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The magazine of TWI

Total welding support for project to convert a tanker to an FPSO

TWI served as the technical authority on all matters relating to welding for the duration of a two-year project to convert a shuttle tanker to a $1 billion floating production, storage and offloading vessel (FPSO).

OOGTK Libra GmbH & Co KG is a joint venture between Odebrecht Oil & Gas and Teekay Petrojarl that oversaw the conversion of Navion Norvegia, a tanker built in 1995, into the FPSO Pioneiro de Libra. Carried out across four shipyards in South East Asia, the conversion process began at the end of October 2014 and was completed in early 2017.

TWI's expertise in welding technology and international reputation in the oil and gas industry meant the company was drafted in to provide technical support throughout the project.

Complete package of support

TWI's contribution to the project included:

- ensuring the correct welding procedure qualifications were in place, in accordance with varying welding standards and codes (ASME IX, AWS D1.1 or ABS) and internal specifications
- auditing the four shipyards, spread across three countries, to ensure the different subcontractors were all following sound working practices
- overseeing inspection of critical areas using phased array ultrasonic and eddy current testing, advising on specific inspection procedures and assessing results
- providing two experienced welding engineers to support the attachment of the FPSO turret head to the vessel.
- assessing the potential risk of distortion when attaching the turret head.

Over the course of the project TWI assessed more than 250 welding procedures. As the project progressed, it provided OOGTK with regular updates, including frequent conference calls and a detailed monthly report.

For OOGTK, this involvement meant the company could be sure that the welding procedures being used during the project were properly qualified and that everyone involved had access to top-tier technical support on any issues relating to welding, inspection, corrosion and distortion.

FPSO ready to go to work

With TWI's input, the conversion project was completed after a total of more than 17 million man-hours of work that saw more than 3000 people working on the vessel every day. *(Continued on page two)*

(Continued from page one) The FPSO Pioneiro de Libra will operate on the Libra pre-salt area in the Santos Basin off the coast of Brazil. As its name suggests, it will be the first vessel to produce oil from the area.

The FPSO will be capable at operating at water depths of up to 2400 metres and producing 50,000 barrels of oil per day. OOGTK expect the vessel to remain in service for the next 12 years.

If your company has a construction, conversion or inspection project ahead, and you would like assurance that all welding-related activities are carried out according to best practice, TWI can help.

We provide a complete range of services to the oil and gas industry.

For more details, please browse our website or contact us.

New Industrial Members of TWI

Haifa Chemicals Ltd Israel	Orchid Orthopedic Solutions Sheffield Ltd United Kingdom	Henry Technologies Ltd United Kingdom	GS Engineering & Construction Corp South Korea
Hollygate Fabrications Ltd United Kingdom	Kaiser Aluminum Fabricated Products, LLC United States	Proserv Offshore Abandonment & Decommissioning United Kingdom	INEOS Enterprises – Sulphur Chemicals Plant (Runcorn) United Kingdom
Aubert & Duval France	Leonardo MW Ltd United Kingdom	Arcam AB Sweden	Renishaw plc United Kingdom
Floteks A.Ş. Turkey	West Special Fasteners Ltd United Kingdom	Warehouse Planning Ltd United Kingdom	LORD Corporation United States
Sol Voltaics Sol Voltaics	WD Close Ltd United Kingdom	Qatar Petroleum – Engineering Technical Services Division Qatar	Burgess Marine United Kingdom

If you are interested in finding out more about Industrial Membership please contact our Membership team.

Lifecycle engineering asset management through digital twin technology

TWI has set its sights on harnessing digital twin technology to transform the process of monitoring and maintaining offshore wind turbines, the outcomes of which will lead to significant benefits for operators in the wind energy industry.

The organisation has built up a wealth of knowledge in the structural health and condition monitoring of wind turbines in recent years as a result of its participation in a number of significant, European and UK collaborative projects including CMSWind, WTBMonitor and TOWERPOWER.

The collective methodology of this work sought to address each component of the wind turbine in turn, first determining potential problems that could arise, for example the blade to develop cracks or the tower to corrode, then subsequently developing new monitoring solutions to mitigate part failure. The application of digital twin seeks to build on this approach by replicating all the constituent components of the wind turbine into a single digital model, thereby enabling real time monitoring of its entire structural condition.

An offshore wind turbine typically consists of the nacelle (generator), blades, a foundation structure (piles/buckets, monopile/jacket), a transition piece and a tower. Experience shows that when problems occur they often arise from ageing, the main phenomena of which are: higher than expected levels of vibration leading to fatigue cracking in the support tower or loosening of flange bolts at its section ends; degradation of the grouted joint between the pile and transition piece; blades with cracking, damaged edges or erosion; and vibration related problems in the generator.

The wind turbine's nacelle was the focus for the CMSWind project, the aims of which were to extend the lifetime and improve the operational efficiency of the generator's rotating parts, and reduce noise levels emitted by the turbine machinery's vibration. The approach used motor current signature analysis, operational modal analysis and acoustic emission techniques, together with vibration analysis, to monitor condition, enabling early detection of defects such as slip-ring corrosion and shaft/bearing misalignment. This led to improvements in the wind turbine's overall operation, reliability and optimisation of its maintenance schedule.

Having identified that blade associated failures featured in a high percentage of wind turbine breakdowns and malfunctions recorded across the globe during the last six years, the Regional Growth Funded (RFG) project, WTBMonitor, was created to tackle the issue. It investigated the feasibility of applying in service, structural health monitoring using acoustic emissions (AE) to identify and monitor crack growth in wind turbine blades. *(Continued on page six)*

Robotic arc welding – Job Knowledge 135

Introduction

The development of automated arc welding solutions continues to be driven by the requirement for higher product quality, productivity and reduced costs. In addition, good manufacturing system flexibility, which is essential for responding to the dynamic behaviours of the market and therefore keeping products competitive, has become a key development target for the manufacturing industries. As a result, robotic welding processes offer attractive alternative solutions to traditional manual operation and hard automation.

Since the first application of a welding robot in industrial production in the early 1960s, robotic welding has expanded across a range of manufacturing industrial sectors. Between 2010 and 2013 alone, over 600,000 industrial robots were commissioned globally [1]. Robotic welding has been recognised as the most popular industrial application of robotics worldwide [2]. It is estimated that approximately 25% of all in-service industrial robots are employed for welding operations [3]. Automotive manufacturing (Figure 1) represents the most active industry sector in terms of robotic welding adoption (approximately 40% of total global robot supply), followed by the electrical and electronics industry (approximately 20% of total global robot supply). Apart from resistance spot welding, the two most common robotised welding processes for production purposes are metal inert gas (MIG) welding and tungsten inert gas (TIG) welding respectively.

Basics of robotic arc welding

A basic robotic arc welding system is formed by two subsystems: the welding equipment delivering the energy from the welding power source to the workpiece, and the robot providing relative positioning of the heat source and the workpiece. Normally six-axis industrial robots comprising a three-axis lower arm and a three-axis wrist are used, since they enable the welding torch mounted at the wrist to achieve all the positions necessary for three-dimensional welding. Traditionally, general purpose industrial robots are employed, carrying arc welding torches as end effectors. Many robot manufacturers have recently developed arc welding-specific robots, which are smaller and less expensive. This reduction of the required capital investment has further increased the sale of robotic welding systems. Another recent development in welding robotics has been the introduction of seven-axis robots, which feature an additional axis in the lower arm providing additional flexibility and saving floor space (Figure 2). The major characteristics of industrial robots are summarised in Table 1.

Table 1 Typical characteristics of an industrial arc welding robot

Payload	2 to 30kg
Axes	Six to seven
Velocity	Up to 5m/s
Acceleration	Up to 25m/s2
Repeatability	≥0.05 mm
Communications	Profibus, DeviceNet, CANopen, Ethernet/IP and serial channels
IO Capabilities	Digital/analogue IOs

In a production environment, workpiece manipulators are frequently implemented as part of the robotised system. The devices extend not only a welding robot's working range but also its accessibility, especially when welding complex and large geometries. The control of a manipulator is often integrated with that of the robot, which enables the synchronised and simultaneous control of the two mechanisms. The integrated control allows coordinating motion between the robot and manipulator (workpiece) which maintains the optimum welding positions (higher deposition rate and quality) and possibly increases the welding speed (higher productivity). Figure 3 shows a six-axis industrial robot integrated with a cold metal transfer (CMT) arc welding system and a two-axis workpiece positioner at TWI Cambridge.

Process sensing

Robotic welding is a challenging combination of welding, robotics, sensor technology, control systems and artificial intelligence. Driven by the increasing demands of improved quality, productivity and flexibility, precise and adaptive control of the robotic welding processes has become a crucial target for the development of modern systems. Sensing technologies designed for welding and its automation are the essential elements for enabling this desired level of control. The sensors are applied to observe and measure process parameters, acting as the sources of input to the control system. By acquiring and analysing the input information from the sensors, the control system adapts output of the robotised welding process in accordance with the defined welding procedure specifications.

There are various types of sensors available for robotic arc welding applications. Depending on their functions, the sensors are classified into two categories: process and geometrical. The former measure the process parameters of the robotic welding process (eg arc voltage, current, wire feed speed and torch rotation), which determine the stability of the process. The latter measure the weld joint geometry (eg gap sizes, weld size changes, deviation from the nominal path and orientation changes) and are used for weld searching, seam tracking and real-time adaptive welding.

Table 2 Typical sensors used in robotic arc welding

Function	Sensor
Welding current measurement	Half effect sensor
	Current shunt
Arc length control	Voltage sensor
Distance control	Capacity sensor
Weld edge searching	Tactile (electrical contact) sensor
	Proximity sensor
Weld Seam Tracking	Tactile (mechanical contact) sensor
	Eddy current sensor
	Through-arc sensing (weaving with electric measurement)
	Vision sensor
	Laser scanning (Figure 4)
Weld penetration monitoring	Infrared radiation sensor
	Ultrasonic sensor
Weld pool monitoring	Vision sensor
	Thermal imaging
Weld quality inspection	Eddy current sensor
	Ultrasonic sensor
	Laser scanning

Key issues

The benefits of implementing robotic arc welding are evident but there are some issues associated with it which should not be ignored. Robotised technology is a good solution to fill the burgeoning skills gap in welding fabrication industry, but using and programming the industrial robots is still a complex and difficult task for regular operators. Despite the fact that modern sensing techniques for robotic arc welding are readily available and reasonably reliable, it is still challenging to effectively and efficiently apply them in some applications. The high temperature, intense light from arc, fume, high current, molten metal, spatter, and other factors involved in arc welding can interfere with the sensors. Developing a control system which can fully utilise the information obtained by the sensors and effectively translate it to the fabrication is still a difficult task.

Summary

Robotic arc welding is an essential component of today's manufacturing plants. The primary benefit of robotic arc welding is the production of high-quality welds in a shorter cycle time, with manufacturing flexibility another major advantage. Through extensive application in many manufacturing industry sectors, robotic welding has been developed to a mature production method. Strong industrial need continues to drive the rapid development of robotic arc welding and associated technologies to overcome technical difficulties and expand their capability.

TWI has established good experience in robotic welding through its services in generic research, contract R&D, technical information, consultancy, standards drafting, training and qualification. For more information, please contact us.

References

1. International Federation of Robotics, 2014, World Industrial Robot Statistics 2014, http://www.ifr.org/industrial-robots/statistics/.
2. United Nations and International Federation of Robotics, 2000, World Industrial Robotics 1996: Statistics and Forecast, New York: ONU/IFR.
3. J N Pires, A Loureiro and G Bölmsjo, 2006, Welding Robots: Technology, System Issues and Applications, London: Springer-Verlag.

(Continued from page three)
The study confirmed that AE signals can be successfully extracted, filtered and classified, thereby demonstrating that AE can yield vital information to help reduce operational and maintenance costs, and ultimately potential failure, when incorporated into a viable, remote condition monitoring system.

TWI was able to apply research undertaken as part of the OPCOM project, into the potential for low frequency, ultrasonic guided waves to monitor large areas of offshore structures over the long term, to the monopile section of wind turbines. Structural integrity may be affected by both corrosion and fatigue cracking over their serviceable life, which is normally in excess of 20 years. The project scope involved developing tools and techniques for the complete examination and monitoring of very large diameter, tubular steel structural components which exist in large numbers in offshore installations. Design of sensor arrays capable of withstanding marine environments, long term environmental influences on the test data, and modelling of the influence of component geometry and condition on the test were all incorporated.

The TOWERPOWER project, currently in its final stages, is aimed at advancing and integrating inspection techniques to produce a system that is able to monitor the entire wind turbine structure. Relying on a network of sensors of various natures, such as guided waves and AE; amplifying electronics; and advanced signal processing algorithms, the TOWERPOWER system will enable self-learning of the normal behaviour "signature" of the wind turbine structure and detect any deviation from the initial record. Real-time wireless connectivity will allow the TOWERPOWER solution to monitor offshore wind turbine conditions from an onshore location, taking into account the unpredictable nature of offshore conditions. For operators, this means the length of time between inspections can be increased leading to reduced maintenance costs.

Building on the combined prior expertise gained from these and other collaborative projects, TWI is now embarking on a digital twin solution for the wind turbine industry, with the intention of forming a joint project with industrial partners to deliver a fully integrated approach to structural health monitoring for improved reliability of wind turbines. A condition monitoring system will encompass the entire physical wind turbine providing ongoing structural health analysis. Simultaneously, this will be mirrored virtually with the creation of a 3D model of the wind turbine in the form of a digital twin, including input from different sensors positioned across the physical entity, to continually feedback monitoring data. The output will be fully comprehensive, real-time assessment of the structural condition of individual wind turbine assets.

For more information, please contact us.

India Manufacturing Summit

TWI is sponsoring the India Manufacturing Summit, which will be held in Central London on 18 July 2017, to establish an understanding of major challenges and opportunities in manufacturing sector for companies in India, UK and Europe.

Manufacturing companies from UK, Europe and India, policymakers from UK and India, Members of House of Lords and House of Commons and other invited guests will gather at the UK Parliament to discuss business opportunities for UK and European companies to invest in India's manufacturing sector.

The event will also inform companies about the regulatory policies which have been relaxed to facilitate investments and simplify doing business in India.

For more information please visit www.bsicc.co.uk/india-manufacturing-summit

7th IIW Welding Research and Collaboration Colloquium

The 7th IIW Welding Research and Collaboration Colloquium will be held at TWI Ltd, near Cambridge, UK on 19-20 September 2017.

The event will bring together representatives from local and global industry and research to exchange ideas and establish cooperative networks for future communication and development.

To register please visit the website.

Efficient manufacturing of advanced titanium aerospace components

TWI is working with an industrial consortium on the application of linear friction welding (LFW) for the efficient manufacture of aerospace components. Rising material costs and the growing use of difficult-to-machine materials are spurring on designers to explore alternative, cheaper production methods.

Near-net-shape forming technologies, which build parts instead of machining them from solid billets, can offer a range of benefits. The TiFab project aims to show how LFW can be used to boost production of aerospace-quality near-net-shape titanium alloy components for the airframe sector.

Save, save, save

TWI identified a cost-effective manufacturing route for titanium parts, with high material utilisation and significantly reduced titanium waste. Engagement with its Industrial Members has allowed the organisation to secure the participation of a major US OEM, to identify candidate parts and assess their suitability for production using the LFW process. More than 150 aircraft components containing hundreds of welds have been assessed so far – the majority have delivered raw material savings of 60–80%. Moving to LFW could save over 185 tonnes of titanium alloys per year, a potential $7.9 million reduction in annual raw material costs. This would also deliver energy savings of 48,100,000kWh – enough to power 15,000 homes for a year – and reduce CO2 emissions by more than 22,000,000kg per year.

Production rate: 24,000 parts/year for 10 years	CNC part	TiFab LFW part
Material cost	£97.6m	£12.6m
Production cost	£22.5	£9.7
Post-weld treatment cost	£0	£1.1m
Total cost	£120.1m	£23.4
Cost per year	£12.0m	£2.34
Total estimated cost per part	*£500*	*£97.5*

Efficient Manufacturing

The project also involved studies of all of the process operations in the value stream. Creating a map of the production operations and the interdependences of the various operations enabled a picture of what a facility for producing tailored blank aircraft components might look like.

By applying latest knowledge from the fields of digital manufacturing and systems engineering, the TiFab project has been able to provide a system concept which is capable of achieving business case metrics in a safe and controlled manner. This state-of-the-art, fully automated LFW production system concept is based on the application of Industry 4.0 philosophy, and full digital integration both on the shop floor and throughout the supply chain. It uses event-based simulation modelling to achieve both low- and high-volume production of a candidate part based on generic assumptions.

To find out more about this project and our work for the aerospace sector, please contact us.

Innovation and technology open day supports European collaboration

TWI was delighted to welcome delegates from across Europe to its recent open day at its Cambridge headquarters – the Nanotechnologies and Advanced Materials Brokerage Event – which was supported by longstanding partners Enterprise Network Europe, Innovate UK and Coventry University Enterprises Limited.

The exhibition showcased:

- six of TWI's Innovation Centres, each one a collaboration with a partner university and industry aimed at knowledge exchange, research and development, and nurturing the next generation of engineers
- TWI's three key technology areas, building on the earlier presentations; and the expertise of the Technology Innovation Management team who is responsible for securing public funding to enable collaborative, blue-sky projects.

Tat-Hean Gan, Business Group Manager, Integrity Management at TWI said "The event brought together representatives from leading research organisations and forward looking enterprises with the aim of promoting European collaboration and co-working. Our guests were able to share their knowledge and expertise with each other as well as develop new relationships, therefore, it achieved its objective and we look forward to future alliances."

For more information, please contact us.

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