Simulation of shear stress on marine coatings using a novel dynamic test system in an open ocean tropical environment

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Marine paint chemists are always under pressure to develop novel coatings to meet the demands of the shipping industry, the government regulators and the environmental groups. Performance targets need to be met with various systems, such as copper-free systems, foul release coatings, biocide-free or low copper paints. While the competition is heavy in this multi-billion dollar market, the methods to assess the performance of coatings have not changed for many decades.

Static immersion tests, in which coated panels are immersed in seawater remains the primary screening method for assessing antifouling performance (see American Society of Testing Materials, ASTM D 3623). The simulation of stress on coating in the laboratory can be accomplished using the method described in ASTM D 4938 in which high velocity seawater is made to flow through a channel where panels are immersed. Alternatively, curved panels may also be attached to a rotating drum and immersed into a seawater container or placed in the sea (ASTM 4939). Both dynamic immersion systems have their own inherent limitations. The laboratory method is used by the industry to a limited extent because of cost of maintaining and operating the system. The rotating drum method (Fig. 1) requires the use of curved panels and limited to a single speed for each drum, requiring multiple drums to assess effects of various seawater velocities. Moreover, laboratory testing is inadequate since the true natural conditions are more complicated, with fouling, debris, particulate matter and temperature affecting the outcome of the tests.

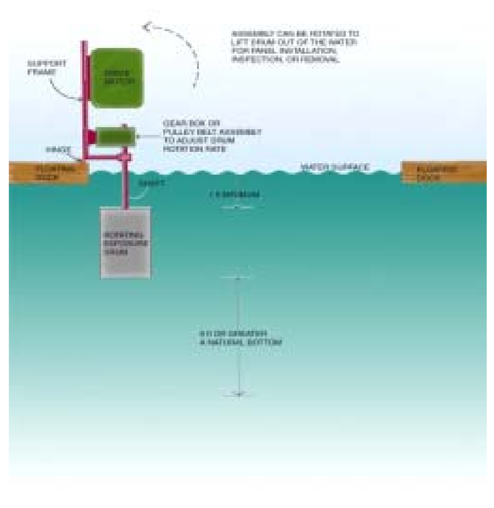

Figure 1. Schematic description of the rotating drum method described in ASTM D 4939.

How the coated surface performs against fouling and shear fluid stress depends largely on the test location. Subtropical locations where fouling are highest only in summer months would be of limited value for fast screening because of low exposure to heavy fouling pressures.

An effective dynamic exposure test system should have the following elements:

- Test should be conducted in a tropical environment with high fouling conditions
- The test should be in an open ocean condition
- The dynamic test system should accommodate multiple panels at multiple speeds

Poseidon Ocean Sciences and Sacred Heart Marine Research Centre (SHMRC) have collaborated in developing marine antifouling systems and identification of marine natural compounds since 1994. In 2003, marine engineers from both organizations have developed an open ocean test platform that has since been in operation for the last five years. This presentation describes some of the salient features of this test facility.

POSEIDON SCIENCES GROUP

Poseidon is a research and development company engaged in a wide variety of projects in marine and biomedical sciences in several countries. Biofouling R&D is conducted under Poseidon Ocean Sciences, Inc., a US company with headquarters in New York. Current projects include nontoxic repellents and contract testing of marine coatings in both laboratory and field conditions. The primary testing operation in marine coatings is conducted under a collaboration with SHMRC in Tuticorin, India.

SHMRC is a non-profit research organization located in Tuticorin Bay (India) where laboratory facilities are available for barnacle settlement and marine bacteria/algae studies. SHMRC has a complete staff of marine scientists and support personnel to undertake basic and applied research. Under the collaboration with Poseidon, dating back since 1994, SHMRC maintains a field research facility at Karrapad Cove for the study of barnacle settlement on coatings under static and dynamic conditions using test platforms in the sea.

ENVIRONMENTAL CONDITIONS IN TUTICORIN BAY

The Karrapad cove in Tuticorin Bay was chosen because it is protected from heavy waves by a coral reef barrier. The cove opens up into the Tuticorin Bay and the adjacent port of Tuticorin, one of the busiest ports in India. The high nutrient load of the seawater in Karrapad Cove has combined with warm tropical temperatures, high sunshine and relatively stable salinity (except briefly declining during the short monsoon season) to create an environment conducive for fast growth of marine algae and other microorganisms. This in turn yields a high density of barnacles, clams, oysters and other bivalves. Barnacle fouling is year-round, while other fouling organisms, such as sponges, follow a cyclical seasonal pattern. The profile of the temperature and salinity conditions in Karrapad Cove is described in Fig. 2a and the varieties of foulers is shown in Fig. 2c.

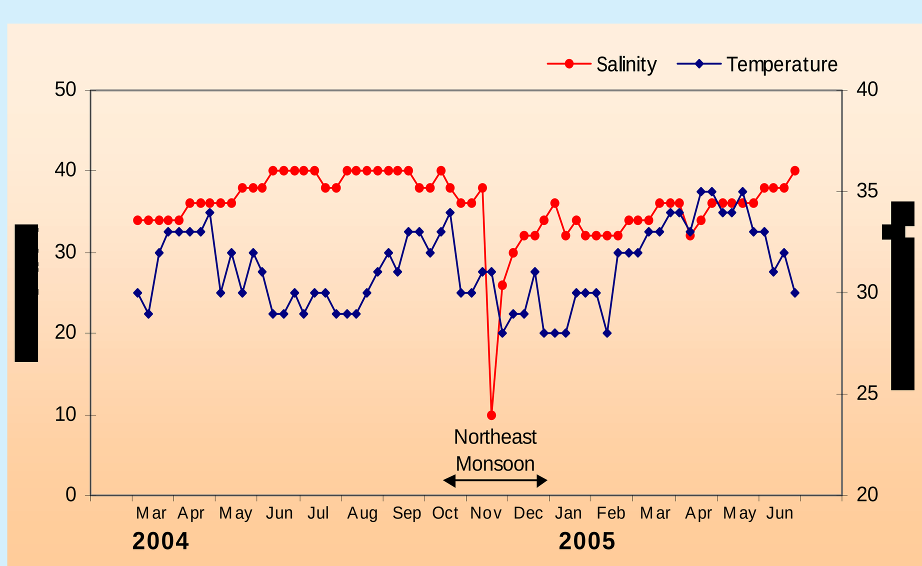

Figure 2a. The temperature and salinity measured in Karrapad Cove (Tuticorin, India) in 2004-2005.

Figure 2b. Location of Poseidon - SHMRC Marine Science Station.

Oysters with barnacle fouling | Barnacle fouling on panel | Macro-algae | Teredo shipworms | Sponges | Green micro-algae covering barnacles | Tubeworm

Figure 2c. The range of species comprising the fouling community in Karrapad Cove.

The PDTS platform being launched out to sea from the SHMRC shore laboratory.

Panels being installed in the dynamic test platform.

SHMRC Shore Laboratory

EROSION RATE

The following sets of graphs describe the erosion rate of panels using the PDTS platform.

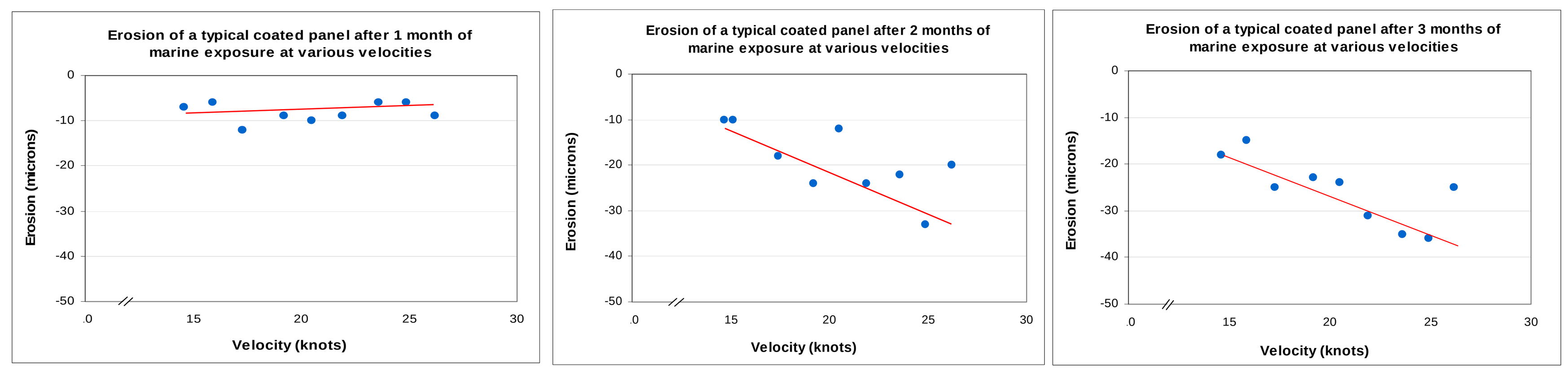

Figure 3a. The erosion of coatings as a function of velocity. The graph on left shows the panel erosion after 1 month of dynamic testing. The erosion was calculated at different points within each panel placed in all three rings/positions in PDTS platforms. There were no diffrences between the various speeds after 1 month of exposure. The middle graph shows the same measurements made after 2 months and the right graph at 3 months. Here we demonstrate a velocity dependent decline in coating thickness at months 1 and 2.

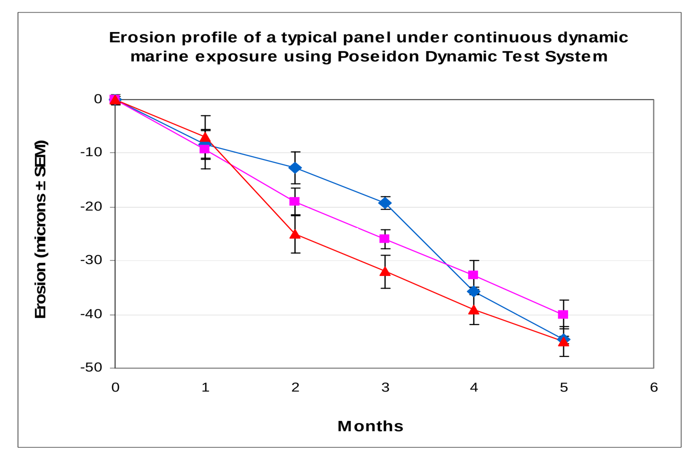

Figure 3b. The erosion rate of self-polishing coplymer coated panels placed at various locations within the PDTS platform. (■) 25 knots (■) 20 knots (■) 15 knots. The data show a progressive decline in coating thickness in all positions over a 6 month period, with the panels at 25 knots showing great erosion.

Poseidon-SHMRC Dynamic Test System (PDTS)

The PDTS platform is situated in the middle of the cove, about 500 m from shoreline, with an underwater electrical cable to supply power to the system. Wave action within the cove is moderate so that the platform can be stabilized with anchors and cables on the seabed. A diagrammatic description of the PDTS platform is shown below in Fig. 3a.

PDTS enables the use of flat panels that moves through the water horizontally, rather than vertically as in the rotating drum method. Each location within the same panel experiences a different velocity depending on its position and distance from the center shaft. It is therefore possible to determine the effect of different velocities at any point in the panel and the corresponding erosion rate resulting from the fluid shear forces generated by the undersea rotation.

PDTS is operated continuously for 11 hours, followed by 1 hour inspection and calibration, and then followed by another 11-hour run. This allows to a continuous operation for 22 hours per day. Currently, the system is configured at 25 knots in the outer ring, 20 knots in the middle ring and 15 knots in the inner ring to simulate the range of speeds of ocean going vessels. A continuous exposure of a panel on the external ring for a period of 1 year will be equivalent to a surface traveling the distance of 200,000 nautical miles.

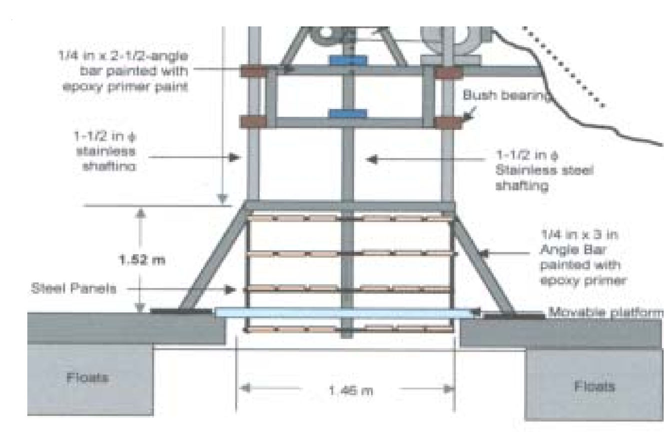

Figure 4a. Diagram of the PDTS platform

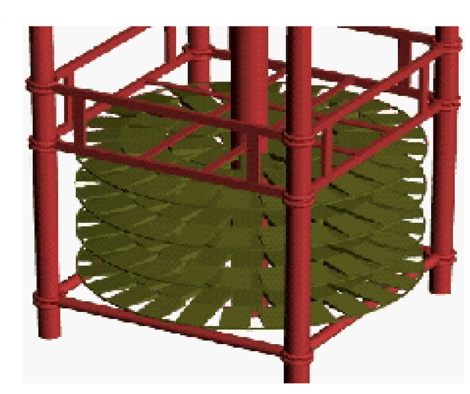

Figure 4b. Schematic diagram of the panel assembly and the concentric rings that hold the panels in place.

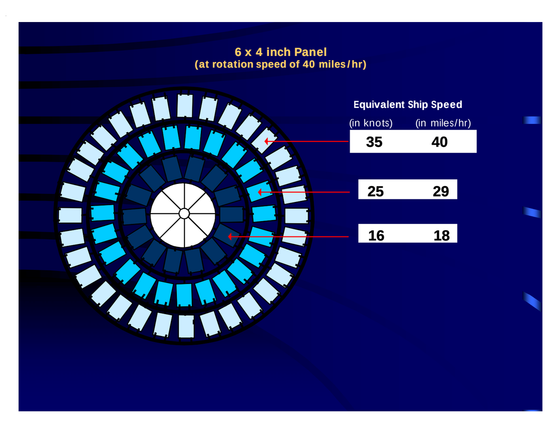

Figure 4c. The position of the concentric rings and panels with the corresponding relationship with the velocity.

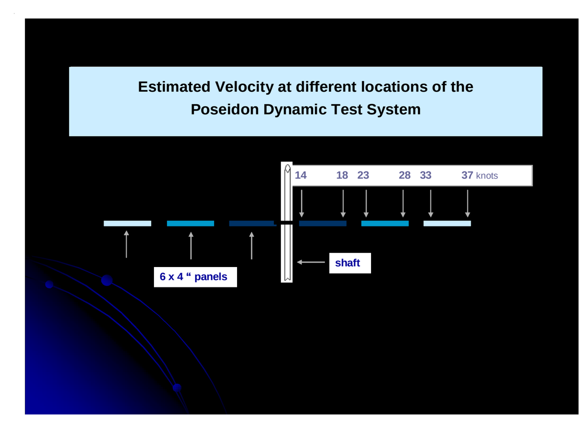

Figure 4d. The velocity at different positions. The velocity can be changed at any time by changing the rotational speed at the center shaft.

COATING FAILURE

PDTS tests in real world conditions also allows for a better assessment of the integrity of the coating after being subjected to fluid shear forces. Typically, static immersion tests provide little information about the integrity of the coating other than its efficacy against fouling attachment. When the same coated panels are subjected to a dynamic test, those panels with poor adhesion to the primer or primer failures are easily observed after a few weeks in dynamic test. Fig. 5 shows a typical example of coating failures.

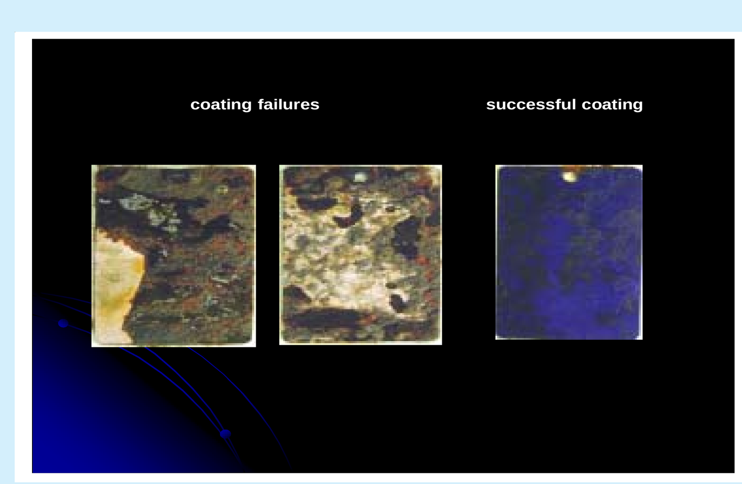

Figure 5a. Example of coating defects seen when panels were subjected to PDTS after 2 months of dynamic test.

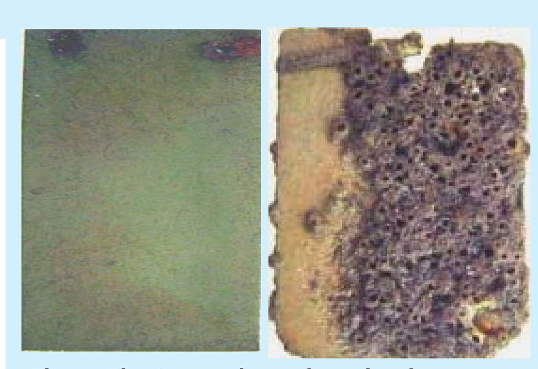

Figure 5b. Comparison of coating from same manufacturer after 6 months (left) and dynamic (right). Both panels had the same coating but exposed to different condition during the same period of time. The static immersion panel on the left showed neither fouling nor damage. The same coating when placed on dynamic test showed erosion damaged and delamination by month 3 and began to accumulate barnacles in the damaged areas.

Figure 5c. A dynamic test panel with sufficient erosion of coatings to allow barnacles to attach and push out of the coating. Dynamic test may cause sufficient depletion of the antifoulant to create microscopic damage, which in turn allows barnacles to attach and eventually damage the coating.

Sr. Avelin Mary on the static immersion platform

Sr. Avelin Mary (left) and Sr. Vitalina (right)

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