Fighting CORROSION with fibre

Grace Bull & Stephen Forrester, NOV, and Qiang Fu, BP, reveal how fibreglass solutions can help reduce a platform's weight and susceptibility to corrosion.

When the word 'innovation' is used in the oil and gas industry, it frequently refers to the modern developments in software and technology, which include drilling automation, Big Data, and algorithm-driven predictive analytics, that are revolutionising the way wells are drilled and explored. Outside of these areas, however, innovation is still occurring on a large scale in the realms of weight control and corrosion prevention. National Oilwell Varco (NOV) worked with BP to develop a solution to manage weight and corrosion on the Clair Ridge platform, a project that transformed from a simple fibreglass pipe installation into an opportunity to develop, from concept to execution, a comprehensive solution that employed a wide range of composite offerings across the entire platform.

Reducing weight and preventing corrosion have long been problematic to the offshore oil and gas industry. Placing these concerns in a historical context, weight control has become more critical to offshore topside development over the past several decades, as the size and complexity of structures has continued to increase. The issues that arise from improper weight control are manifold – reduced personnel safety, loss of long-term structural integrity, inaccurate centre of gravity, and inefficient operating schedules, to name a few – and must be dealt with to allow platforms to achieve maximum operational efficiency.

Corrosion – the breaking down or destruction of a material, especially metal, through chemical reactions – has similarly been a major issue for the oil and gas industry since the offshore market's rise to prominence in the 1970s. External corrosion of offshore structures is caused by seawater, which has an average salinity of 3.5%. As salinity increases, oxygen solubility decreases, in turn allowing the seawater to erode metal and protective coatings at an average rate of 2.5 in. (60 mm) per year. Corrosion affects nearly all aspects of oil and gas field development, at every stage of equipment lifecycles, leading to far-reaching consequences if left unchecked. It has become increasingly apparent that the impact of corrosion on safety, the environment, and project economics is significant enough to warrant research and development into new ways of preventing or delaying corrosion and corrosion-related failures.

Clair Ridge case study

Located in the North Sea, BP's Clair Ridge facility is the second development phase of the giant Clair Field. Clair Ridge has two bridge-linked, fixed-steel jacket platforms and topsides. The complex design of the facility involved linking a drilling and production platform with a quarters and utilities platform to streamline operations.

Primary objectives

When NOV's work on the Clair Ridge project began, BP's primary objectives were simple: reduce the platform's weight and its susceptibility to corrosion through the installation of fibreglass pipe. An engineer from Pipex px®, part of NOV's Fiber Glass Systems business unit, was sent to work in BP's London-based design offices to provide onsite technical specifications for the project. After this design phase, NOV mobilised to the worksite and, per a determined work scope, installed approximately 9843 ft (3000 m) of Bondstrand® glass-reinforced epoxy (GRE) pipe systems throughout the platform to reduce weight. Then, almost 29 528 ft (9000 m) of phenolic fibreglass-reinforced polymer (FRP) grating was installed across the platforms, providing an anti-slip surface while eliminating additional amounts of excess weight and, as an added benefit, the persistent fear of seawater-related corrosion. Finally, 278 safety gates and four phenolic FRP structures to create stairwells and landings were designed and installed. Beyond reduced weight and increased corrosion resistance, longevity was an important advantage, as composite materials have a significantly longer lifecycle than steel and other corrosion-prone metals while providing similar strength. The life of the composites installed on the Clair Ridge platform is expected to range from 30 to 60 years.

Phenolic FRP composite materials and GRE pipe systems were the clear choices in these applications, as both options provided similar strength to steel but weighed significantly less, were more resistant to internal and external corrosion, and ensured negligible combustibility, conductivity, smoke, and toxicity risk. Further benefits of using these composite materials were reduced future maintenance requirements, extended asset service life, and enhanced safety in the harsh North Sea environment where the Clair Field is located. Additionally, safety on the platform benefitted by eliminating the need for 'hot work' repairs, which would be necessary with a traditional metallic solution.

BP, satisfied with the weight reduction and corrosion resistance from implementing these technologies, sought additional ways of achieving these objectives throughout the platform. NOV suggested a complete redesign and application of the handrails as the next step in the process. Approximately 2.6 miles (4.2 km) of NORSOK-compliant handrail systems and almost 12 000 compression-moulded fittings based on 600 proprietary designs were installed as a result of this inquiry. The MARRS® OFFSHORE handrail system was designed and rigorously tested to ensure that it met the required strength, toughness, and fire reaction performance and safety standards for offshore oil and gas installations as dictated by NORSOK. A continuous round top rail eliminated sharp corners and provided an operator-friendly, warm-to-touch safety rail. The corrosion-resistant material ensured long-term structural integrity, and the nature of phenolic FRP materials enabled a significant weight reduction over standard steel railing systems.

Figure 1. *The Clair Ridge platform, a state-of-the-art facility where BP will begin recovery of 640 million bbls of oil and deploy their LoSal® EOR technology for the first time.*

Figure 2. *Almost 2.6 miles of the MARRS® OFFSHORE handrail system was installed throughout the entire Clair Ridge facility. The handrail system meets strict NORSOK safety requirements and is dramatically more corrosion resistant than steel.*

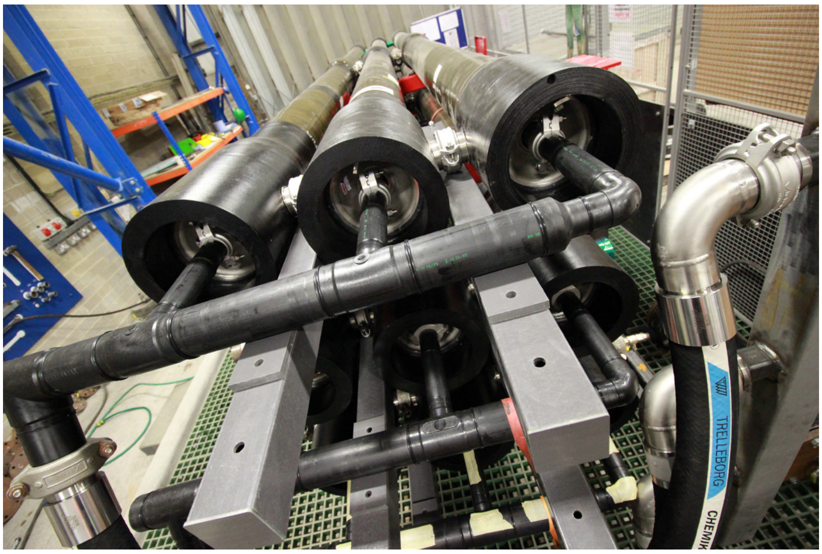

Figure 3. *NOV designed, manufactured, and tested 290 composite pressure vessels for the Clair Ridge platform, working in BP's office and at the shipyard to ensure quality, performance, and corrosion resistance.*

Industry-wide issues

In the final part of the project, NOV sought to help with the industry-wide problem of leaking offshore seawater reverse osmosis (SWRO) pressure vessels. BP had developed, over the past several years, a waterflood enhanced-oil-recovery (EOR) technology that involved injecting modified water into a reservoir to increase recovery rates. The technology, which BP calls LoSal®, is designed to use low-salinity water in oil reservoirs to allow oil molecules to flow more freely toward producing wells. In typical high-salinity water, such flow is often inhibited by the way oil molecules bind to clay particles. Using this EOR technology in Clair Ridge is expected to cost-effectively yield an extra 40 million bbls of oil over the lifetime of the project.

Some of the most vital pieces of equipment for BP's technology investment included the LoSal skids on which the SWRO pressure vessels are incorporated. These pressure vessels had initially been scheduled for deployment and installation on the Clair Ridge platform earlier in the project, but the original vessels suffered from leaking nozzles, delaying delivery. Despite this setback, BP had committed to a delivery schedule for the SWRO pressure vessels and needed a supplier who could complete the successful manufacture of all 290 vessels, as well as permeate collars and FRP supports, to extremely stringent tolerances within a short timeframe.

Although this final phase of the project was of considerable complexity and size, issues compounded by the extremely restricted time schedule, NOV determined that it was feasible given the company's experience in this domain. To manufacture the pressure vessels to the required specification parameters while simultaneously maintaining repeatable quality and production flow, two computer numerical control (CNC) machines were custom designed and built from the ground up. These machines automatically performed precision drilling of both holes and internal recesses and could clamp and rotate the pipe through 180°, re-clamping into a secondary position and continuing to drill additional holes. The vessels underwent factory acceptance testing in a secure, high-pressure test area at 118 bar to ensure adherence to design specifications. Finite element analysis of GRE materials investigated the material shear limit at the machined end cap groove and machined side port penetrations were analysed to determine maximum stress and deflection of GRE material when under operating conditions, which simulated the biaxial nature of helically wound material. After verifying all results through destructive testing, the completed composite pressure vessels, measuring 22.3 ft (6.8 m) long with an 8 in. diameter, were delivered to BP in sets of twos and threes with up to six titanium side ports (nozzles) each.

Results

The scope of the project, which had transformed from simple fibreglass pipe delivery into a major turnkey package solution, showcased the wide breadth of application for composite materials and solidified the role of these materials in addressing weight and corrosion issues. BP saved more than 700 tonnes of weight on their topside modules due to the combination of advanced design and manufacturing solutions provided. Everything used, from the fire-performance phenolic FRP structural products to GRE pipe systems and pressure vessels, was significantly more resistant to rust and the corrosive effects of the harsh North Sea environment. These improvements were vital to BP, as the Clair Ridge development is expected to extend production life of the field until 2050.

Conclusion

Sometimes, the most difficult issues that the oil and gas industry faces can be addressed through a combination of engineering ingenuity and dedicated technical expertise. The size of offshore structures has necessitated that more attention be paid to weight control, with the issue being of such importance that engineering and construction is now governed by stricter design philosophies and standards. Corrosion on structures of such size and complexity is a similarly problematic issue, particularly as operators seek to drill in more challenging, unexplored frontiers and eliminate the threat of assets having to be prematurely replaced. This project brought together fibreglass product solutions, comprehensive engineering services, and technical authority to deliver major results, thus reinforcing the belief that sometimes, one has to break tradition to achieve success.

Figure 4. *GRE pressure vessels during skimming of outside diameter to allow for the pipe to be positioned within the CNC machine for precision drilling of holes and internal recesses. Production ran for 24 hours a day, 7 days a week to meet strict project deadlines.*

Figure 5. *One of two custom CNC machines built to manufacture the pressure vessels to BP's specification parameters while maintaining repeatable quality and production flow.*