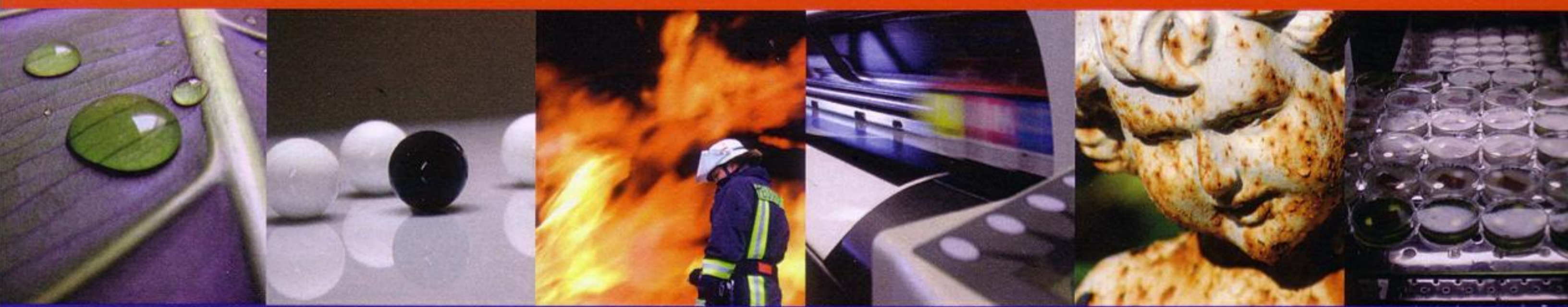
EC European Coatings CONFERENCE

www.european-coatings.com



Simulation of marine coating performance under natural tropical seawater conditions using the Poseidon Dynamic Test System

Jonathan R. Matias[1] & Sister Avelin Mary[2]

1 Poseidon Ocean Sciences, Inc. 122 E 42nd St., New York, NY USA 10168

2 Sacred Heart Marine Research Centre Tuticorin, India 628001

EC Conference: Marine Coatings II

Berlin, Germany, February 9-10, 2010

Simulation of marine coating performance under natural tropical seawater conditions using the Poseidon Dynamic Test System

Jonathan R. Matias[1] and Sister Avelin Mary[2]

[1]Poseidon Sciences Group, 122 East 42nd Street, New York, NY 10168 USA. [2]Sacred Heart Marine Research Centre, Beach Road, Tuticorin, India 628001

Abstract

While static immersion of coated panels is adequate to assess antifouling performance, a dynamic simulation is essential to accurately predict the usefulness of any experimental coating system prior to a more expensive patch test or full ship test on ocean going vessels. Launched in 2003, the Poseidon Dynamic Test System (PDTS) is comprised of electrically-powered, horizontally-oriented rotating frames mounted on a floating platform positioned 500 meters from shoreline in the high fouling, year-round tropical marine environment of Tuticorin Bay (India). The PDTS test platform accommodates a total of 171 panels that experience fluid shear stress at speeds ranging from 15 to 25 knots. The panels at the highest velocity experience a simulated ocean travel of 200,000 nautical miles in a single year. The fluid shear forces produce a stress on the coating in the same manner it would on the underside of the ship resulting in erosion of the coatings and loss of antifouling effects. Those top coats with poor adhesion and those with primer incompatibility are detected by the PDTS system within 2 months, thus allowing for reformulation or re-assessment of the application methods. Effective antifouling coating systems have been in experimental tests for over two years without structural problems or loss of antifouling effects. Using an alternating static-dynamic operation (1 month static to accumulate fouling followed by 1 month of dynamic test) provides a reasonable simulation of the activity of a ship in port and at sea. This method is also effective in the evaluation of foul release coating system since it allows accurate determination on what velocity fouling organisms can detach from the surface. This six-year field testing experience provides supportive data on the usefulness of the PDTS system in marine coatings R&D.

Introduction

The marine paint industry is always under pressure to develop novel eco-friendly coatings to meet the demands of the shipping industry, government regulators and environmental groups. While the competition is heavy in this multi-billion dollar market, the accepted methods to assess the performance of coatings have not substantially changed for many decades. Many laboratory tests have been developed in the past to enable faster assessment of experimental coatings. However, the marine coating industry is a conservative one and field testing on panels and actual ship tests cannot be replaced by any current laboratory methods to estimate coatings performance. 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 uses the method described in ASTM D 4938 in which high velocity seawater is made to flow through a channel where panels are immersed. This laboratory method is used by the industry to a limited extent because of the high cost of maintaining and operating the system. Moreover, laboratory testing using high velocity seawater is incomplete since the true natural conditions are more complicated, with fouling, debris, particulate matter and temperature affecting the outcome of the tests. Alternatively, curved panels may also be attached to a rotating drum and immersed into a seawater container or placed in the sea (ASTM 4939). The rotating drum method requires the use of curved panels and limited to a single speed for each drum, requiring multiple drums to assess effects of various velocities. Both dynamic immersion systems have their own inherent limitations.

How the coated surface performs against fouling and fluid shear forces depends largely on the test location and the equipment employed for such test. Subtropical locations where fouling are highest only in summer months would be of limited value for fast screening because of the short fouling season.

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

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

This paper describes research on the development of a novel dynamic test system, referred here as Poseidon-SHMRC Dynamic Test System (PDTS), which incorporates the above elements and offers an accelerated evaluation of coatings performance in a dynamic environment of the tropical sea.

The Strategic Partners

Poseidon Sciences Group (PSG) is a research and development organization engaged in a wide variety of projects in marine and biomedical sciences in several countries. Ongoing research at PSG ranges from marine chemistry, aquaculture, repellents, fisheries, fish diseases, biopharmaceuticals, drug delivery systems and engineering. Non-profit programs, such as malaria control, livelihood technology development and conservation, are undertaken under Poseidon Science Foundation. Biofouling R&D is conducted through Poseidon Ocean Sciences, Inc. (Poseidon), headquartered in New York.

Sacred Heart Marine Research Centre (SHMRC) is a non-profit marine science research organization established in 1989. Located in the port city of Tuticorin in southeast coast of India, SHMRC research facilities include: [1] laboratory for barnacle settlement and marine bacteria/algae studies; [2] field facilities for immersion studies on coated panels, on wooden boats, propellers; and [3] mariculture facilities for seaweeds. SHMRC has a complete staff of marine scientists and support personnel to undertake basic and applied research. (Fig. 1) The collaboration between Poseidon and SHMRC began in 1994 to discover naturally occurring barnacle anti-settlement compounds and other bioactive chemicals from the Gulf of Mannar. Having completed its major research programs Poseidon-SHMRC has continued operating its facilities in support of the R&D efforts by marine paint companies to develop novel coating systems through providing access to its facilities and expertise in immersion testing (subsea, total, dynamic and waterline) and laboratory testing (cyprid anti-settlement, algal/bacterial fouling and release rates of bioactive chemicals).

Figure 1. Poseidon-SHMRC facilities, biofouling organisms, test platforms and the Karrapad Cove.

The Test Site

The Karrapad cove in Tuticorin Bay was chosen because it is protected from heavy waves by a coral reef barrier. The cove opens into Tuticorin Bay and the adjacent port of Tuticorin, one of the busiest ports in India. The high nutrient load in the seawater in Karrapad Cove 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 that feed on these microorganisms. Barnacle fouling is present on a year-round basis. These conditions allow for testing of coated panels at any time of the year against barnacle fouling. The profile of the temperature and salinity conditions in Karrapad Cove is shown in Fig. 2. The temperature range from 27 ^{o}C to 35 ^{o}C throughout the year.

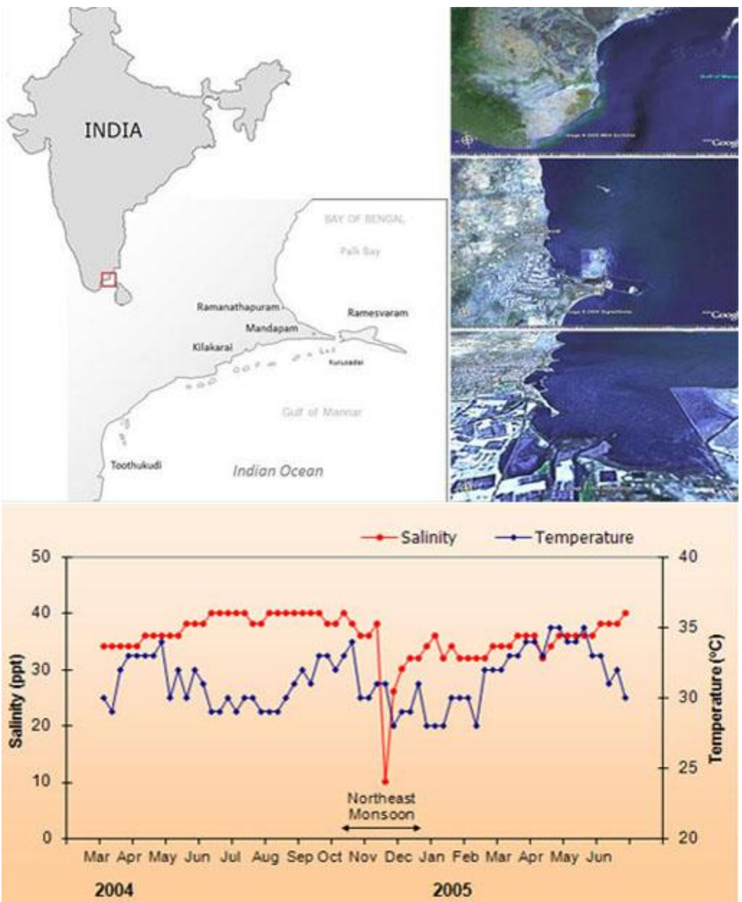


Figure 2. Map location of test site in south Indian port city of Tuticorin (Toothukudi) and the profile of salinity (red line) and temperature (blue line) over a 2 year period.

The seasonal pattern of barnacle and other fouling is currently being monitored by placing uncoated PVC panels (7.6 cm x 20.3 cm) under total immersion in the floating platform in the middle of the cove. The immersion period was 1 month to allow for month to month evaluation of fouling abundance. Fig. 3 shows the interim data as of December 2009 showing a continuous fouling by barnacles with peak period of settlement just prior to the monsoon season. Green algae covered the panels during the intense sunshine of the summer and declines just prior to the monsoon while tubeworms appear to show two peaks of seasonal activities. The results shown here is part of the ongoing data collection to establish those basic environmental data on the Karrapad Cove site.

Dynamic Test

In 2003, marine engineers and biologists from Poseidon, SHMRC and Symrise collaborated on developing a concept of horizontally moving panels to create fluid shear forces that will simulate the erosion of coatings. Current method of dynamic test typically involves curved panels affixed to a cylindrical drum that rotates at a fixed velocity. (see Fig 4a). The PDTS unit uses flat panels affixed on a horizontal frame and rotating under water (Fig 4d). The distance from the center shaft dictated the speed that a particular surface on the panel experiences (Fig 4e). This system allows for evaluation of multiple panels at multiple speeds at any given time.

The PDTS platform is situated in the middle of the cove, about 500 meters from the 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. 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 for 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 is equivalent to a surface traveling the distance of 200,000 nautical miles.

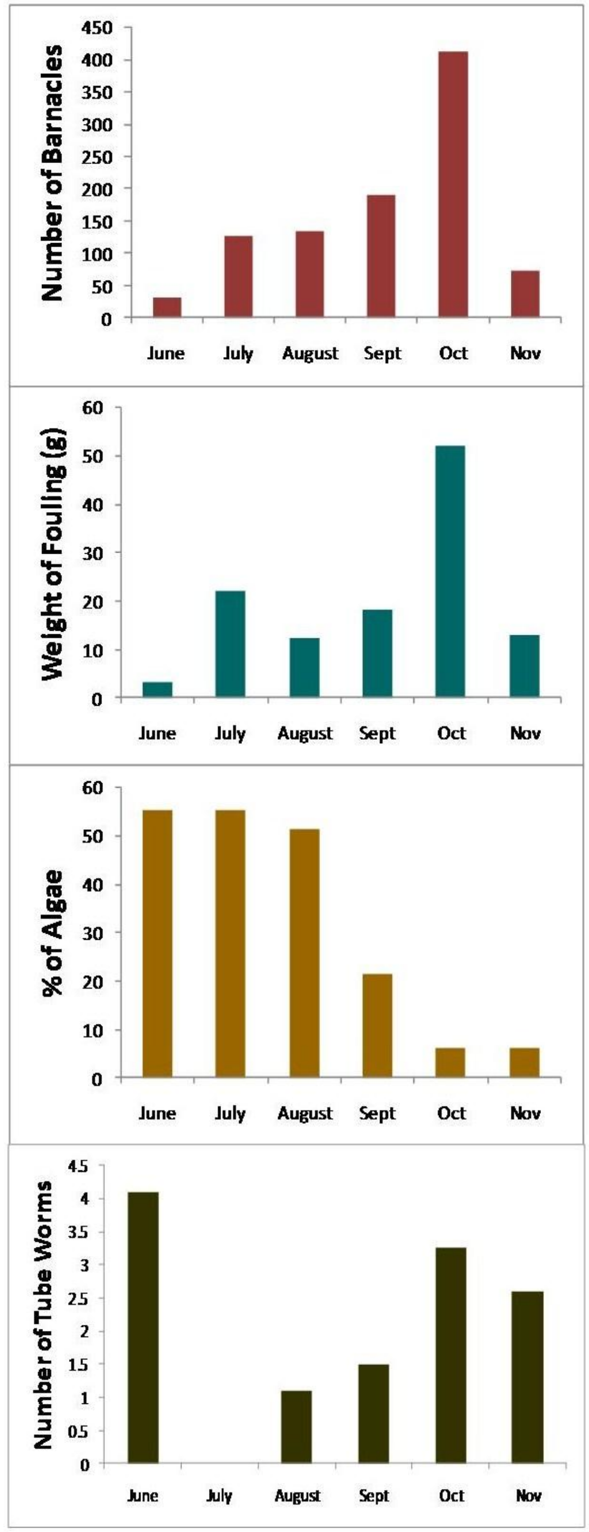


Figure 3. The fouling abundance in Karrapad Cove of Tuticorin Bay at different months of year. Each data is the mean of 10 panels placed in total immersion for a period of 1 month.

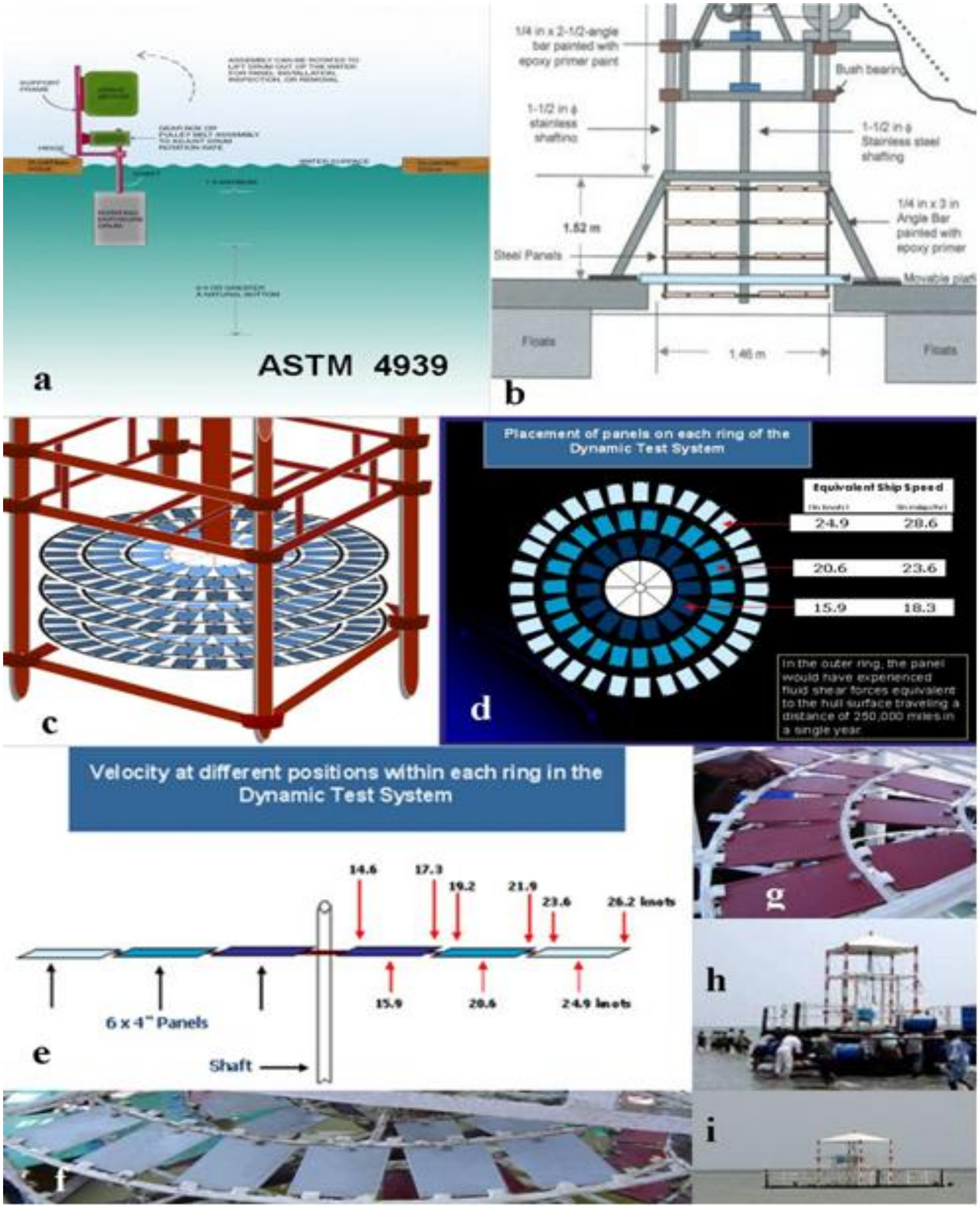


Figure 4. [a] Schematic diagram of the ASTM 4939 method that uses cylindrical drum and curved panels. [b] Schematic diagram of the PDTS platform with horizontal frames rotating on a center shaft and being moved vertically in the seawater by pulley.[c] 3-D schematic of the PDTS system. [d] Placement of the flat panels on a typical frame and the corresponding velocity at the center of the panel. [e] Velocity at different sites in the panels depending on the distance from the vertical rotating shaft. [f and g] placement of the panels on the PDTS frame. [h] Launching of the platform to the sea. [i] The PDTS platform at anchor in the cove.

A dynamic test is important in product development since total immersion test alone is insufficient to determine the viability of a coating system. Total immersion simply measures the antifouling characteristic of a stationary panel and provides useful information on the period the panel begins to lose its antifouling activity. However, it does not tell whether a coating system can survive the shear forces that the coating surface may experience during the expected life of the coating on a ship. Fig. 5 shows an example of the same coating placed in a static and dynamic environment. After 6 months of static immersion, the panel appeared to do quite well against fouling. When the same coated panels were subjected to a dynamic test, those panels with poor adhesion to the primer or primer adhesion to the substrate was easily observed to fail after a few weeks. Immersion of the panel to PDTS in natural seawater allows for a better assessment of the integrity of the coating after being subjected to fluid shear forces.

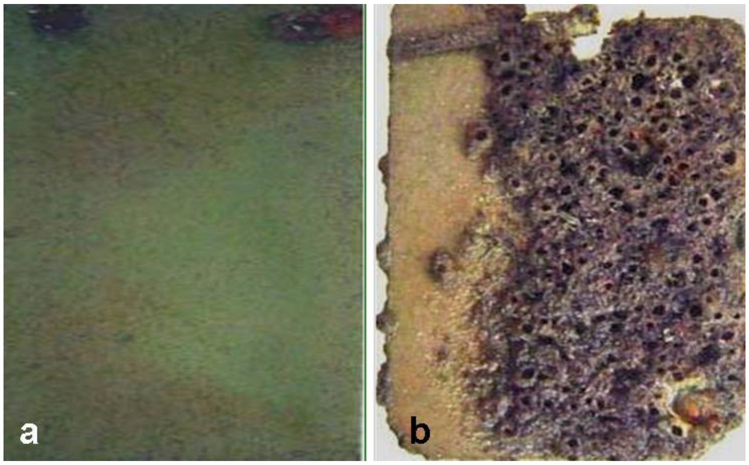


Figure 5. Comparison of coating from same manufacturer after 6 months of static (left) and dynamic (right) immersion. Both panels had the same coating but exposed to different conditions during the same period of time. The static immersion panel on the left showed neither fouling nor damage. The same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

Alternating the immersion test between 1 month in static and then followed by one month in dynamic test simulates what occurs in a ship as it travels from port to port. While it is impossible to simulate the exact conditions, this test provides a better approximation of the efficacy of the coating system as a whole. In the case of foul release coatings, the panel may accumulate some attachment during that one month immersion cycle. Once subjected to a dynamic test, high performing foul-release coating sheds the fouling attachments, depending on the velocity. The PDTS allows calculation of the speed at which such fouling attachments are removed from the surface by fluid shear forces.

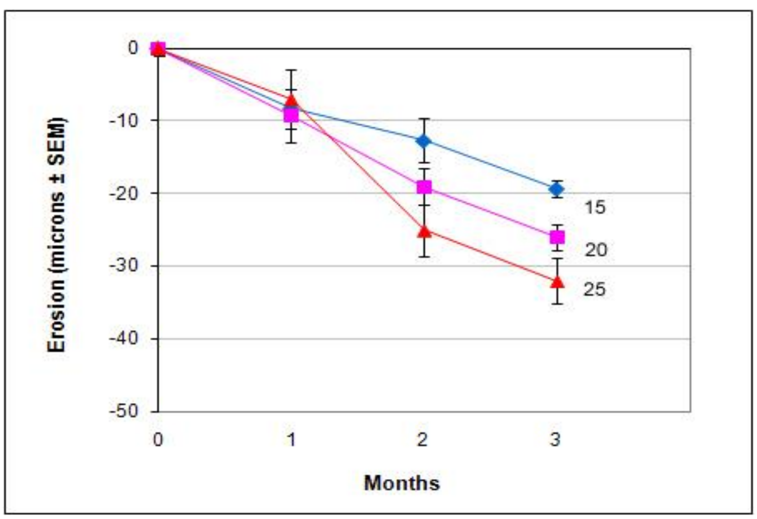


Figure 6. The erosion rate of self-polishing copolymer coated panels placed at various locations within the PDTS platform. The velocity in knots is shown by the number associated with each line. Dry film thickness was measured using QuaNix 1200 in µm. Mean ± SEM of 6 measurements per data point.

As the panels continue its alternating immersion test, poor performing coatings will begin to show substantial erosion leading to loss of antifouling biocides, resulting in fouling attachment during the next cycle of static immersion. Since the test site has year-round fouling, the 1 month static immersion is more than adequate for barnacle attachment to occur, with visible, measurable adult barnacles within the one month exposure period.

Erosion of the coating is measured by taking dry film thickness measurements at specific locations at the center line of each panel prior to immersion and at specific time points specified by the project sponsor. The technician can return to the same exact location so that a reproducible data can be generated for each site at any time point for each panel. Fig 6 shows a typical pattern of erosion as the panels are subjected to fluid shear forces under continuous dynamic test. The coating showed erosion during the first 3 months of exposure. The degree of erosion was dependent on the velocity experienced by the coating surface. As would normally be expected, the greater the velocity the greater the erosion. When the data are further analyzed, the erosion rate was not velocity dependent during the first month of the dynamic test. As the dynamic immersion test progressed, the erosion rate became more velocity dependent so that by months 2 and 3 a linear relationship was clearly evident (Fig.7).

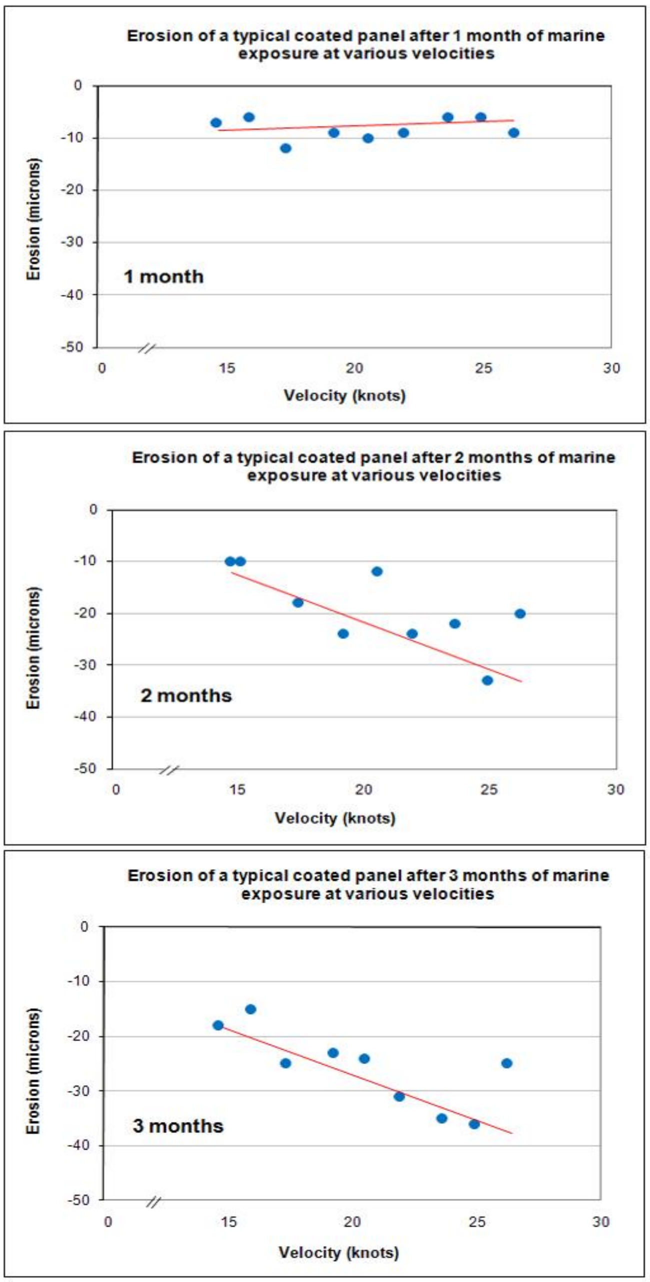


Figure 7. The erosion of coatings as a function of velocity and duration of immersion.

Conclusions

The Poseidon-SHMRC Dynamic Test System is a novel method of testing marine coatings. This system, in concert with being located within the tropical, high fouling environment of Tuticorin Bay, enables year-round testing of various coatings. A continuous mode of dynamic test creates a simulated environment that challenges the coating so that poor performing coating systems can be identified earlier on during the R&D program. Alternating static-dynamic offers as close to real-world situation of ships traveling from port to port. Since the PDTS can accommodate a large number of panels, more samples can be loaded into the test facility. Moreover, since the velocity depended on the position of the panel from the center rotating shaft, it is possible to simulate the effect of variable velocities on the erosion pattern on the coated surface. With the 6+ years of operation, the PDTS has evaluated over 1,500 panels and contributed to accelerating the R&D programs of marine coatings companies.

Suggested reading

For more information about dynamic tests, please see the sections on "Testing services" and "Publications" at www.poseidonsciences.com.

ASTM D 3623-78 (reapproved 1998). Standard test method for testing antifouling paints in shallow submergence. *American Society for Testing and Materials*. West Conshohocken, Pennsylvania, USA.

ASTM D 6690-05. Standard practice for evaluating biofouling resistance and physical performance of marine coatings. *American Society for Testing and Materials*. West Conshohocken, Pennsylvania, USA.

ASTM 4938-89 (reapproved 1998). Standard test method for erosion testing of antifouling paints using high velocity water. *American Society for Testing and Materials*. West Conshohocken, Pennsylvania, USA.

ASTM 4939-89 (reapproved 2007), Standard test method for subjecting marine antifouling coating to biofouling and fluid shear forces in natural sweater. American Society for Testing and Materials. West Conshohocken, Pennsylvania, USA.

Matias JR (2001). Life on the ocean wave. *Polymer Paint Coatings Journal*. 191:21-23.

Matias JR (2001) Searching for antifoulings. *Asia Pacific Coatings Journal*. 14:44-46.

Matias JR, Parpan L (2003). Shedding light on the marine paints industry. *Asia Pacific Coatings Journal,* August 2003, pp 33-35.

Matias JR, Rabenhorst J, Mary A, Lorella A (2003). Marine biofouling testing of marine paints. Technical considerations on methods, site selection and dynamic tests. *Proceedings of the Society of Protective Coatings) 2003: The Industrial Protective Coatings Conference*, New Orleans, Louisiana, Oct. 27-30. 8 pages.

.

Matias JR (2005). Simulation of shear stress on marine paints. *Asia-Pacific Coatings Journal*, April 2005, pp 22-24.

Matias JR (2009). Barnacles, Darwin and marine paint research, *Paint and Coatings Industry Magazine*. July 2009. pp 36-40.

Vincent LD (2009). Coatings performance: Offshore service vs. Lab tests. *CoatingsPro Magazine*, November 2009, pp 36-39.

Acknowledgements:

The authors wish to thank the expert assistance of Ms. Coleen Sucgang and Ms. Sheila Serrano during the preparation of this manuscript.