Subsea coatings research and the challenges of the deep sea

Araceli Q Adrias and Jonathan R Matias explain how the Athena subsea test facility offers a rare opportunity to validate the performance of coatings for applications such as pipelines and oil drilling platforms, which operate in much deeper waters

The offshore oil and gas industry is growing at an unprecedented rate as multinational companies scramble to explore new energy sources from the deep sea. The Asia Pacific region has the second largest market share in the world, with estimated capital spending of more than US$97bn by 2013, according to Infield Systems' *Asia Pacific Market Update Forecast 2009/13*. The 16 shipyards of Keppel FELS of Singapore lead the world in the building of jack-up rigs, controlling more than 70% of the market for newbuildings. Tens of thousands of miles of subsea communication cables criss-cross the world's oceans. Offshore drilling platforms and subsea pipelines are often located in the world's harshest marine environments, where long-term asset protection is essential to overall planning. Subsea structures need to survive 25 years, preferably longer, to provide an uninterrupted service life.

Applications where coatings are used in much deeper waters, particularly for pipelines and oil drilling platforms, are rarely tested – primarily because of a lack of available facilities to make such tests possible

Subsea coating is an integral part of this asset protection. Anti-corrosion coatings are applied to the external surfaces of subsea pipelines and the underwater support structures of submersible and fixed oil platforms. This industry has evolved from the old hot-melt coal tar poured on the pipe to more recent high-technology systems comprising three-layered coatings. Pipeline-laying barges have similarly evolved to become more sophisticated vessels that can lay pipelines with maximum efficiency and precision.

Coatings are essential to the success of this endeavour, since they reduce the thickness of the steel necessary to convey the product under extremes of pressure, impact, temperature and flow rates. These new coatings systems come in the form of fusion bonded epoxy (FBE), liquid epoxy (LE), heat shrink sleeves (HSS) and high-density polyethylene (HDPE) pipe coatings, to name a few. The recent Applied Market Information Pipeline Coating 2010 global conference in Vienna saw new developments in coatings technology from Bredero Shaw, Borealis, Dow and BASF. The subsea coatings market is exploding with the worldwide expansion of the energy sector. In 2007, 190M m^2 of coatings were applied and this has increased by 15% annually since then.

CORROSION IN SUBSEA PIPELINES

Failure at any point along the length of a pipeline can lead to oil leaks, with serious financial consequences for the owner and catastrophic effects on the marine environment. Technical and cost-based decisions made at the early phase of planning can have long-term effects on the integrity and safety of the pipeline. Cathodic protection as a means of corrosion control has been around for almost half a century, virtually unchanged. However, cathodic protection, if in disrepair, can also lead to catastrophic failure. External coatings remain to date the first barrier protection against the harsh conditions that subsea pipelines may encounter in the natural environment.

BIOFOULING AND CORROSION

Barnacles, oysters, tube worms, algae and other marine organisms occupy ecosystems from

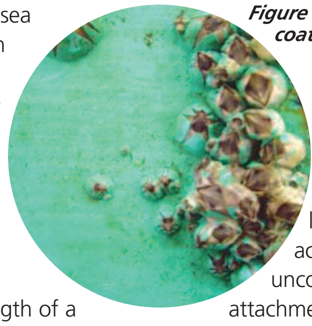


Figure 1: Barnacles growing out of a coating from surface defects

shallow submergence to deep ocean environments. Marine bacteria that grow in association with barnacles cause microbiologically induced corrosion that accelerates damage to coated and uncoated ferrous surfaces. Barnacle attachment can lead to heavy, pitted corrosion, causing the wall thickness of the pipeline to decline by as much as 50%. These biofouling organisms are numerous along the shallow submergence zones, particularly in nutrient-rich environments. Barnacles in particular are gregarious organisms and will congregate in groups as they find places to anchor. The most ubiquitous one, *Balanus amphitrite*, is present in practically all the ports of the world from centuries of being carried on the submerged hulls of ocean-going vessels. But, as the pipeline continues on to deeper waters, the type of fouling species encountered changes in composition and in abundance. There are more than 1000 species of barnacles, with some species growing even in the hot environment of hydrothermal vents. While barnacles in the inter-tidal zone measure just a few millimetres in height, deep-sea barnacles, such as goose barnacles, can grow as big as 80mm.

Corrosion becomes more progressive as soon as the barnacle finds a pinhole-sized area of damage or imperfection on the coating surface. The barnacle larvae can establish a foothold into the pinhole defects on the coating and can seriously damage the paint from underneath (see Figure 1) as it grows, leading to major corrosion in a fairly short period.

Very little testing has been undertaken on the corrosion effects of fouling organisms on subsea coatings at deep ocean depths. Most of the typical anti-corrosion biofouling tests are done by coatings companies on shallow submergence, usually 2 to 4ft from the surface. This test is sufficient to determine the performance of anti-fouling coatings for applications in small boats and ships. Poseidon Sciences' marine anti-fouling research centre in Tuticorin, India, provides R&D services to support this industry. However, applications where coatings are used in much deeper waters, particularly for

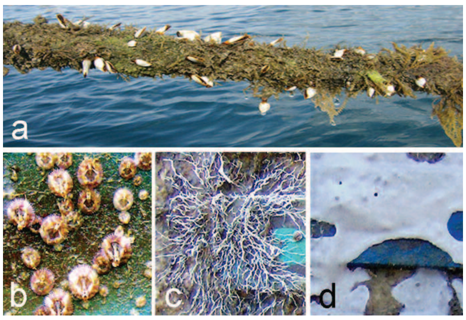
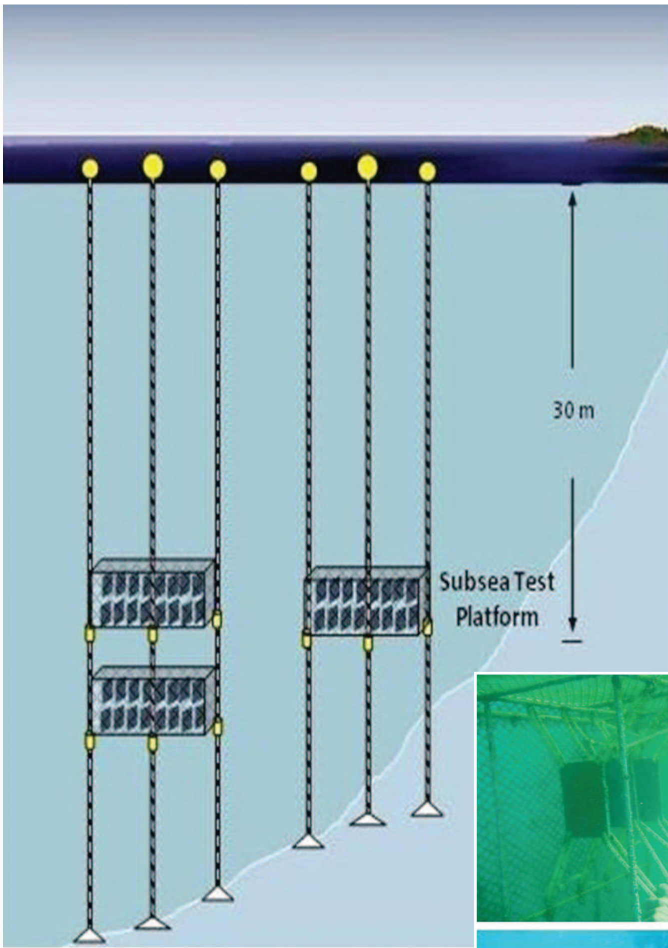


Figure 2: a) submerged cable at 50m encrusted with algae and goose barnacles; b) the barnacle Balanus trigonus Darwin settling on submerged surfaces at 30m depth; c) branching corals establishing colonies on a coated surface at 30m; d) plate corals on a test panel



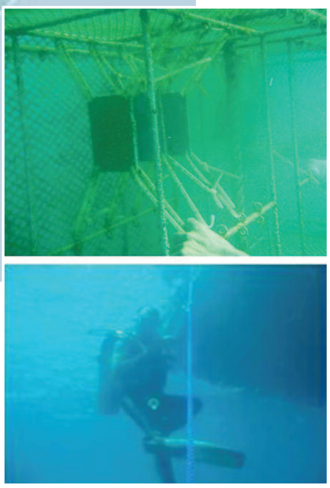


Figure 3, above: Diagrammatic representation of the subsea test structure.
Figure 4, right: Test panels inside the sea cage, with divers inspecting the subsea test platform

pipelines and oil drilling platforms, are rarely tested – primarily because of a lack of available facilities to make such tests possible.

The subsea region is a new and challenging world. The fouling communities, environmental conditions and deep-sea pressures are markedly different from the near-shore areas.

The Athena subsea facility is envisioned to provide marine coatings chemists with the means of fine-tuning their formulations to meet subsea fouling challenges

Understanding the interactions between fouling communities and surfaces is a complex issue. Coating systems that work well against fouling at the submerged bottom of a ship's hull do not necessarily perform well on surfaces in deeper waters. Building a subsea test facility offers the opportunity to begin validating the performance of coatings against a host of deep-sea challenges, especially biofouling.

SUBSEA TEST FACILITY

In December 2008, Poseidon Sciences launched a test facility at its Athena Biosystems Station on the island of Panay, Philippines. This new Athena subsea test facility comprises an underwater platform anchored to the sea bottom by 500 and 1000lb cement anchors from which are tethered cables that suspend net-protected sea cages to host test panels securely at various depths. Figure 3 shows a simplified diagram of the underwater structure. The sea cages are locked in place and released when the sea cages are hoisted up to the surface, guided by divers, for inspection of the coated panels (Figure 4). Multiple cables hold the sea cage in place and it can be hoisted up mechanically, just like riding a subsea elevator shaft. Having the panels secured in a netted cage allows unimpeded seawater flow while protecting the valuable test panels from damage by large fish such as sharks, tunas and barracudas. The first test unit has been sited at 30m and there are plans for deeper submergence levels in the near future.

Because it is located in a tropical environment, fouling attachment is rapid, with settlement of barnacles as the primary hard fouling species. The typical fouling found on an unprotected panel in static immersion for only one month is shown in Figure 2. As the immersion tests continue, other fouling organisms, such as corals, start forming as well.

WHY THE PHILIPPINES?

Why build the site in Philippine waters? There are many reasons. First, Athena Biosystems Philippines, a division of Poseidon Sciences, already had an operating subsea facility that samples pelagic fish from depths down to 50m. Second, the research group already had marine biologists, botanists and divers maintaining the subsea test site. Adding another component to the current operation minimises the capital cost of developing the programme. Third, the marine tropical location is ideal for testing because of the existing aggressive year-round fouling environment, enabling faster evaluation of subsea coatings. Test results are supplied electronically after the inspection period, along with barnacle counts and other relevant biological and structural information.

As test panels are submitted for testing from various subsea coating companies, we are surprised by the coating damage (loss of adhesion, fouling, loss of cohesion and delamination) even at the 30m depth, a relatively shallow immersion test considering the great depths that most subsea pipelines achieve. Coating failure is evident along with adhesion failure, which likely are as a result of a combination of fouling, water intrusion and the pressure experienced by the coating. If we are seeing such results at a 30m depth, one can only imagine the potential damage that may occur in the future with subsea pipelines such as the Independence Trail, located in the Gulf of Mexico, which is the deepest export pipeline in the world, going down to depths of 8000ft (2438m).

The subsea world is both fascinating and unforgiving. Despite years of underwater research, there are still many unknowns in the deep sea. The understanding of how deep-sea cables and pipelines affect the ecosystem and how these ecosystems affect the performance of the subsea structures is just beginning. The Athena subsea facility is envisioned to provide marine coatings chemists with the means of fine-tuning their formulations to meet subsea fouling challenges. Better protective coatings that can prevent fouling translates to longer term asset protection and increased safety for the deep ocean marine ecosystem. **APCJ**

Araceli Q Adrias is managing director, Athena Biosystems. Jonathan R Matias is executive director, Poseidon Sciences Group

SUGGESTED READING

1. Britton, J: Improvements in offshore pipeline cathodic protection and anode life extension, 2006 (www.stoprust.com/1improvements.htm).
2. Fairhurst, D: The future of pipeline coatings, Proceedings PCE 2000 Conference on assessing the future of coatings work, 2000, pp101-108.
3. Papavinasam S; Attard, M and Revie, R W: External polymeric pipeline coatings failure modes, Materials Performance, 2006 (October), pp28-30.
4. Tator, K B: Qualification testing of fusion bonded epoxy coatings for pipeline exteriors (www.kta.com/knowledge/PACE2006/FusionBondedEpoxy.pdf).

For more information on this article, please contact:
Jonathan R. Matias, executive director,
Poseidon Sciences Group
122 East 42nd Street, Suite 1700, New York,
New York 10168, USA
Tel: + 1 718 454 5065
Fax: +1 718 454 1931
Email: jrmatias@poseidonsciences.com
www.poseidonsciences.com