Robust high strength welding solution for demanding offshore jack-up rigs

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OFFSHORE STRUCTURES MUST WITHSTAND THE HARSHest environments where failure is never acceptable. Offshore structural designs take into account anticipated loads, including relevant environmental loads. Often, these structures work in remote locations far from land. One popular mobile offshore drilling unit (MODU) called the jack-up rig is towed or self-propelled to the work site and designed to then "self-install" for drilling oil wells. Jack-up rigs are also used to perform other work functions including offshore wind tower installations.

As the jack-up rig concept uses the ocean floor to support its typical three or four structural legs, there is a practical limitation to the water depth jack-up rig systems can work due to the stability of the self floating unit when the legs are fully retracted for relocation. Premium jack-up rigs are generally defined as rigs capable of drilling in water depths of 76 m and greater with an independent leg design. Jack-up rigs are available for working in water depths up to 168 m.

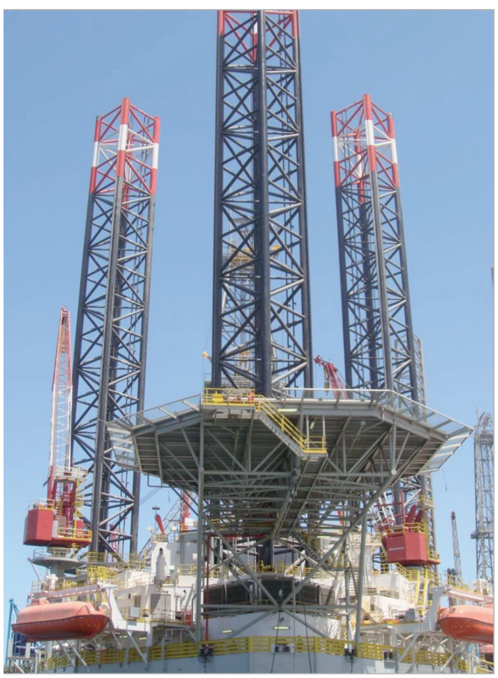

Figure 1. Premium jack-up rig

High strength steels have played an important role in reducing the weight of jack-up rigs for the benefit of increasing accessible water depths and reducing the overall jack-up rig weight for increased payload and topside equipment. Plate thickness for a 690 MPa yield steel is about half compared to a 355 MPa yield steel. Hence, engineers have standardised on 690 MPa yield steels and the advantages of a truss leg design to optimise weight savings for the premium jack-up rig design. Welding this high strength, thick section primary load bearing structure to withstand harsh offshore conditions requires the highest level of weld quality and integrity.

Submerged Arc Welding (SAW) is capable of high deposition productivity for thick high strength offshore structural sections with robust quality. Most commonly, traditional d.c.+ polarity has been selected for welding the higher strength steels but expanding these options to a.c. and tandem arc welding are now successful.

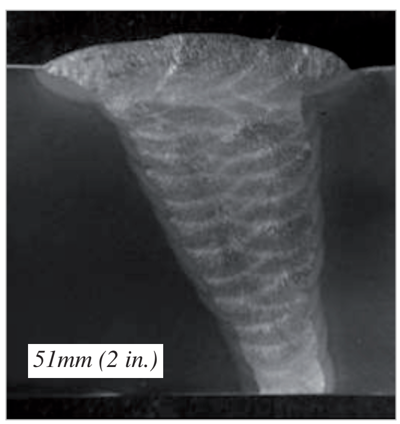

Figure 2. Macro photo of welded test plate

Cored SAW welding consumables such as Lincoln Electric's Lincolnweld® LAC-690 are capable of delivering weld deposits that meet these highest levels of weld quality in d.c, a.c. and tandem configurations. Such consumables when combined with an appropriate flux have been approved to meet ABS 5YQM690 H5 and DNV V YM69 (H5) agency classifications using a.c. or d.c.+ polarity.

Welding with power sources that can provide tandem welding, such Lincoln's Power Wave® AC/DC 1000 SD, can offer productivity increases when compared to d.c.+ without sacrificing the quality of mechanical properties. In addition to electrical savings achieved from the inverter and switch, precise control of the welding waveform gives a consistent

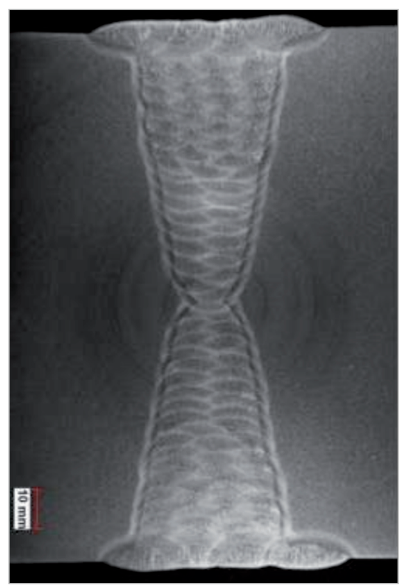

Figure 4. Rack-to-rack weld using Lincolnweld® LAC-690/888

Polarity (Electrode Diameter)	Heat Input, kJ/mm	Number of Passes	Deposition Rate, kg/hr	Deposition Rate Increase	Weld Mid CL Impact Toughness Joules @ -60°C
d.c.+ (4.0 mm)	2.02	26	8.7	Baseline	117
a.c.+ (4.0 mm)	2.03	24	10	15%	124
Tandem (both 3.2 mm)	2.13	23	13	50%	111

Figure 3. Productivity Comparison for Lincolnweld® LAC-690/888 at comparable heat inputs

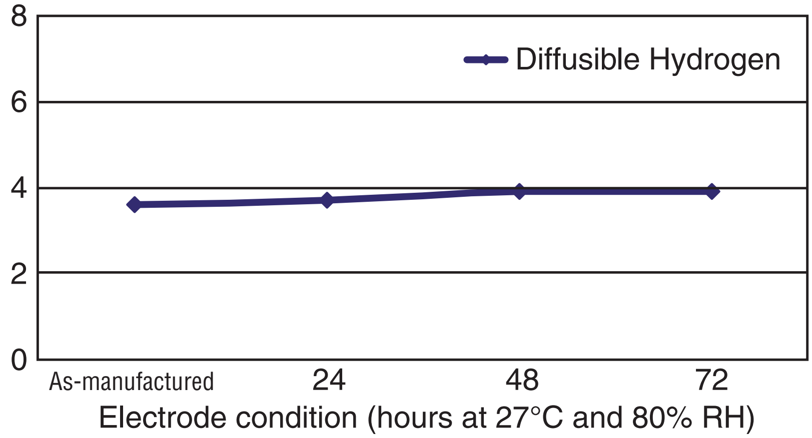

Figure 5. Lincolnweld® LAC-690 diffusible hydrogen results after exposure

stable arc. Three 51 mm plates with a 30 degree single bevel joint were welded in d.c.+, a.c. and tandem (see Figure 2), all using a 32 mm contact tip to work distance. Similar heat inputs were targeted by increasing the travel speeds of the higher productivity procedures. Figure 3 shows the reduction of welding passes and the difference in deposition rates. Welding with a conservative tandem setup using d.c.+ for the lead and a.c. for the trail resulted in a deposition rate increase of 50% with three fewer passes compared to single arc d.c.+.

Achieving higher productivity without sacrificing weld quality is especially important when welding on thicker sections. Welding a solid rack-to-rack joint can be very time consuming and poor weld quality can lead to expensive repairs. Figure 4 shows a macro of a 140 mm thick PQR qualification plate for a production 210 mm rack-to-rack section. When dealing with thick weld joints associated with these applications, tight included angles are desired to reduce the amount of required welding.

High strength, thick welds under restraint are especially prone to the effects of diffusible hydrogen in the weld metal. If low hydrogen consumables and processes are not used for welding high strength steels, the risk of experiencing fabrication hydrogen-assisted cracking (HAC) increases. Electrode exposure has traditionally been a concern with regards to its effect on the diffusible hydrogen content of the weld metal. Using an environmental chamber, Lincolnweld® LAC-690 cored welding consumable was exposed to a 27ºC environment at 80% relative humidity for periods of time and then tested for deposited weld metal diffusible hydrogen (see Figure 5). Such welding consumables are resistant to moisture pick-up, resulting in low diffusible hydrogen content, even after the electrode has been exposed to hot, humid environments.

The offshore industry is driving the use of higher strength steels for the most demanding applications. The welding consumables used must be able to deliver robust mechanical properties at more stringent levels such as those seen in offshore classifications of 5YQ690M H5. The ability to weld using AC and tandem processes allow for increased productivity without sacrificing weld metal quality, this helps fabricators reduce their overall welding costs.