8:00 am  Morning Keynote - Emerging Challenges in Welding and Inspection Technologies in the Oil & Gas Industry

Tom McGaughy, Sr. Technical Advisor, Edison Welding Institute

Welding and inspection technologies play an integral role in the fabrication, operation and maintenance of much of the infrastructure used by the oil & gas industry to extract, process and transport the numerable energy products our economy demands. While many welding and inspection techniques are considered technically mature and have been in use for several decades, gaps and challenges remain. Thus, research and development is needed to take advantage of new materials; to improve upon current safety, environmental, and cost efficiency standards for infrastructure construction and operation; and to aid in life extension. This presentation will highlight the outcomes and priorities of a recently completed national roadmap for materials joining and forming technologies that was commissioned by the National Institute of Standards and Technology (NIST) and coordinated by EWI. While this roadmap addresses needs across all manufacturing sectors, the presentation will focus on materials joining elements and applications relevant to the oil & gas industry. In addition, gaps in inspection and condition monitoring will be discussed with respect to weld quality and suitability for service. The presentation will include examples of recent advancements that address some of the gaps with a look toward future advancements that may offer enhanced safety and operational integrity for the oil & gas industry.

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8:45 am - Comparing Cladding Techniques Applied to the Oil and Gas Industry

Erik Gnaedinger, NobelClad, Houston, TX

In recent years, the requirement for clad metals has amplified with the increased focus on processing heavy and sour crudes. Cladding is frequently leveraged in processes that include high temperature, high pressure, and corrosive environments. Cladding has a long history of bonding relatively thin layers of corrosion resistant alloys to thicker carbon or alloy steel substrates. These clad metals are subsequently used in the fabrication of equipment. It is typical in many cases for clad metal to have a net economic or other design advantage over solid material. Clad metals are therefore used in pressure vessels, heat exchangers and related equipment and piping in a number of
processes in both refineries and upstream oil & gas operations. This presentation will focus on comparing the methods of manufacturing clad for fabrication, including explosion welding, weld overlay and roll bonding. It will also highlight a few case studies of applying cladding within the industry.

9:15 am - Development of Sour Service Drill String Products

Lucien Hehn, NOV Grant Prideco

Sour service drill pipe products present special challenges for manufacturers with initial testing programs, alloy selection, and production. An overall understanding of the environment in which the product is intended to be used is necessary. A general overview of NACE requirements for low alloy steels exposed to environments containing H2S will be reviewed. Sour service drill pipe requirements, which in turn, are based on NACE requirements will be also be discussed. How these NACE requirements were used in the successful development of a high strength drill pipe and sour service friction weld will be also be discussed. Some general metallurgical considerations for sour service low alloy steels will also be addressed.

9:45 am - Junction Growth and Microstructural Evolution during Ultrasonic Welding of Nanocrystalline Alloys

Austin A Ward, Zachary C Cordero, Rice University

Nanocrystalline materials have high strength, hardness, and wear resistance, making them ideal for use as hard-facing in oil and gas applications. However, they are difficult to join using traditional fusion-based welding methods because they exhibit rapid grain growth at the elevated temperatures required by such processes. To overcome this problem we have explored joining nanocrystalline foils using a low-temperature solid-phase joining process termed ultrasonic welding. In ultrasonic welding, the workpieces are clamped between a stationary anvil and a sonotrode that oscillates transverse to the loading axis at ultrasonic frequencies. These oscillations, which have an amplitude on the order of 10 μm, create clean metallic junctions by disrupting the native oxide on the surfaces of the workpieces at the weld interface. Welding is complete when the oxide layers are dispersed and the surfaces asperities are flattened so that the real contact area equals the nominal contact area.

Although ultrasonic welding is a solid-phase joining process, the ultrasonic vibrations cause some frictional heating at the weld interface, which can give rise to coarsening. This talk will summarize our efforts to model this frictional heating and to determine
parameter sets that give strong bonds with retained nanostructure. We combine a classical model of frictional heating due to Jaeger with the Burke-Turnbull grain growth equation to relate the ultrasonic welding process variables to the extent of grain growth in the weld nugget. We next develop a junction growth model that predicts the real contact area over the course of an ultrasonic weld. Finally, we integrate these grain growth and junction growth models into a complete framework for predicting process variables required to completely bond the foils, without causing unnecessary heating and excessive grain growth. Critically, we find that reducing the weld time and using higher pressures is better than using long welds and lower normal pressures.

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10:15 to 10:30 - Break

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10:30 am - METALLURGICAL FAILURE INVESTIGATIONS

Annelise Zeemann. Materials Life Database

When a failure of a component, equipment or system occurs, there are several questions that need to be answered, like "did I use it in a wrong way?", "did I build it correctly?" or "did I specify the right material for the application?". The next questions will be "should I replace with the same material?" and "are there other parts in the same condition?". A good way to answer these questions and avoid future problems is through a ROOT CAUSE ANALYSIS (RCA), that may be quite complex and usually needs a multidisciplinary qualified team.

One important piece of this big RCA puzzle is the metallurgical failure investigation, because metallographic examination of the materials always reveals, in their structure, the signals (damage) of what was imposed to them, and they behave exactly as their nature allows (structure and properties). From the materials point of view, there are only three main causes of a failure: bad specification (or design), bad manufacturing (fabrication) or bad use (operational conditions).

This presentation brings several examples of failed parts, all of them of engineering materials in specific applications. There are cases of defective parts that failed during manufacture, and there are parts that presented defects but failed only when in service. Metallurgical fabrication defects like hot cracks, cold cracks and reheating cracks of welded joints are shown. Some of these defects were detected only after the equipment failure in service, with high associated costs. There are cases where the fabrication procedure was sound but the metallurgical characteristics were not suitable for a special service, like high temperature and corrosive environment. There are also cases of parts that failed due to a improper design.
All these cases are part of a searchable database on the site www.materials.life. The website has been under development in Brazil since 2016 and is based on donations of materials and images.

11:00 am - Novel Functional Testing to Characterize Weld & Braze Joints for Critical Down-hole Use

By Krutibas Panda and Hossam Gharib, Halliburton

Welding as well as brazing processes typically utilize a Welding Procedure Specification (WPS) and a Process Qualification Report (PQR) in order to develop and qualify the process. From a component standpoint these processes are further verified using non-destructive testing means (such as Ultrasonic Testing, Radiographic Testing, Magnetic Particle Inspection, Liquid Penetrant Inspection) in order to validate that the process is devoid of gross weld or braze defects (such as voids, cracks etc.). There are cases where additional functional testing is also deployed (such as pressure testing, Helium Leak Testing) in order to ascertain that these joints possess the required strength and desirable properties to carry out their intended function. This presentation uses 3 case studies using distinctly different joining processes to demonstrate the need for novel functional testing for critical components that are used in harsh down-hole conditions. The use of advanced analytical means to optimize these functional testing is highlighted in this presentation. These functional tests not only have the ability to distinguish the minor differences between the individual processes employed but also have the ability to validate a design feasibility from a Technology Readiness Level (TRL). This presentation demonstrated the need for such testing when the design has significant down-hole risks and where the joining process employs unique material combinations that are difficult to mechanically characterize for analytical modeling.

11:30 ASME BPVC SECTION IX QUALIFICATION OF WIRE WRAPPED SCREENS WITH THE RESISTANCE WELDING PROCESS

Lex Palmer, Weatherford

Austenitic stainless steel (316L) and solid solution nickel alloys (825) are often the alloys of choice in shaped wire for sand screens. The gap between wires is critical and requires a tight tolerance. The surface profile of the screen is also critical in controlling small particles, as such; “fish-scaling” is monitored and kept to a minimum. A variation of the resistant spot welding process is used to join these shaped alloys wires to the perforated base pipe or to a screen jacket. The novel equipment and
process qualification variables are discussed. A walk through of qualifying this process in accordance with ASME BPVC Section IX is presented.

12:00 – 1:00 Lunch and Exhibits

1:00 pm – Afternoon Keynote: INCONEL FILLER METAL 680: STRONG, TOUGH, AND CORROSION-RESISTANT

The Oil and Gas Industry has sought a stronger replacement for INCONEL Filler Metal 625 for over 20 years. The strength of interest is as-welded yield strength because the high cost of operating lay barges and spool-bases precludes post-weld heat treatment for enhanced strength. In addition, corrosion resistance equal to or better than that of INCONEL Filler Metal 625 is needed. Finally Charpy V-Notch (CVN) toughness and CTOD toughness are required to be sufficient for strain-based design. INCONEL Filler Metal 680 is designed to meet these challenges. Inconel FM680 is a solid-solution strengthened austenitic nickel-based alloy which also responds to PWHT and auto-aging during welding. Response to PWHT will be shown in addition to substantial as-welded, all-weld-metal tensile data.

This presentation will provide 0.2% offset Yield Strength as a function of heat input as well as CVN toughness at -50°F as a function of heat input. Also, ASTM G-48D critical crevice temperature is given and compared with that of weldments made with INCONEL 625 and INCO-weld 686CPT. Mechanical properties will be presented for various welding processes including GTAW, GMAW, and SAW. CTOD test results will be provided for both SENB and SENT testing on X-65 and X-70. Details of X-70 pipe ID. Cladding with INCONEL Filler Metal 625 will be presented and welding and testing details of circumferential narrow groove welds will be given. Gleeble test results on our production heat will be provided and the implication of good resistance to DDC cracking will be discussed. Finally, an ongoing metallurgical investigation is designed to improve the CTOD-SENT toughness performance. CTOD-SENB data will be presented that show excellent toughness.

1:45 pm One Welding Procedure Is Not Enough for Welding Corrosion Resistant Overlays

Dave Hebble, ARC Specialties, Houston, TX

Everyone wants to save money, so the desire is to make due with one welding procedure. This may look good on the books but can be a real problem in the weld
shop. The problem comes when trying to put the weld in the corner of a valve seat pocket or the corner of a ring groove using the GTAW-HW welding process. Most procedures don’t have a high enough heat input to make these welds without pushing parameters to the max and sometimes giving them a little extra push. Welding amps, volts, and travel speed are nonessential variables by code, but heat input is the essential variable. ASME Section IX allows for increasing the heat input by 10% for the first layer versus what was used for the PQR. However, some OEMs do not allow for this increase. During the past four years we have developed welding parameters and machines that have doubled, tripled and quadrupled deposition rates and travel speeds. This drops heat input even lower. If the travel speed is three times faster and the heat input is half the qualifying procedure, how do we know the weld chemistry and HAZ hardness values are acceptable? If the original qualifying procedure has difficulty making the seat pocket weld, what does it really take to make a successful weld and stay within the procedure? An additional question; when the procedure heat input is too low to make a good weld, is it acceptable to “fix” the problem using a “wash pass” or autogenous weld to smooth out the previous bead?

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2:15 - Best Practices in Welding Super Duplex Stainless Steels

Rick Duncan, Rolled Alloys

The welding of super duplex stainless steels is not difficult, but they are different. And SDX products are much less tolerant of deviation from the desired welding process. We will review fundamentals of super duplex, factors that are important to the metallurgy of super duplex stainless steel, and problems that arise when those issues are ignored. Phase formation due to time at temperature will be reviewed, particularly formation of sigma. The impact of gas on weld PREn and ferrite balance will be considered, along with joint design, inter-pass temperatures and other considerations. We will briefly review welder qualification and procedures (though NO procedure will be recommended). Questions and discussion are encouraged.

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2:45 pm Effects of Weld Parameters Changes on Dilution Rates During Mechanized Gas Tungsten Arc Welding and the Corresponding Implications to ASME Section IX Rules for Overlay Welding.

Clint Wildash, Schlumberger

In the oil and gas industry, application standard API 6A governs the iron dilution for Nickel alloy grade 625 corrosion resistant overlay (CRO), for applications using low
alloy and carbon steels. The standard specifies a maximum of 5% or 10% at 1/8 inch from the fusion line. Corrosion-resistant weld overlays (CRO) are used to improve the service life of components made with an otherwise corrosion prone material (TWI, 2010). While it is recognized that there is a level of conservatism within standards that specify dilution (TWI, 2010), it is still considered necessary to achieve that specified to provide assurance of long term fitness for purpose. Hence the welding engineer needs to understand the effect of changing weld parameters on dilution and control these variables during production welding.

Rules for qualification of clad welding procedures are governed by ASME B&PVC Section IX. These allow the application of ranges to welding parameters compared to that qualified to provide some flexibility during production welding. It has been observed, throughout the authors extensive industrial experience, that for mechanized gas tungsten arc welding (GTAW), widely used to deposit CRO, this standard does not control all the parameters that affect dilution. Also, where it has been observed there is a level of specified control of a relevant parameter, it is unclear as to whether this is sufficient for dilution control. The work presented here refers to a design of experiments approach, which assessed the significance of the influence of key CRO welding parameters on dilution. The work has quantified the significant individual and cumulative effect of these parameters on dilution, and determined them not to be adequately controlled in the applicable code, ASME Section IX. The audience will be guided to presented graphical evidence and statistical analysis, showing these relationships, as a basis for an improved understanding. These results allow for reasonable fact based decisions to be taken when applying ranges to CRO procedures, as governed by the essential variable range rules of ASME IX. This work also provides opportunity for a review of this standard to enhance its control of welding variables that influence dilution and hence CRO weldment performance when using mechanized GTAW.

3:15 to 3:30 - Break

3:30 pm – Microbiologically-Influenced Corrosion of Welds due to Post-Fabrication Hydrotesting

Krista L. Heidersbach, Stress Engineering Services

Stainless steel components often experience post fabrication corrosion issues due to microbiological corrosion during hydrotesting or post-fabrication storage. This damage
is most commonly found in welds or within the heat affected zone. While the steps to prevent corrosion are often well understood, many projects still succumb to this problem. This presentation will review two recent examples and summarize the precautions fabricators or operators can take to prevent this corrosion.

4:00 pm - “Sublime Subsea: How joint criteria is driving Corrosion Resistant Overlays to new extremes”

Nathan Sumrall, Superior Cladding

As designers continue to expand their use of weld overlays, historically proven welding techniques and procedures are being challenged. This theme hits home in small, hard to access joints. Lower volumes of weld with possible cost-savings are enticing in these economic strained times. Unfortunately, as the joint size decreases, difficulty can sharply increase, resulting in delays, rejections and strained company relations. A study was performed in one such case, identifying possible ways to improve welding for sensor plugs and ports. Relevant Industry Codes and Standards include ASME IX, API 6A PSL3 and PSL4, and NACE MR0175. Relevant materials include SA-182 F22 and Inconel 625 Overlay.

4:30 - Thermal Diffusion of Zinc

Ian MacMoy, Atomic Alloys

Engineers at Atomic Alloys, LLC here in Houston, TX. are now applying an anti-corrosion process called thermal diffused zinc to ferrous and non-ferrous metals. The process was invented and patented by a British metallurgist, Sherard Cowper-Coles, around 1900 when it was called Sheradizing and vapor or dry galvanizing. Over the years, improvements have been made to the zinc diffusion process and it is now more widely known as Thermal Diffused Zinc.

In the updated process, which is covered by ASTM A1059M-08(2013), parts to be coated are placed inside a sealed container and heated together with a mixture of powdered zinc to a temperature of 343°C (650°F). At this temperature the zinc mixture sublimes and fills the container as a vapor. Being soluble in iron, the vapor diffuses into all the surface of ferrous parts in the container. How much of the zinc mixture gets used is based on the total surface area of the part(s) in the container, which results in control of the coating’s thickness and consumption of the zinc powder. Part size or the number of parts being coated is limited by the size of the container. After the diffusion, sealers can be applied, but do not have to be.
**5:00 pm - Embedding Components for Industrial Applications**

Scott Poeppel, American Cladding Technologies

The need for process monitoring or temperature control of components has become an increasing challenge as numerous industries push their technological boundaries. Examples of these components include but are not limited to thermocouples, accelerometers, heating coils and cooling channels. Laser Metal Deposition (LMD) is showing significant promise in exploring and testing some of these possibilities. Welding processes are currently being developed that enable thin walled components to be fully welded (encased) into the process tooling. Embedded components with a wall thickness as little as 0.006” (0.15mm) have been successfully welded directly into the body of functional tools. Powder filler metal is then laser welded in sequential layers to bring the pre-machined region to a “positive” condition in order to facilitate final machining. Subsequent post-weld machining to dimension of the tool body results in the embedded components being completely concealed within the body of the tool, with the exception of needed input / output hardware connections. Some application examples include: Aerospace welding used to seal high-temperature heating elements into aircraft, monitoring equipment to prevent freezing, yet allowing the body of the device to be machined to an aerodynamic profile. Thin walled (0.050” diameter) tubing embedded directly into the cavity face of molds to facilitate faster cooling. Thermocouple devices embedded 0.010” – 0.020” below the surface they are monitoring. Industries currently showing interest include the Department of Defense and companies engaged in Aerospace, Chemical Processing, Power Generation and Injection Molding. The presentation will include informal case study information, example photos, metallurgical cross-section photos and discussions on future applications.

**5:30 to 7:00pm - Social Hour and Exhibits**