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ANALYSIS OF ANTIFOULING PAINTS USING DRUM-TEST APPARATUS

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SUMMARY

Ship has been recognized as a major factor in introduction of non-native and harmful organisms which causes deleterious effects on the performance of the vessel. More than 70% of Invasive species worldwide have found to be due to hull fouling. To mitigate fouling, underwater parts of the vessels are coated with antifouling paints. Antifouling paints provide foul-free hulls up to a maximum of 95 % of the vessels underwater area. There are a number of types of these paints but “self-polishing coatings” are predominantly preferred by the shipping industry. In these types of coatings, a thin layer of biocide containing paint (typically 2 to 5 microns/month) is leached or “polished” away. This polishing action primarily depends on the hydrodynamic surface forces on the vessels hull. The higher the fluid velocity, the higher are the polishing rate. Certain areas of the vessel such as near the bow, stern, etc experience higher fluid velocity and therefore higher polishing rates thereby resulting in premature fouling. Conversely, areas where the flow rates are considerably smaller would experience lesser polishing rates which would result in insufficient amount of biocides being delivered which would again result in premature fouling. In order to study and estimate the polishing rates of Anti Fouling paint we have designed, fabricated a rotating drum test facility .Wall shear stress are to be calculated by CFD methods.

1. INTRODUCTION

Prevention of fouling on ship hulls has long been a priority for ship owners and operators because of the negative impact fouling have on the economy and performance of a vessel. Hull fouling reduces vessel speed, increases fuel costs and imposes time and costs for hull maintenance [1] .Biocide based antifouling paints are designed to continuously leach biocides at the paint/seawater interface to control fouling and are also the most economical method to do so [2] . Recent advances in antifouling paint technology have led to the development in highly effective antifouling paints which generally result in foul free hulls for periods ranging from three to five years. However, even the best maintained vessels are fouled to the extent of at least five percent of the total surface area, particularly towards the end of their respective dry-dock cycle. This fouled area, although a small fraction of the entire vessel surface and does not affect the general performance of the vessel, is the primary vector for transmigration of invasive species, which is a serious environmental issue and immediate measures to address this issue are imperative in order to prevent major and possibly irreversible damage to the marine ecosystem [3]. It is therefore necessary to first identify areas on the hull that are prone to paint failure and subsequently to alleviate this issue by applying suitable paints/paint schemes at these pre-identified locations.

2. ANTIFOULING PAINTING SCHEMES

In order to minimize fouling, virtually all vessels are coated with antifouling (AF) paints on the submerged area on the vessels hull. Many different types AF coatings are available, the most prominent among them are self-polishing copolymers and foul-release coatings. The commercial shipping industry primarily uses self- polishing copolymer paints (SPC) paints as anti- fouling coatings. These paints were introduced in the mid-1970s and in this class of paints, the biocide is chemically bonded to a copolymer [4-5] .The leaching rate of the biocide is very controlled due to the fact that biocide is released when sea water reacts with the surface layer of the paint. The SPC paint allows the application of thicker coatings with the biocide chemically bonded throughout the coating. This results in the slow and uniform release of biocides to the surface. The biocide release for these coatings is only a few nanometres deep and the spent layer is slowly eroded away and a new active layer develops.The popularity of these AF coatings was primarily due to a controlled chemical dissolution of the paint film capable of long dry-dock intervals, typically between five to seven years; predictable polishing, enabling tailor- made specifications by vessel/operation; thin leached layers, making it easy to clean and recoat; good weather ability, quick drying, and extremely good value for money.
The extent of polishing action in these types of coatings

depends primarily on the hydrodynamic forces at the paint-seawater interface. The higher the hydrodynamic forces, the higher are the polishing rates. Conversely, lower hydrodynamic forces at the paint-seawater interface imply lower polishing rates. This implies that at locations where the hydrodynamic forces are high, the polishing rates would be high and this would result in premature depletion of the antifouling coating. Conversely, when the hydrodynamic forces are low, low polishing action would result and this would lead to insufficient biocide release at the paint-water interface. In both the preceding scenario's, the paint film does not offer antifouling protection and there is a tendency for fouling to take place at these locations.

The practice of application of antifouling coating is that a uniform coating of a specified pre-calculated thickness is applied on the underwater hull of the vessel taking in to account the average speed of the vessel, its trading routes, length of stay in port, etc. However, they do not account for the fact that there are non-uniform polishing rates along the vessels hull in certain niche areas in the proximity of bow thrusters, sea chest, stern tube, rudder, shoulder, water line, etc that are prone to premature fouling . Although these areas are less than five percent of the total underwater area of the vessel and therefore have negligible effect as far as the operational parameters of the vessel are concerned, they are the primary vector for the transmigration of invasive species.

Invasive species also called as alien species or non-native species are introduced in the marine environment by human activities threatens biological diversity and ecological integrity worldwide. They can cause irreversible reduction in biodiversity by preying on or by competing, or causing or carrying diseases, or altering habitats of native species. They can also cause serious economic and ecological damage. Some can damage shorelines, man-made marine structures, equipment and vessels. The UNEP has declared that the invasive species are the most serious environmental issue only next to habitat loss. Many studies show that hull fouling the primary vector for invasive species. [6-10]. Even the best maintained vessels are fouled to the extent of at least three percent of the hull area and are more than sufficient to cause the transmigration of alien species [9].

As non-uniform wall stresses are present on vessels hull, there is a close relation between paint film removal (or polishing rates) and wall shear stresses. Once polishing rates are known as a function of wall shear stresses, the AF film thickness could then be computed for the corresponding shear stress. Analysis of photographs and the results of the simulation also indicate that on the average, about 10 – 15 % of the vessel's underwater area is exposed to high shear stress and thereby prone to fouling. Although this level of fouling has limited effect on the routine operation of the vessel (such as increase in fuel consumption or reduced speed), it drastically increases the probability of propagule pressure for the transmigration of invasive species as fouling could build up to 150 kgs per square meter for an unprotected hull. For example for a large tanker whose under water surface area is in the range of 20,000 m^2,and even if one percent of the area is depleted of AF coating, it could lead up to approximately three tons of fouling material. However, if the hull areas are properly identified for high shear stresses, AF paint film thickness could be appropriately applied and thereby considerably reducing the risk of invasive species establishing themselves in an alien environment.

Figure1&2 are photographs of a tanker initially coated with a self-polishing antifouling coating that has just arrived for a mandatory dry-dock after a gap of five years, showing areas on the hull that have been depleted of antifouling paint. Figure 3 depicts the computed wall shear stresses of a similar tanker using commercially available CFD software (FLUENT). Comparison of fouling data from a large number of photographs and the computed wall stresses indicates that regions where the latter are high are highly prone to fouling which indicates that uneven polishing rates take place around the vessels hull which strongly depends on the vessel profile, speed and draft. This gives an important clue that AF painting schemes must take in to account the non-uniform hydrodynamic forces that exist along the vessel's hull which would be best served by obtaining a correlation between polishing rates and shear stresses in a laboratory set up. Once polishing rates are known, the AF film thickness could then be computed for the corresponding wall shear stress. In order to find a correlation between the hydrodynamic forces and polishing rates, a “Drum Test Apparatus” has been fabricated.

3. DRUM TEST APPARATUS

The sketch of the drum test apparatus is shown in figure 4. It essentially consists of tow concentric cylinders. The inner cylinder which is 250 mm in diameter rotates about a vertical shaft that is connected to a variable speed motor. The outer cylinder is 600 mm in diameter and is stationary. The gap within the inner and outer cylinders is filled with sea water. Plates coated with various antifouling paints are affixed on the inner cylinder and the inner cylinder is rotated at a known fixed speed for a predetermined time. Figure 5 shows a photograph of the drum test apparatus while in figure 6, shows the central rotor with one of the attached plate that is coated with the antifouling paint that is to be tested. A total of six such plates can be attached to the central drum. The drum is then rotated at a fixed RPM. The residual thickness of the antifouling coating is then measured at regular intervals. This procedure is repeated for various speeds.

Typical results of paint film depletion versus time for a fixed speed of 590 RPM are shown in figure 6. As can be seen in this figure, that after an initial sharp decrease, there is a further slow decline in paint film thickness. The residual film thicknesses are be predicted for a length of time that corresponds to a typical dry-dock cycle of a commercial vessel which is approximately five years. The wall shear stress on the inner cylinder (and therefore the plate coated with antifouling paint) at various speeds is to be computed using computational fluid dynamics techniques (CFD) to obtain a relation between wall shear stress and paint film removal. The relation between wall shear stress and paint film removal depends on a number of parameters that includes type of coating, its formulation, method of application, backbone polymer, additives etc. Thus by establishing the correlation between wall shear stresses and antifouling paint film depletion for a particular paint, suitable painting schemes could be designed at regions of excessively high shear stresses and other niche areas to minimize the risk of antifouling paint failure and thereby increasing the risk of transmigration of invasive species.

The wall shear stress on the inner cylinder (and therefore the plate coated with antifouling paint) at various speeds is computed using computational fluid dynamics techniques (CFD) to obtain a relation between wall shear stress and paint film removal. The relation between wall shear stress and paint film removal depends on a number of parameters that includes type of coating, its formulation, method of application, backbone polymer, additives etc. [11]. Thus by establishing the correlation between wall shear stresses and antifouling paint film depletion, suitable painting schemes could be designed at regions of excessively high shear stresses and other niche areas to minimize the risk of antifouling paint failure and thereby increasing the risk of transmigration of invasive species.

4. PAINTING SCHEMES

As non-uniform wall stresses are present on vessels hull, there is a close relation between paint film removal (or polishing rates) and wall shear stresses. Once polishing rates are known as a function of wall shear stresses, the AF film thickness could then be computed for the corresponding shear stress. Analysis of photographs and the results of the simulation also indicate that on the average, about 10 – 15 % of the vessel's underwater area is exposed to high shear stress and thereby prone to fouling. Although this level of fouling has limited effect on the routine operation of the vessel (such as increase in fuel consumption or reduced speed), it drastically increases the probability of propagule pressure for the transmigration of invasive species as fouling could build up to 150 kgs per square meter for an unprotected hull. For example for a large tanker whose under water surface area is in the range of 20,000 m^2, and even if one percent of the area is depleted of AF coating, it could lead up to approximately three tons of fouling material. However, if the hull areas are properly identified for high shear stresses, AF paint film thickness could be appropriately applied and thereby considerably reducing the risk of invasive species establishing themselves in an alien environment.

5. CONCLUSION

Flow around ship hulls and estimation of stresses due to various loads on ship structures have been the subject of research at many institutions in India, but no effort to correlate this to paint erosion has been made. With the fabrication of drum test facility, study could be done to measure the self polishing rate in the laboratory conditions. This kind of tests also help in establishing the correlation between wall shear stresses and antifouling paint film depletion resulting in design of suitable painting at regions of excessively high shear stresses and minimize the risk of antifouling paint failure by increasing the risk of transmigration of invasive species.

Figure 1: Photographs of a vessel taken on arrival at dry-dock indicating areas on antifouling paint deterioration

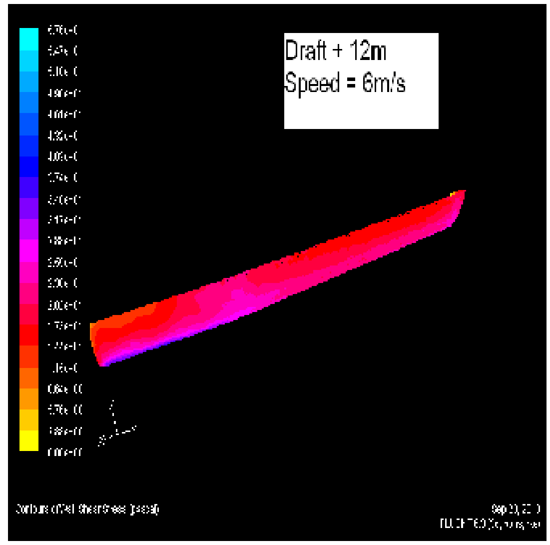

Figure3: Wall shear stresses of a tanker at a draft of 12m and speed of 6m/s

Figure 2: Photographs of a vessel taken on arrival at dry-dock indicating areas on antifouling paint deterioration

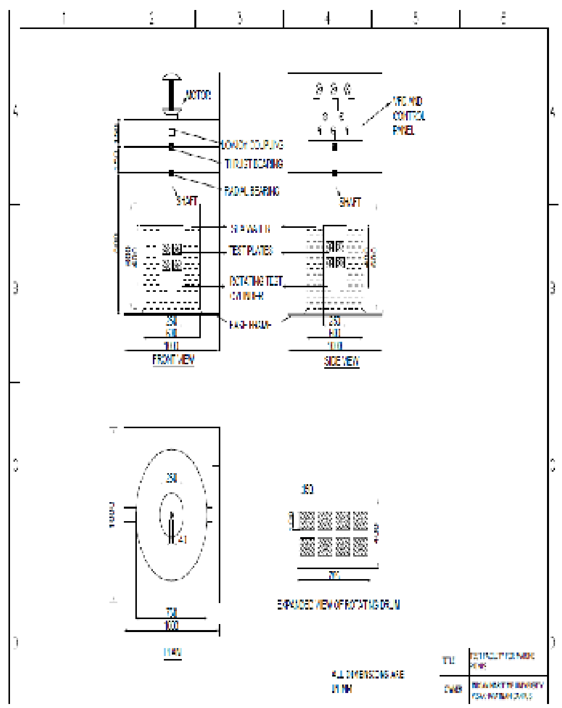

Figure 4: Sketch of Drum-test Apparatus

Figure 5: View of Drum Test Apparatus

Figure 6: Central rotor of the drum test apparatus with the attached test plate

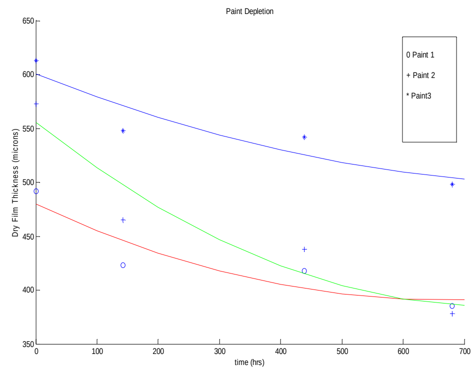

Figure 7: Paint film depletion as a function of time at a 590 RPM

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