed in compliance with DNV OS-F101, including mechanical, fracture toughness and sour service testing [8].

Welding Procedure Specification

Choosing the right Weld Procedure Specification (WPS) for the material to be welded, the application of the pipeline and the environment in which the pipeline is to be exposed to, is key when ensuring pipeline integrity in all phases of the pipeline lifetime. Choosing the wrong set of weld consumables may enhance the formation of certain weld flaws, like the lack of fusion when using Super Duplex consumables in addition to making the pipeline more prone to HISC, moreover, increasing the risk of inducing undesired microstructures in the HAZ. Undesired microstructures such as LBZs deteriorate the mechanical properties of the pipeline, like the strain capacity of girth welds. An example of the difference choosing a suitable WPS can make on the final weld microstructure can be seen in *Figure 2*. The corresponding steps of the original and transformation WPS can be seen in *Table 2* and *Table 3*, respectively. In the original weld, about 80% of the HAZ was found to consist of unfavourable microstructure (GCHAZ/ICGCHAZ) within the central 75% thickness of the sample. Additionally, larger volume fractions in microstructure increases line-fraction in CTOD specimens and increases probability of unstable fracture initiation. A transformed WPS was proposed with the result of reducing the fraction of the HAZ consisting of unfavourable microstructure (GCHAZ) to about 10% to 15% within the 75% thickness of the sample. Larger volume fractions of unfavourable microstructures increases line-fraction in CTOD specimens and increases probability of unstable fracture initiation occurring. As seen when comparing *Table 2* and *Table 3*, the transformation WPS includes two fill passes. This has a good effect on the CGHAZ/ICGHAZ final microstructure, as microstructures, detrimental to the properties of the steel are allowed to transform in a better way. With thinner passes, the likelihood of transforming detrimental phases formed during preceding passes is increased, sustaining the mechanical properties of the steel.

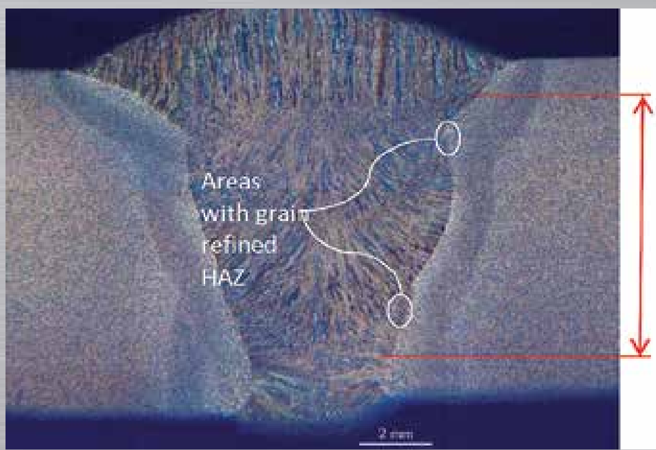
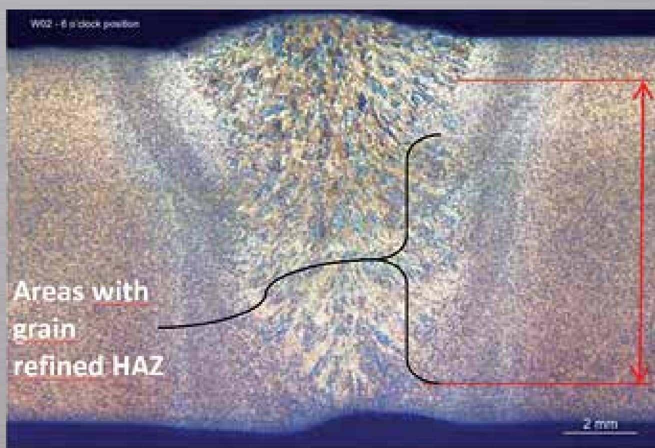


Figure 2: a) Weld using original WPS



b) Weld using transformation WPS

a) ~80% of the HAZ was found to consist of unfavourable microstructure (GCHAZ/ICGCHAZ) within the central 75% thickness of the sample. Larger volume fractions in unfavourable microstructure increases line-fraction in CTOD specimens and increases probability of unstable fracture initiation.

b) Within the central 75% thickness of the sample (marked with red lines in the figures) ~10% to 15% of the HAZ was found to consist of unfavourable microstructure (GCHAZ) whereas for the old WPS used to obtain the weld.

Table 2: Original WPS

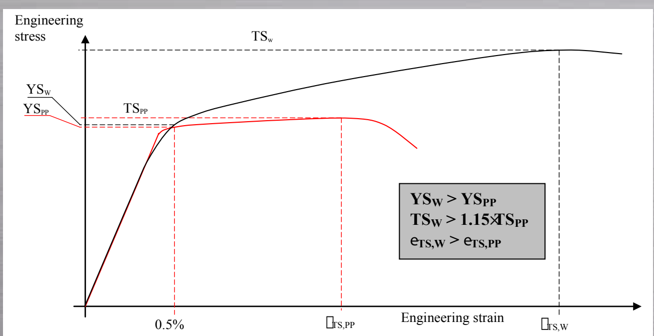
Pass	*Process*	*Current (A)*	*Voltage (V)*	*Travel speed (mm/s)*	*Heat input (MAX) (kJ/mm)*	*Preheat/ Max Interpass temp. (°C)*	*Estimated Weld cooling time, $Dt_{8/5}$ seconds*	*Heat flow*
Root	GMAW(CMT)	200-240	11-13	6-9	0.5	50	2.7	3D
Hot	PGMAW	160-210	20-24	9-12	0.6	100	3.98	3D
Fill	PGMAW	160-220	19-24	6-8	0.9	250 (150)	27.0 (12.3)	2D
Cap	PGMAW	130-160	21-25	5-10	0.7	250 (150)	16.3 (7.46)	2D

Table 3: Transformation WPS

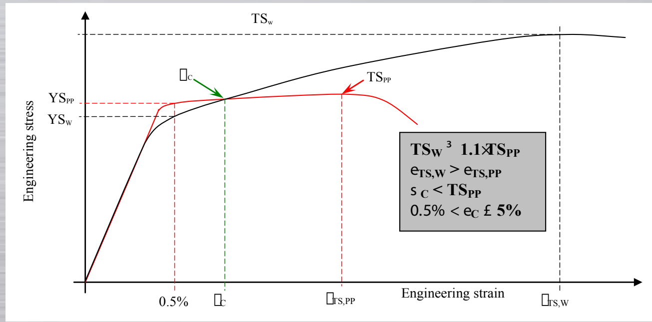
Pass	*Process*	*Current (A)*	*Voltage (V)*	*Travel speed (mm/s)*	*Heat input (Max) (kJ/mm)*	*Preheat/ Max Interpass temp. (°C)*	*Estimated Weld cooling time, $Dt_{8/5}$ seconds*	*Heat flow*
Root	GTAW	145-157	10	1.68	0.9	21	3.3	3D
Hot	HWGTAW	160-210	20-24	1.8	1.1 incl.HW	50	5.65	3D
Fill 1	HWGTAW	160-220	19-24	1.88-1.92	1.1 incl.HW	150	6.94	2D
Fill 2	HWGTAW	160-220	19-24	1.88-1.92	1.1 incl.HW	150	6.94	2D
Cap	HWGTAW	130-160	21-25	1.98	1.1 incl.HW	150	6.94	2D

Corrosion Resistant Alloys

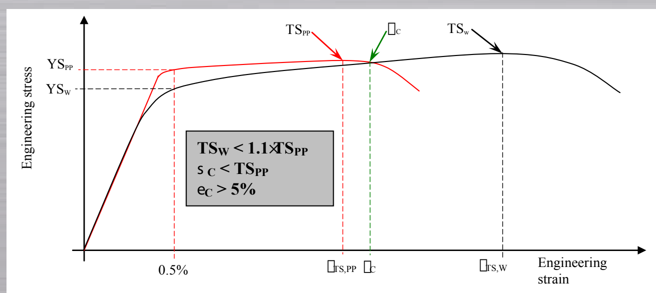
It is not only the heat input value and the weld cooling time that are of importance for the final weld microstructure and overall pipeline integrity. The choice of welding consumables, especially for CRA clad and lined pipes with high operating temperatures *i.e. 140-150°C*, is vital, as partial or under matching weld metal was found for girth welds deposited using nickel base alloys. Avoiding partial or full under matching for the weld metal of girth welds can be a challenge when welding pipelines of increasing strength as illustrated in *Figure 3*.



a) Weld using original WPS



b) Weld partial overmatch



c) Weld undermatch

Figure 3: Illustration of stress-strain curves showing weld and filler material over- and undermatch. For case a), assessment can be made using DNV-OS-F101, Appendix A. For case c), no procedure is applicable for case c), and special advice is needed.

In addition, HT/HP wells pose challenges with thermal gradients, which can cause lateral or upheaval buckling. For the associated high cyclic strains developed in the pipeline from variations in operating conditions, a strain-based design approach is needed. In addition, for CRA clad and lined pipes, performing ECA is a challenge. ECA procedures are only applicable for weld defects in the filler passes, the reason being that an ECA for installation will typically accept flaw heights above 3mm, however such large defects cannot be accepted in the weld root due to fatigue concerns and potential galvanic corrosion *(Figure 4)* which would destroy the integrity of the pipeline.

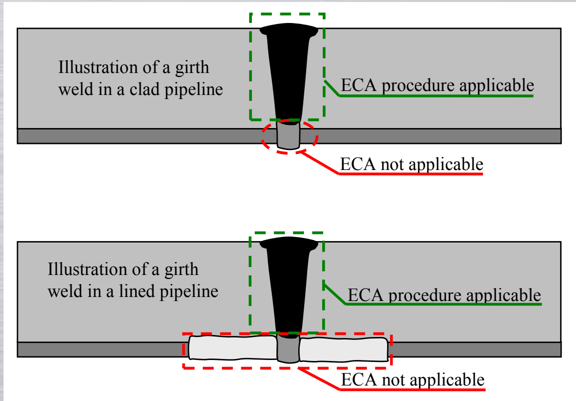


Figure 4: ECA procedures are only intended for use on weld defects in the filler pass. The reason for this is that an ECA for installation will typically accept flaw heights above 3mm. Such large defects cannot be accepted in the weld root due to fatigue concerns and loss of corrosion resistance.

For CRA clad and lined pipes, weld defects, such as lack of fusion and defects at the weld root *(Figure 5)* may lead to the C-Mn steel being exposed to the electrolyte causing rapid galvanic corrosion *(Figure 5)* and pipeline degradation. Choice of welding procedure and NDT method is especially important for these pipelines to ensure the pipeline integrity.

For CRA clad pipelines, installation challenges such as minimizing hi-low giving stress concentrations and defects at the root *(Figure 5b)* is highly important, as avoiding pitting corrosion caused by accidental seawater ingress during installation, could potentially destroy the integrity of the pipeline in a few months' time from leaks caused by galvanic corrosion between the CRA and C-Mn steel.

Concluding Remarks

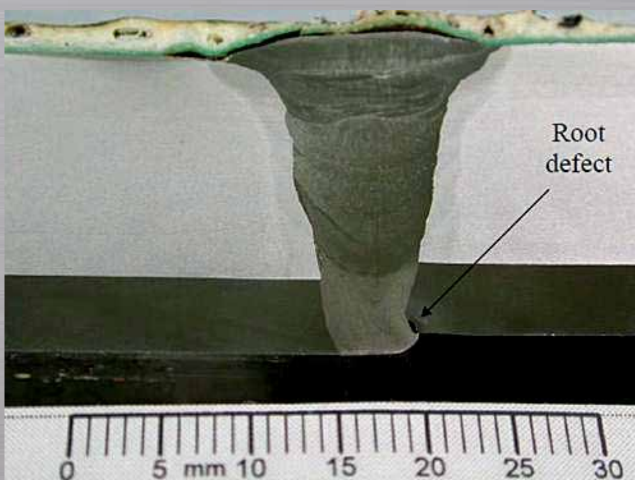
Although there are many challenges related to the use of higher strength steels in high strain applications, in deeper waters and under harsher environmental conditions, some recent studies performed have showed that X80 can be applied for challenging applications and even for high strain applications such as reeling.

Some of the main issues related to welding and weld properties for the higher strength pipeline steels still needs to be resolved, these issues include formation of LBZs, HAZ softening, maintaining high tearing resistance and strain capacity of the girth welds as well as ensuring weld metal yield strength overmatch.

For strain-based designs, there are other issues apart from the above such as the pipe buckling capacity, weld misalignment, selection of an NDT method that can detect and size planar defects accurately.

Currently one challenge is with the variation in the level of detail provided by the available SBD and ECA methods and this issue needs to be further addressed in future code developments required for application of higher strength line pipe offshore.

Figure 5
a) Failure of the root weld in 625 clad riser caused direct contact between electrolyte and carbon steel with small area compared to the internal Inconel 625 clad surface area



b) Root lack fusion of 316L clad pipe welded using Duplex 2509. The lack fusion is associated with weld misalignment.

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First row from Left: ***Mr. Shoichi Nomura*** *(Japan),* ***Mr. P Radhakrishnan*** *(Singapore),* ***Mr. Eric Montes*** *(Philippines),* ***Mr. Wataru Mizunuma*** *(Japan),* ***Mr. Katavut Suchin*** *(Thailand),* ***Dr. Liu Zhenying*** *(China).*

Second row from Left: ***Mr. Mochammad Moenir*** *(Indonesia),* ***Mr. Juerg Schweizer*** *(Singapore),* ***Mr. Eddie Ko*** *(Singapore),* ***Dr. Budi Utomo*** *(Indonesia),* ***Mr. Suradi Yasin*** *(Malaysia),* ***Dr. Sun Zhenguo*** *(China),* ***Mr. Slamet Subagyo*** *(Indonesia),* ***Ms. Aini Ghazali*** *(Malaysia),* ***Mr. Mac Ong*** *(Malaysia),* ***Mr. Sze Thiam Siong*** *(Singapore)*

AWF WORKING GROUP MEETING IN SINGAPORE TO REVIEW ITS CHARTER

By: Mr. Eddie Ko, Vice President/ Chairman, International Affairs

One of the actions taken at the last AWF meeting in Surabaya last year was the formation of a special Working Group (WG) to review its Constitution (or Charter) and to make recommendations as to whether or not changes are necessary. The member countries represented in the WG that met in Singapore on 18-19 January 2016 were from China, Indonesia, Japan, Malaysia, Philippines, Singapore and Thailand (an apology for absence was received from Korea). There were in total around seventeen delegates and observers present that sat through the sessions chaired by Mr. Wataru Mizunuma, Executive Director of JWES. One initial and important question that was put forward by Japan to member delegates to deliberate on includes:

1. To maintain if possible, the current scheme without any amendment(s) to the Constitution.
2. If it is absolute necessary to make the amendment, only the “smallest” change should be carefully considered.

In addition to the above he also highlighted the background to the problem that had arisen over the Constitution issues. Continuing on, Mr Mizunuma took time to provide a detailed presentation covering the following items which were comprehensively discussed by members present:

- Clarifying the goal of the WG
- Procedures to amend the Constitution
- A table of comparison between AWF Constitution and that of other Welding Associations
- Current AWF Scheme and on other relevant Article of Constitution
- Review of Questionnaire and feedback from member countries concerning AWF as an Organisation and its sustainability
- Other matters such as the role and/or chairmanship of CWCS, Governing Council, Secretariat, Secretary General, etc., were revisited and debated

In all, the WG had a very friendly, open and fruitful meeting, despite the fact that there were some diverse opinions in the beginning, the WG was able to come to a unanimously accepted conclusion not to make any amendments to the Constitution. However the WG agreed to propose a list of Administrative Procedures instead which will be put forward to the Governing Council for acceptance in the next AWF meeting scheduled for April 2016 in Osaka, Japan.

Being the host country, January 18 was also a historical occasion for SWS as the meeting was held in our newly acquired office at 18 Boon Lay Way, #18-112 TradeHub 21. The interior of the SWS office was given a good makeover and the renovation was completed just in time to allow our overseas guests the opportunity to see our set-up which can comfortably accommodate more than 40 people by rearranging our sitting pattern. Our Property Acquisition Committee (PAC) was delighted that the countless meetings and hard work put in to meet the short renovation deadline have resulted in significant cost savings to SWS as it was no longer necessary to organise the meetings at a hotel or club house.

SWS is honoured and privileged to be given this opportunity to host this special Working Group and thank all the delegates for their attendance and especially JWES for their strong commitment to ensure that AWF will continue to serve its members effectively and be an important organisation throughout Asia.

INTERNATIONAL INSTITUTE OF WELDING (IIW) INTERMEDIATE MEETING

By: Mr. Eddie Ko, Vice President/ Chairman, International Affairs

From Left: ***Ing. Henk Bodt*** *(LA-Nethelands),* ***Mr. Christian Ahrens*** *(LA-Germany),* ***Prof. Gary Marquis*** *(IIW President-France),* ***Mr. Eddie Ko*** *(ANB-Singapore),* ***Ms. Yevgenia Chvertko*** *(ANB-Ukraine)*

Ms. Cecile Mayer *(IIW CEO) enjoying a copy of our SWS WELDPOINT (sent by our Secretariat)*

Following the 68th IIW Annual Assembly and International Conference in Helsinki in 2015, several working groups' (WG) recommendations, draft documents and other IIW matters that were not fully resolved or approved were brought forward for further deliberation at the IIW Intermediate Meeting in Paris. This annual management review meeting was held at the HQ of the French Welding Institute in Villepinte from the 1 – 5 February 2016.

Despite the heighten security and emergency regulations in place within France due to the recent spate of terrorism, a fairly large numbers of delegates and representatives from member countries were present.

The following are highlights from a selection of items and documents that were discussed in the various working groups and special committees:

IAB Working Group A (WGA) - Education, Training and Qualification

The chairman of the WGA #3b summarized his report on the work done dealing with the review of the IWIP Guideline (revision 3). This means that ANBs can start developing the training material and after approval of the Practical Exams in Part III, it can be fully used. The number of hours (40) for Part I remains unchanged and the WG will look into the possibility of a Welding Inspector skipping Part 1. The above guideline was approved.

IAB Working Group B (WGB) – Implementation, Authorization and Certification

Mr. Chris Smallbone informed the organization of the IIW Annual Assembly in Melbourne and presented the Conference place, social events, hotels and amenities.

The chairman of the IAB-WGB-457-16 made a report of the work done to change the Rules and Operations of the documents IAB-001, OP-3 and OP-11 and to ensure its respective legal compliances with WGB#1+ concerning the international competition legislation. These documents incorporating the changes were explained and approved.

Of significant interest to all ANBs/ANBCCs is the requirement to develop a business plan. A draft template was presented. The objectives as explained are to have a better understanding of the global market demands of IAB services and to monitor the performance of its members.

IAB Member's Meeting

At the IAB member's meeting, the IIW President gave an update on the status concerning its obligation to comply with the international competition regulations. The Interim Report proposed a new concept to ensure that IIW activities are spread as widely as possible and should be of the highest quality leading to technicality and the safety of welded structures. A WG B1+ was formed to revise the rules and procedures as necessary and these will be sent to IIW legal counsel for comments.

Information on the Board of Directors Decisions and Actions

It is of great interest to note that on 5 February, the IIW Directors had among other items, carefully evaluated the presentation and documents presented by SWS to host the IIW Annual Assembly in 2020. Of the 2 bids being considered, the Board had proposed to select Singapore to be the venue for the 2020 Annual Assembly. This recommendation will be presented as an item in the Agenda to the General Assembly in Melbourne for final acceptance.

Delegates of ANB member countries in attendance at the IAB Working Groups meetings

JAPAN WELDING ENGINEERING SOCIETY (JWES) WELDING ENGINEER COURSE & CERTIFICATION

By: Mr. Sze Thiam Siong, Honorary Secretary, SWS

The Singapore Welding Society (SWS) signed a cooperation agreement with the Japan Welding Engineering Society (JWES) on 13 May 2015. Under this agreement, SWS will organize the various training courses leading to the certification of Senior Welding Engineer (SWE), Welding Engineer (WE) and Associate Welding Engineer (AWE).

The JWES WE System *i.e. SWE, WE and AWE*, is accredited by the Japan Accreditation Board (JAB) as a personnel certification organization based on ISO 17024 and is recognized by the industry and government body. The training materials are prepared by the Japan Welding Society (JWS) and the examination questions are prepared by the "WE Education Committee" of JWES.

The first "Welding Engineer" course was conducted in Singapore from 9 – 13 January 2016. It was conducted by two Japanese experts, Prof. Dr. Kunio Takahashi and Mr. Hideaki Harasawa.

Prof. Dr. Takahashi obtained his Master and PhD degrees in Welding Engineering from the Osaka University in 1987 and 1990 respectively. He is currently the Professor at the Tokyo Institute of Technology. He received many distinguished awards from the JWES, High Pressure Institute of Japan, American Welding Society (AWS) and Robotics Society of Japan and has published many papers

Mr Harasawa obtained his Bachelor and Master degrees in Engineering from the Osaka University in 1968 and 1970 respectively. He is currently the Technical Advisor at JWES and possesses the IWE, SWE and AWS-CWI qualification/certification. He has over 40 years of experience as a senior welding researcher/engineer in the shipbuilding, offshore, construction, pressure vessels, storage tanks, pipeline, railway and many other related industries, while working in NKK Corporation (now known as JFE Engineering Corp) and its subsidiaries. He has published a number of papers involving weld cracking, weldability and CTOD among others.

The objective of the course is to equip the welding personnel with the necessary knowledge to prepare them for the examination leading to the "Welding Engineer" (WE) Certification in accordance with JWES - WES 8103 (Standard of Certification of Welding Coordination Personnel) and ISO 14731 (Welding Coordination Tasks and Responsibilities). It was an intensive 5 days course, covering topics including welding processes and equipment, materials and their behaviour during welding, design & construction, fabrication and application engineering as well as exercises for the participants to enhance their learning. This is the first time the course and certification was conducted in Singapore and the response was overwhelming with 21 participants attending and completing the course. All participants also took the examination on 15 January 2016 with the same goal of attaining the "WE" certification, which will be jointly awarded by JWES and SWS for successful candidates.

The renewal and validity of the WE certificate is based on JWES WE System accredited under the JIS Q 1704 (ISO/IEC 17014) and is as shown below.

- Surveillance Assessment Exam – two years after receiving the certificate
- Re-certification Assessment Exam – five years after receiving the certificate

The re-certification assessment consists of "lectures", "exercise" and a "written examination".

Overall, the event was considered a success, based on the feedbacks received. The participants interacted actively amongst themselves and with the trainers, sharing their experiences and knowledge. Every one of them had a very satisfying experience during the course, particularly with respect to the training facilities, course materials and their trainers.

PROGRESS IN STANDARDIZATION OF ADDITIVE MANUFACTURING

By: Prof. Zhou Wei, Chairman of Welding Technology & Standardisation Committee

For any manufacturing processes, standards are required to ensure the product quality and to improve the productivity and safety levels. International standards on welding and allied processes (such as cutting and post weld heat treatment) are mainly made by ISO/TC 44 (Technical Committee 44). This committee currently has 30 participating countries (P-members) and 35 observing countries (O-members). Since November 2009 Singapore has been a P-member of the committee and formed its own National Mirror Committee (NMC) to ISO/TC 44. As Chairman of the NMC, Prof. Zhou Wei had the honour to represent Singapore at many ISO meetings. At a recent meeting in October 2015, in Seattle, USA, he was appointed as a Liaison officer to ISO/TC 261 on "Additive Manufacturing" (AM) and since then, has paid special attention to the development of AM standards.

Another reason for Prof. Zhou Wei's strong interest in AM is due to the fact that AM, can essentially be viewed as a welding and joining process. AM, popularly known as 3D printing, is a direct digital manufacturing process in which a component is produced by "adding" and "joining" layer by layer directly from 3D digital data. AM technology existed 30 years ago and was known as rapid prototyping but has developed rapidly in the recent decade. It has demonstrated significant potential for reducing the cost of aerospace components and created unique opportunities in the medical, energy and marine sectors. Benefits can be realised through

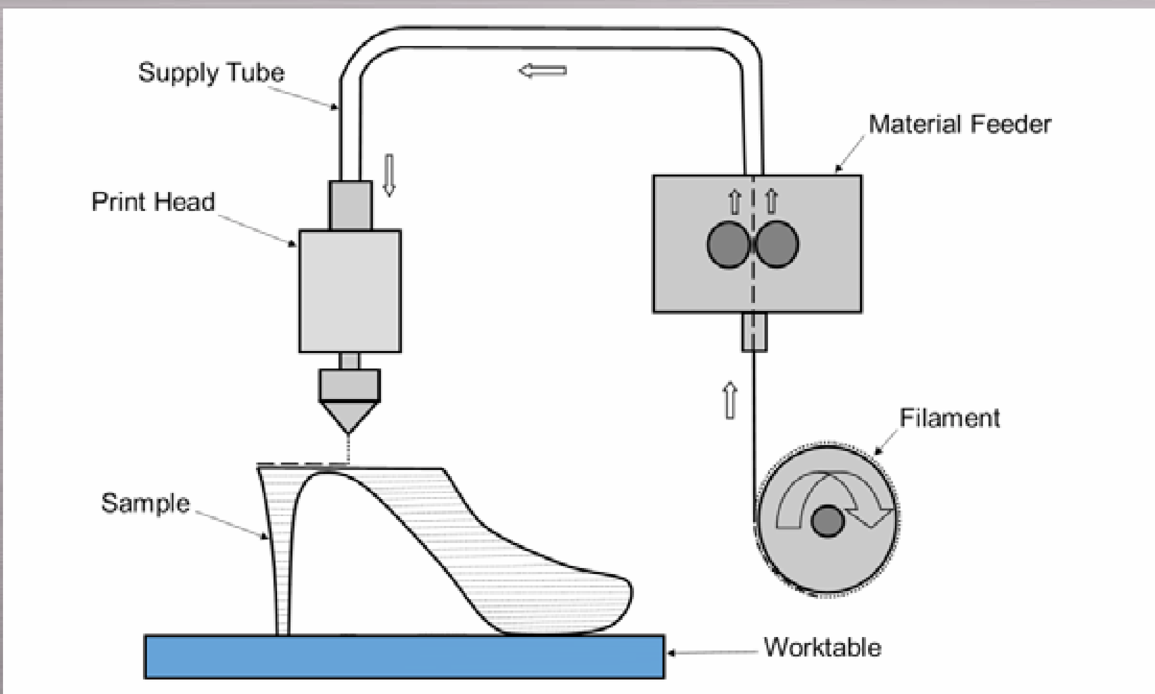


Figure 1: Illustration showing innovative use of welding technology for 3D printing.

Figure 2: Laser cladding is an additive manufacturing process

improved design freedom, weight reduction and lower tooling costs (especially for low volume manufacturing).

As the market for additive manufacturing (AM) is expanding rapidly, there is the clear need for the standardisation concerning AM's processes, terms and definitions, test procedures, quality parameters, and safety. A few initiatives have been established by national and regional standardization groups, notably the German VDI working group, the ASTM F42 committee on Additive Manufacturing, CEN/TC 438 "Additive Manufacturing" and SASAM. In 2011, International Organization for Standardization (ISO) created the Technical Committee 261 "Additive Manufacturing" (ISO/TC 261).

It is noted that the progress in AM standardisation is very slow. ISO/TC 261 has so far published 6 standards only:

- ISO 17296-2:2015 Additive manufacturing -- General principles -- Part 2: Overview of process categories and feedstock
- ISO 17296-3:2014 Additive manufacturing -- General principles -- Part 3: Main characteristics and corresponding test methods
- ISO 17296-4:2014 Additive manufacturing -- General principles -- Part 4: Overview of data processing
- ISO/ASTM 52900:2015 Additive manufacturing -- General principles – Terminology
- ISO/ASTM 52915:2016 Specification for Additive Manufacturing File Format (AMF) Version 1.2
- ISO/ASTM 52921:2013 Standard terminology for additive manufacturing -- Coordinate systems and test methodologies

In contrast, ISO/TC 44 has published 305 standards concerning welding and allied processes.

In Prof. Zhou Wei's opinion, many ISO/TC 44 standards can be adopted or adapted for AM applications, since additive manufacturing is essentially welding and joining processes. Manufacturing standards play an important role in ensuring structural integrity and they also serve to facilitate international trade, raise productivity, and improve safety, health and environmental protection. We hope that the short article stimulates your interest in the work of making international standards.

If you are interested to participate in the work of NMC, you are most welcome to contact Prof. Zhou Wei by sending an email to *wzhou@cantab.net*.

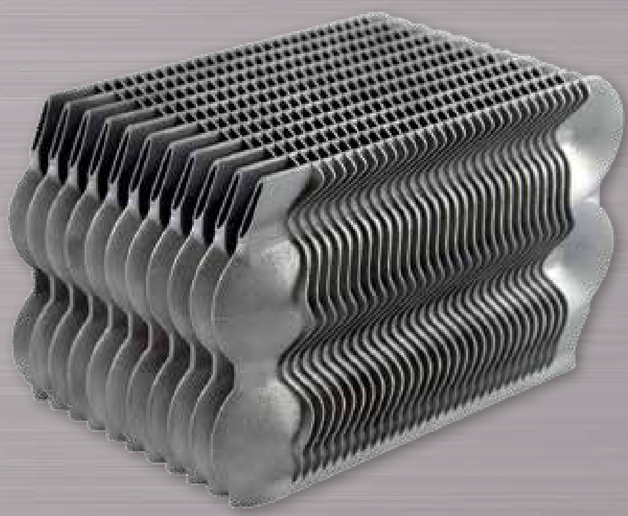
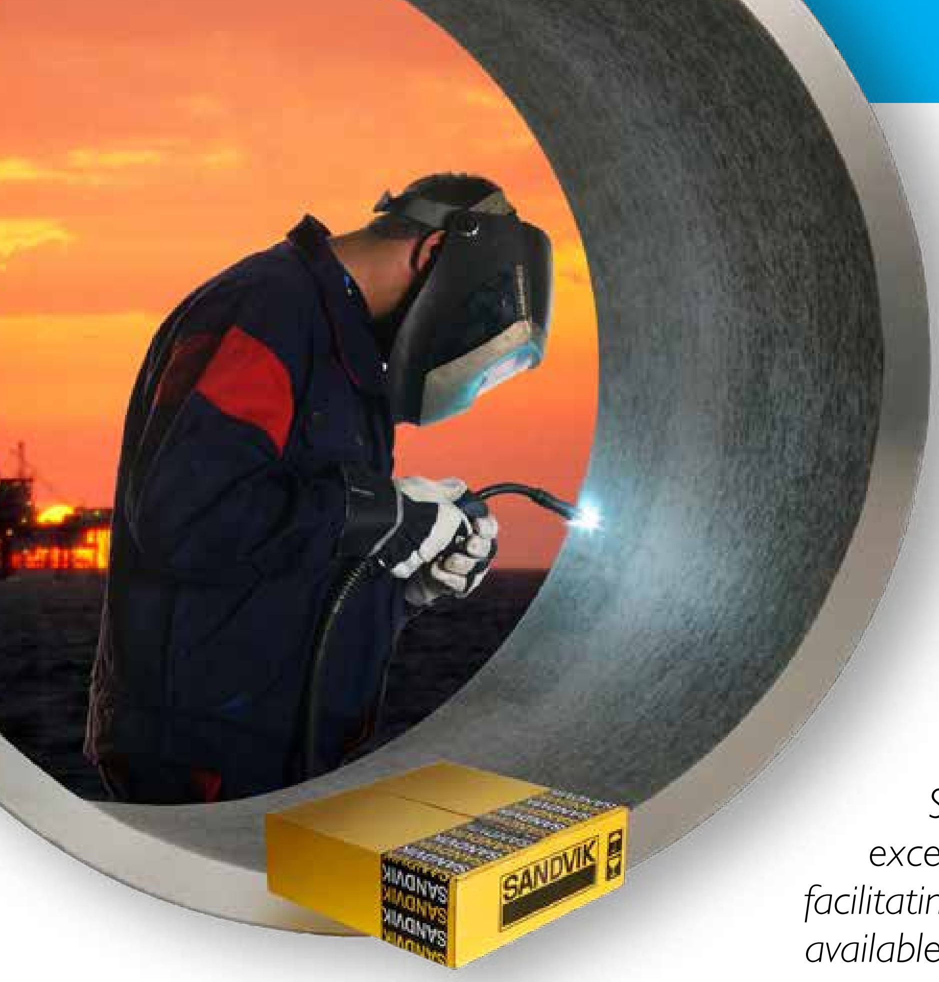


Figure 3: Additive manufacturing technology makes it possible to design and produce smaller, lighter and more efficient heat exchanger (image credit: EOS)



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