

Ultrasonic peening: a life extender for FPSOs?

With structural fatigue posing a threat to active FPSOs, a cost- and time-efficient method is required for maintaining these vessels' integrity. Malcolm Hedmar, project manager and director of LETS Global do Brazil, presents the case for his company's ultrasonic peening methodology

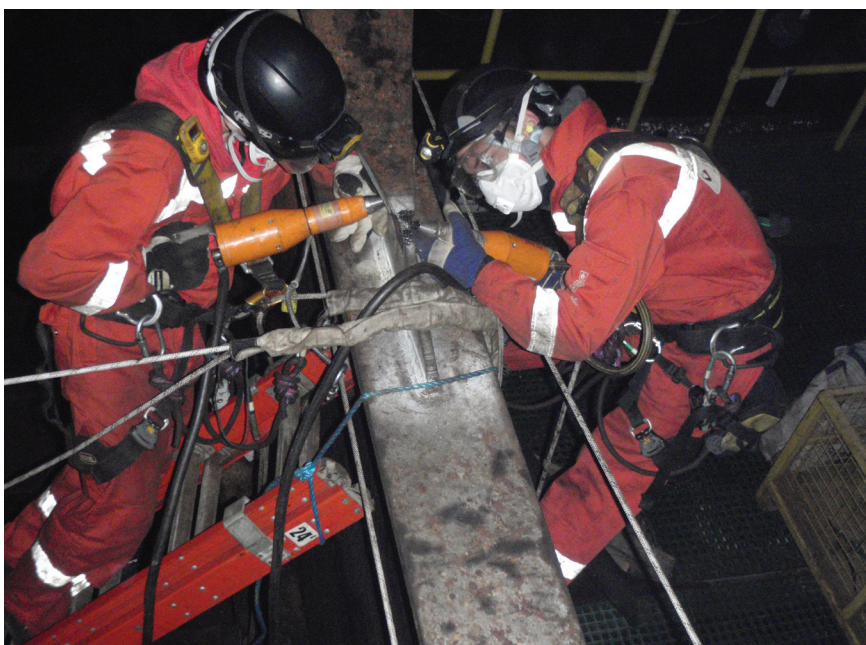
Life extension for offshore installations has become a popular topic, as it should be; one thing man cannot stop is time, and with time comes aging. More and more offshore installations are reaching the ends of their original design service lifespans. All rigs are designed for a certain amount of time out on the open sea, and with all the elements pitted against them; at a certain point, all rigs will start to show signs of fatigue.

The structural integrity of offshore installations is very important because without the body keeping the production equipment and oil afloat, there is not much of an installation to talk about. So, operators must ensure that the structural integrity of their aging rigs is kept intact, and safeguard it well – at any cost. This used to be an expensive process, not only because of the actual extra steel that had to be hauled onboard, plus the man hours necessary to put this steel into place, but mainly because of the hot work involved. The heat incurred by welding never did mix very well with oil. Subsequently, production frequently had to be halted and tanks had to be emptied before any work could take place. A lost profit is a loss, whichever way you look at it.

But with time comes progress, and the topic of this article is the technology that arose from that progress. It is referred to as the 'Life Extension Concept' and it is intended to help operators solve problems related to structural integrity.

Hammering out the faults

This concept is built around the possibility of considerably increasing welded joints' strength against fatigue. The technique, which has come to be known as ultrasonic peening, was originally invented in the Soviet Union, when it was applied to submarines during the Cold War.



Ultrasonic peening produces no heat, meaning it can be applied aboard oil- and gas-producing FPSOs with no disruption to operations, whilst the vessel is still at sea

Ultrasonic peening might sound similar to ultrasonic testing, which tends to mislead people into thinking that it is a type of inspection method. To break it down for the average reader, 'ultrasonic' refers to the utilised frequency, which happens to be in the ultrasonic spectrum which starts at 20KHz, and the verb 'peening' is derived from the hardened steel peen which works the steel surface.

So, when performing ultrasonic peening, a hardened steel peen is oscillated, or hammered, against a weld-toe or steel surface at approximately 20,000 times per second, with an amplitude of only 0.05mm. As the peen hammers the weld toe, a couple of things happen; first of all, all non-geometrical features and crack-like flaws are removed, leaving a smooth groove with a diameter

of > 4mm. As the peen's amplitude is small, the created groove consists of a compressive layer that has high resistance against fatigue cracking.

Numerous projects have been carried out in collaboration with DNV, the International Institute of Welding (IIW), Sweden's SSAB, the Norwegian University of Science and Technology (NTNU) and the Royal Institute of Technology, Sweden (KTH), among others, in order to measure the benefit of the LETS Global Ultrasonic Peening Procedure on offshore installations.

The benefit that this procedure has on a given welded joint on an offshore installation is largely dependent on the stress range that the component is under. Therefore, it is actually difficult to give a constant regarding how much



of a difference the treatment will make. However, as a rule of thumb, the fatigue life of a welded attachment on an offshore installation, under high cycle fatigue with stresses of 200MPa, will be increased fivefold.

Previously, when fatigue hotspots were located and classed as a threat to the structural integrity of the installation, the common approach was to start to add steel, in order to reinforce the specific area. The downside of this approach is that you end up changing the stiffness of the vessel in one specific area, making nearby areas prone to the development of more fatigue hotspots.

The ideal solution is to strengthen the area of concern without altering its stiffness, keeping the dynamics of the vessel the same. This is one of the reasons why ultrasonic peening is becoming viewed as an ideal solution for integrity challenges deriving from high cycle fatigue.

The procedure will only be significantly beneficial if the welded joints selected for treatment are of full or almost full penetration. As only the surface of a weld can be treated, the root of the weld is left untouched, demoting it to become the 'Achilles heel' in the operation. This is because, even if the weld toe and surface are greatly strengthened, the crack initiation can still take place at the root of the weld, limiting the possible gain in fatigue life.

FPSO applications

As you might expect, ultrasonic peening can be applied to any structure suffering from structural fatigue. However, FPSO operators in particular are finding the concept appealing.

The first reason for this is the fact that FPSO operators want to avoid any cessation in production aboard their assets, as well as any subsequent drydocking for structural repairs, so naturally they are keen to do their utmost to avoid this scenario. Secondly, and related to the first reason, the contracts that FPSOs tend to enter are relatively long compared to, say, those for drilling rigs, so the majority of FPSO structural maintenance jobs must be conducted whilst the vessel is out at sea.

Another advantage for this vessel sector is that the ultrasonic peening procedure does not produce any heat when performed, so it is a relatively easy procedure to perform aboard an oil- and gas-producing FPSO.

During Q3 2012, Brazilian oil major Petrobras put its first FPSO through a life extension project involving the use of ultrasonic peening. Petrobras realises that, in order to reach the production goal it has set for 2020, it needs to safeguard the structural integrity of its existing fleet of production platforms; downtime caused by unforeseen structural failures will greatly jeopardise this goal.

The first phase of the project was identical to that of the then HESS-owned FPSO *Triton*, namely the application of ultrasonic peening to fatigue hotspots located near the FPSO's pallet stools. The production deck that rests on the pallet stools is much stiffer than the less rigid FPSO hulls, so, as the hull moves with the sea, the pallet stools, supporting the stiff production deck, will experience immense stresses against the vessel's deck, often leading to fatigue cracks.

As the project commenced, signs of structural fatigue were already evident, with 23 pallet stools showing the first signs of fatigue cracks. In total, 30 pallet stool fatigue hotspots were treated with ultrasonic peening, in many cases removing shallow cracks from the deck. At some specific locations, the fatigue cracks were too developed, hindering the possibility of successfully extending lifespan with ultrasonic peening alone; in a scenario like this, weld repair is the only viable solution.

Triton was ahead of the game, having had the ultrasonic peening procedure applied to her pallet stools back in 2005/2006. However, as this vessel's service lifespan is scheduled to continue until 2022, a more comprehensive life extension programme has been put into place.

In total, eight of *Triton*'s ballast tanks will undergo ultrasonic peening, treating a total of 640 fatigue hotspots. The aim of the project is to avoid fatigue cracks developing in the water ballast tanks in the future. The life extension ballast tank project was initiated in 2008 and remains

ongoing. The underlying aim is still to treat all fatigue hotspots without a single interruption of production.

Identical issues

So, is it necessary to use ultrasonic peening after a conventional weld repair? At LETS Global do Brazil, we would have to answer: "Yes". In addition to the results of the aforementioned case studies, there is the fact that, with conventional weld repair, you will only get to restore 'what once was', which means that the relatively high stresses will still remain and the material will be unchanged; the only thing that will have changed will be the considerable increase of harmful residual stresses in the heat-affected zone (HAZ). All of these factors combined mean that the crack will re-initiate sooner rather than later if ultrasonic peening is not applied.

Engineers tasked with maintaining the structural integrity of FPSOs often seem to work in a state of relative isolation from their counterparts at other companies. FPSOs, and especially FPSOs originating from conversions, all tend to encounter the same structural problems.

To some extent, it is understandable that operators do not want the shortcomings of their rigs to become known to all. However, by disclosing this information, the industry as a whole can work together to cut downtime and costs, as it is very likely that the neighbouring rig is facing the same problem, or has maybe even just recently solved the same problem your rig or FPSO is facing.

We are now entering an era where FPSOs are no longer viewed as a new phenomenon. Today, there are FPSOs whose fatigue life is close to an end, but headstrong operators are keen to do everything in their power to keep them producing in a safe manner. Much can be learned from these stalwart rigs, as it becomes increasingly obvious how much time and money can be saved if a more proactive approach towards structural integrity is taken.

To this date, four offshore installations have undergone life extension with ultrasonic peening. It is just a matter of time before that number also increases fivefold. **OMT**