Simulation of shear stress on marine paints

Jonathan R Matias, executive director of Poseidon Sciences demonstrates how the simulation of shear stress on marine paints can be illustrated using a novel test method

Compliance with global environmental law and the pursuit of high quality, cost-efficient performance coatings are the drivers of innovations in the marine paint industry. Paint laboratories of both multinational and small companies devote significant efforts in testing new additives and formulations in a bid to surpass present coating standards.

The global convention prohibiting the use of tributyl tin as a biocide in antifouling systems has yet to enter into force, but many seafaring nations have taken unilateral steps to impose the ban. As the legislative process to ratify or disapprove the convention grinds along, the search for more effective, environment-friendly antifouling systems continues. Copper-based paint systems, which are still acceptable, may eventually face some regulation and its phase-out is not inconceivable. The driving force for the change is not only the regulatory climate but also the desire by end users, particularly cruise lines, to use copper-free paint systems or more environmentally acceptable coatings. 'Since the use of many biocides, specifically cuprous oxide, in antifouling coatings are under the microscope by government and private environmental groups, a great need exists to test the performance of 'new generation' nontoxic antifouling or environmentally safe fouling-deterrent coatings,' said Ernie Soeterik, paint chemist of Proline Paints (Sherwin Williams Company).

Marine paint formulators are under pressure to develop new coating systems with reduced copper, preferably metal-free systems, and versatility in colour (apart from the traditional red imparted by the cuprous oxide binder) without sacrificing the performance targets required by the shipping industry. Numerous patents have been issued for novel paint systems in the last few years. Digital photography and increasing Web access has made it easier to obtain real time data on the conditions of the panels. However, progress in the development of commercial products is hampered by the typically long duration required of panel tests in marine exposure to verify the efficacy of an experimental formulation. This, before the formulation even undergoes ship tests on ocean going vessels. There is therefore a great need to develop systems that allow for simulation of the stress experienced by marine paints even before an expensive ship test is undertaken. 'The best method to obtain satisfactory test performance data of these 'new generation' coatings is through efficient, scientific and reliable static and dynamic underwater testing,' Mr. Soeterik said.

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CURRENT METHODS OF TESTING

The American Society for Testing Materials (ASTM)'s guide -- 'Standard Test Method for Testing Antifouling Panels in Shallow Submergence' (D 3623) -- is the standard for testing marine coatings in the aquatic environment]. Coated test panels are submerged in natural seawater conditions susceptible to heavy marine fouling under static immersion, and left for periods of time to determine the degree of resistance provided by the test coatings against attachment of hard fouling (such as barnacles, oysters) and soft fouling (algae, seaweeds, sponges). Most major companies maintain their own marine test stations in various port areas, as fouling conditions tend to vary from site to site. Testing in major ports, such as Singapore and Los Angeles, provides a representation of the performance of coatings at these ports of call. However, there are certain notable degrees of fouling even within the same port area.

ASTM D 4938 stipulates the use of high velocity seawater flowing through a channel with coated panels to simulate erosion of the coatings as the ship travels through the water. ASTM D 4939 is another version of the test, which is commonly referred to as the rotating drum test, used for similar simulations. These test systems serve as the standards of the industry and allow for better simulation of the stress on coatings. After a period of time in which the panels are immersed in a fouling environment, the panels are retrieved and evaluated subjectively to determine the performance of the antifouling coating.

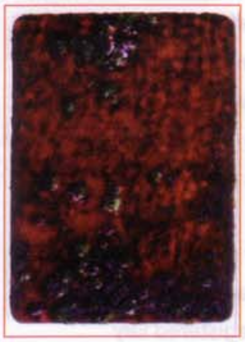
The use of high velocity water has some drawbacks, such as the high cost of construction and operation of the system. The rotating drum test equipment can also be expensive, requiring the use of curved panels and accommodating only a small number of test panels per drum. The machine simulates erosion only at one speed at any time so testing of coatings at various ship speeds requires a change in the rotation of the drum or the water's velocity in the course of erosion testing.

SELECTION OF THE TEST SITE

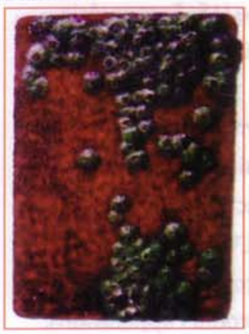
Although it is important to test the antifouling performance of marine coatings in various temperate, subtropical and tropical ports of call, it is less of importance when undertaking screening of experimental paints. Paint chemists need to be able to eliminate poorly performing systems early in the development process. This is not so easily done if the test site is located in subtropical locations where fouling challenge occurs seasonally during the summer months. The test site must have continuous aggressive fouling throughout the year thus creating the heavy fouling challenge to enable faster discrimination between poor performing and effective paints.

Figure 1. The progression of fouling of steel panels by the barnacle, Balanus amphitrite, submerged in seawater in Tuticorin Bay

1 month



2 months



3 months

Early in the research and development work on natural antifoulants, we have decided to establish marine biological stations in subtropical and tropical locations. Poseidon established research collaboration with Sacred Heart Marine Research Center (SHMRC) in Tuticorin, India in 1994 to study natural antifouling compounds extracted from soft corals. Located in the southernmost part of India in the State of Tamil Nadu, Tuticorin port turned out to have a very aggressive fouling environment. This occurs due to the high nutrient load of the Tuticorin Bay and, with exception during the brief monsoon season, fairly constant year-round warm temperature and salinity. As a result of these environmental conditions, test panels can become easily fouled by the barnacle, Balanus amphitrite, the predominant fouling organism that is also present in all major ports worldwide. *Fig. 2* shows the progression of fouling of an uncoated panel in static immersion in Tuticorin Bay. The surface becomes heavily fouled by the second month of exposure. To obtain the same result in southern California or Florida waters will require at least six months of exposure.

THE POSEIDON DYNAMIC TEST SYSTEM

Simulation of the erosion of the paint on the underwater surface of a moving ship typically utilises a dynamic test machine as described above. However, the velocity varies depending on the type of ship or boat. Testing panels at different speeds can be an expensive operation if one uses the rotating drum system. A new dynamic test method has been designed by Poseidon scientists to address critical issues related to the dynamic test — increased number of panels, use of flat panels, and simultaneous simulation at multiple ship speeds. A diagrammatic representation of this new system is shown in *Fig. 2.* Instead of mounting curved panels vertically on the outer surface of drum, flat panels are oriented horizontally on a disc, using bolts to hold the panel on the edges. It is then possible to construct multiple discs that can be rotated at a fixed speed on a central shaft. Since the velocity experienced by the panel depends on the distance from the center of the disc, the panels placed at various positions on the disc will therefore experience different velocity and shear stress. *Fig. 3* shows the positioning of the panels on the disc and the equivalent ship speeds when the disc rotates.

The Poseidon Dynamic Test System or PDTS is mounted on a floating platform in a protected cove adjacent to the Port of Tuticorin *(Fig. 4).* This platform is anchored by cables to the seabed and placed adjacent to the static immersion platforms. The test panels in the PDTS machine can be removed after a given travel time on the machine and transferred to the static immersion platform. This combination of dynamic and static exposure provides a means of simulation of the time the ships are stationary in port or travelling in the open ocean.

Figure 2. Diagrammatic representation of the rotating discs of the Poseidon Dynamic Test System. The rotating unit is completely submerged in seawater under the floating platform

Figure 4. The PDTS machine and floatation platform prior to deployment to the open sea.

'The Dynamic Test System at Poseidon would allow us to measure the polishing rates at different speeds on the same run. As a result, more useful data can be generated in the same test period of a conventional Rotating Drum System,' said Scot Swan, of Atofina (now known as Arkema).

This method offers the opportunity to investigate the shear stress on the coating at ship at various speeds up to 40mph. The velocity can be easily adjusted by simply changing the speed of rotation. Flat panels can then be used to permit erosion tests on both sides of the panels. This dynamic testing machine, with a capacity of 280 standard Q-panels (4 in x 6 in), was constructed with these specifications and has been in operation for two years in seawater simulating over 200,000 miles of travel.

CONCLUSION

Simulating the erosion of coatings on the hull at various speeds is an important tool in evaluating the efficacy of a paint system. Optimising the testing protocols to accommodate improved accelerated test systems then becomes necessary.

Among the protocols to be strongly considered is the selection of a marine environment with aggressive biofouling conditions. This is necessary to obtain early results on the performance of experimental antifouling coatings. Coupled with a novel modified dynamic test system, paint manufacturers will be able to stretch their research and development budgets much further.

By combining the optimum site with aggressive fouling condition for marine exposure testing and a versatile dynamic system, it is possible to accelerate the evaluation of experimental coatings to create improved marine coatings for the future.

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Figure 3. The velocity experienced by the panel at various distances from the center of the disc as the system rotates horizontally.