EXPERIMENTAL INVESTIGATION OF FOUL RELEASE COATING ON FLANGE COUPLING

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Abstract— *Silicone coatings are largely used in marine to release foul and corrosion presents processes; This work on quantitative way represents improvement, in terms of wear and corrosion resistance, which is obtained by depositing silicone coating on foundation material. Chemical vapour deposition systems are very versatile, allowing to use a variety of substrates (like steel, zinc, copper, aluminium and plastic), and they provide bright and long-lasting appearance to the silicone components, so that they have great use in auto-industry. silicone coating has been a valuable surface treatment for parts in high wear environments due to its high hardness, reactivity of silicone and low coefficient of friction. Its use has grown considerably in the aerospace and automotive industry for several decades. Corrosion testing is done on coupling with contact geometry at sliding contact of silicone hard coated sample with coupling.*

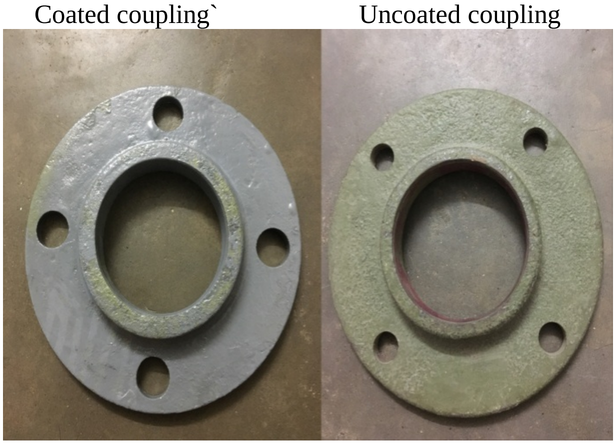
1. INTRODUCTION

The very common meaning of corrosion to the great majority of the people is rust. The word “Rust” is more specifically reserved for iron, whereas corrosion is commonly defined as the deterioration of a substance (usually a metal) or its properties because of a reaction with its environment. The terms corrosion and rust are almost synonymous since iron and its alloys are the most commonly used material by mankind and corrosion of iron must have been the one of the first serious corrosion problems affected humans. Corrosion is a naturally occurring phenomenon and just like all natural processes, corrosion of materials is spontaneous and it drives the materials to its lowest possible energy states. Most of the metals and alloys have a natural tendency to combine with water and oxygen present in its environment and return to its most stable state. Iron and steel quite often interact with their environment return to their native and stable oxide states. Similar to any natural disasters such as earthquakes or severe 2 weather changes, corrosion results in dangerous and expensive damage to everything from automobiles, home appliances, drinking water systems, gas and petroleum pipelines, bridges and buildings

2. CHEMICAL VAPOUR DEPOSITION (CVD) IMAGE

IMAGE OF COUPLING

Coated coupling` Uncoated coupling



3. LITERATURE SURVEY

Matsushita tested a foul release system on both boat hulls and a propeller from the training ship ‘Yuge-Maru’. These tests showed that a foul release system can protect propellers from fouling and electrochemical corrosion, with only a small amount of fouling near the hub of the propeller and a 30% reduction in the consumption rate of the ships sacrificial anodes. Matsushita also found problems with the robustness of the coatings used past a surface time of one year. Since 1993 more development of these coatings generally has taken place, and in particular research into improving the adhesive qualities of these coatings to marine propellers12.

4. METALS AND FLOATING MATERIAL USED IN FABRICATION

A. ISILICONE POWDER

Silicon is a chemical element, one of the 97 natural building blocks from which our minerals are formed. A chemical element is a substance that can't be subdivided into simple substances without splitting atoms. Silicon is the second most abundant element in the earth's crust, making up about 27% of the average rock. Silicon links up with oxygen (which makes up 55% of the earth's crust) to form the most common suite of minerals, called the silicates. Quartz, feldspars, olivine, micas, thomsonite, jadeite, and prehnite are all silicates. There is so much oxygen around that pure native silicon is almost never found naturally.

UNCOATED COUPLING

In piping industries coupling is one of the most important component and it is available in different materials . A **couplings** (used in piping or plumbing) is a very short length of pipe or tube, with a socket at one or both ends that allows two pipes or tubes to be joined, welded (steel, brazed or soldered (copper, brass etc.) together

CVD(CHEMICAL VAPOUR DEPOSITION)

Chemical vapor deposition (CVD) is a widely used materials-processing technology. The majority of its applications involve applying solid thin-film coatings to surfaces, but it is also used to produce high-purity bulk materials and powders, as well as fabricating composite materials via infiltration techniques. It has been used to deposit a very wide range of materials

5. LOW SURFACE ENERGY, NON-STICK, FOULING RELEASE TECHNOLOGY

Non-stick Fouling Release coatings are based on a technology which initially prevents the adhesion of fouling organisms by providing a low-friction, ultra-smooth surface on which organisms have great difficulties in adhering. Most, if not all, sessile species rely on attaching mechanism involving some kind of glue, with the adhesion strength highly dependent on the ability of this glue to spread over the surface and bind physico chemically to it. For a given amount of glue (e.g. the case of Ulva spores), the higher the surface tension of the substrate the better the glue can wet the surface and the higher numbering of “anchoring points “translating into better adhesion of the organism (Callow et al., 2005). Some organisms, such as the blue mussel (Callowet al., 2005), seem to compensate the latter by secreting larger amounts of glue when in contact to low surface energy surfaces. The first trials for non-stick surfaces were based on polytetraflourethylene (PTFE; e.g. TEFLON®) which is known for a very low surface tension (16 - 18 mN/m; Figure 1).However a stronger bio adhesion was seen on PTFE surfaces. One explanation is that the micro porosity of the PTFE surface allows the organisms a mechanical anchoring Polydimethylsiloxane binders usually have a surface tension of 23-25 mN/m combined with a great smoothness which leads to the minimum bio adhesion. There is, however, one more parameter which comes from fracture mechanic studies (Towns in and Anderson, 2009). Data from practica measurements, where a disc is being glued onto a substrate, shows that the adhesion, P, is proportional with the square root of the product of the Elasticity modulus, E, and the critical surface tension, γc of the polymer (the glue)and inversely proportional with the dry film thickness of the polymer (glue) film, t, see equation 1 (Brady and Singer,2000).Compared to Figure 1, Figure 2 shows the relative bio adhesion as a function of $(E\cdot\gamma c)^{1/2}$ and shows that the elasticity modulus is equally important as the surface tension when it comes to fouling release performance (see data in Table 3). Summarizing, silicone elastomers combine all known factors associated to high resistance to surface colonization, namely surface energy or surface tension, smoothness and elasticity.

6. TRADITIONAL FOULING RELEASE COATINGS

The first commercial breakthrough of silicone coatings into the market took place thanks to “pure silicone” formulations (Anderson et al., 2003 and Towns in and Anderson, 2009). The PDMS matrix was reinforced through the addition of low molecular weight silicone polymers(‘oils’) to enhance foul-release properties of PDMS polymers. This is thought to be mainly due to the surface tension and hydro phobicity changes deriving from the self stratifying of these oils to the surface due to immiscibility with the cured PDMS. These coatings provided self cleanability when sailing at a certain speed at a certainactivity, typically above 15kn during minimum 75% of the time. Traditional fouling release coatings showed very good initial performance against shell fouling and macro algae, whiles lime fouling could be rapidly observed after a few months sailing (Townsin and Anderson, 2009). Multiple studies demonstrate that the ideal substrate for one fouling type may not be the same for another (Finlay et al. 2002). As an example, the green algae Ulva’s zoospore was shown to have a higher affinity to hydro phobic substrates, but with very weak adhesion to such, while diatoms showed strong adhesion to hydrophobic surfaces. The same can actually happen between different species of the same family. Clare and Aldred (2009) hypothesize that the barnacle Balanus Improvisus could prefer more hydrophilic surfaces, just opposite as its relative the Balanus Amphitrite. As mentioned before, it was soon realized that slime didmanage to stick tenaciously to the early hydrophobic PDMSbasedfouling release coatings, “masking” the non-stick surface therefore facilitating subsequent colonization by superior organisms such as macro algae and shell fouling. These may or may not be released upon sailing depending on mainly 1) vessel speed, 2) length of idle periods, 3)sailing time at high speed, 4) adhesion strength and 5) foul release capabilities of the coating. The end result of the above is that the now broadly accepted fuel saving properties of fouling release coatings(e.g. Schultz, 2004) start to decrease, eventually to a lower level than top-quality self-polishing copolymer paints, largely fouling free during their service life. It seems clear that the latest developments in the field of fouling release are related to the optimization of these nonstick properties through the addition of polymeric additives. This is demonstrated, for example, in patent WO02074870dealing with the development of PDMS matrixes modified with low molecular weight fluorinated polymers and which has led to one of the most recent commercial launches.

7. HYDROGEL SILICONE

Hydrogels consist of a network of polymer chains that are water-insoluble but highly absorbent so that they can contain over 99% water. Hydrogels also possess a degree of flexibility very similar to natural tissue, due to their significant water content. The use of hydrogels is common in medical applications (Henriqueset al. 2005) due to their well-known capability to minimize protein and bacterial combined with some sort of antibiotic or biocidal agent for this purpose (Wirtanen et al. 1998, Ahearn et al. 2000). Several studies point at the potential use of hydrogels for fouling control purposes. As an example, Rasmussen and Østgaard(2001) tested various gels against marine bacterial adhesion finding best results with a modified polyvinyl alcoholgel. Similarly, Ekblad et al. (2008) report about the testing of a protein-resistant poly(ethylene glycol) (PEG) based hydrogel coating for antifouling applications. Despite the promising results, one could argue that even if a practical coating based on this approach was developed, there could be doubts about the long term stability, mechanical properties and performance of the hydrogel. Gateholm’s et al. (1995)approach was slightly different, since their idea was basedon immobilizing viable marine bacteria secreting compounds with antifouling properties. His et al. (1999), chose to load the hydrogel with benzalkonium chloride. Potentially, enzymes could be alsoimmobilized in a similar manner way (Olsen et al., 2009)even though how to get the hydrogel from the can to thehull keeping activity might prove cumbersome.Hempel A/Shas taken the traditional Fouling Release coatings one stepfurther by making use of the hydrogel technology. Recent findings have shown that a PDMS coating with a hydrogelintroduced at the water interface of the coating provides animproved resistance towards algae and slime fouling,whilethe intrinsic properties of pure PDMS, such as releasemechanisms and drag reduction, remain. Due to acertain,controlled immiscibility, the hydrogel polymers have atendency to slowly phase-separate to the PDMS-water hydrated and impart a certain hydrophilic character to the otherwise hydrophobic matrix and additives. The PDMS matrix now also serves as reservoir for hydrogel precursors which self-regenerate the hydrogel surface layer in case

8. EXPERIMENTAL RESULTS

Contact angle measurements

Contact angles with distilled water were measured on different compositions. Table 4 shows the contact angles ofa traditional fouling release coating and the Hydrogel Silicone. Substrates prepared by drawdown method. Results show, that the Hydrogel Silicone has a lower contact angle with water, especially the receding contact angle is less than 50% the value of a non-hydrogel commercial fouling release coating. The lower receding contact angle measured on the Hydrogel Silicone indicates that the water has a larger affinity towards this surface than towards a traditional FR surface. It is believed that this is due to the presence of highly hydrated hydrogel layers combined with hydrophobic PDMS surface functionalities.

High-throughput screening results

Webster et al. (2009) describe the use of high throughputscreening methods as a useful tool to design and optimisefouling release coatings based on non-toxic mechanisms. InFigure 3 the experimental workflow is described. Candidatecoatings are first pre-Ieached to evaluate their potentialtoxicity. Subsequently, the coatings are exposed to foulingorganisms, namely marine bacteria (Cellulophagalytica),marine diatom (Naviculaincerta) and barnacles The results are shown in Figure 4. As references, 2 commercial fouling release coatings, one commercial silicone elastomer and one polyurethane coating (negative reference) are used. Compared to these references, the Hydrogel Silicone coating experienced clearly lower settlement of C. lyticaand N. incerta. This can be seen in the markedly lower Crystal Violet Absorbance and Fluorescence Intensity values reported in Figure 4, which are directly related to presence of these organisms on the coating surface (a) and b) left plots. Inaddition to lower C. lytica settlement, the HydrogelSilicone coating featured virtually 100% removal of those cells when the coating was exposed to a 10 psi water jet.For the case of N. incerta, the percentage removed after10 psi washing was approximately 20% lower than oneofthe commercial references, but the settlement of thisdiatom on the Hydrogel Silicone was approximately 45%lower compared to the mentioned commercial coating.Finally, plots c) show how the Hydrogel Silicone coatingwas effective in inhibiting the settlement of B.Amphitrite barnacles which, furthermore, were veryweakly attached to the surface (low force was needed todetach them).

Exposure tests

The improved resistance to fouling of this innovative combination of a hydrogel surface in an elastic PDMS matrix has been evaluated over time in several worldwidelocations (see Sanchez and Yebra, 2009). Panelscoatedwith experimental paint compositions have been placedin near vicinity of each other and evaluated at regularintervals. The various locationscover a broad spectrum offouling scenarios, which means that paints are exposed toboth soft (algae- and slime) and hard (e.g. barnacles, tubeworms) fouling species. The first overwhelming results were obtained back in 2005 where the HydrogelSilicone was tested alongside similar compositions withhydrophobic oils (first and second generation commercialcoatings). Figure 5 shows the results after almost 4 yearsof static exposure in the Mediterranean Sea.

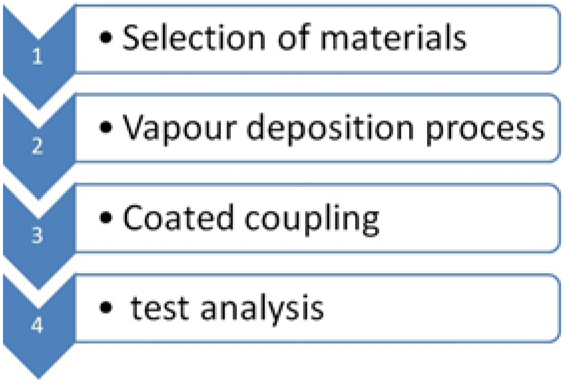
9. Knoop Hardness Test

S.No	Materials	Thickness	Value
1	Non coated flange coupling	-	238
2	Coated flange coupling	(55)µm	342

Corrosion Test

Material	Liquids	Initial Weight (Gms)	Final Weight (Gms)	Corrosion Rate/ Mm/ Week
Non coated flange coupling	Sea water+ Sodium chloride	1250	1239	11
Coated flange coupling	Sea water + sodium chloride	1250	1244	6

10. DESIGN PROCESS



11. WORKING OF FOUL RELEASE COATING ON COUPLING

Coating is a covering that can be applied to the surface of an object, normally called as substrate. The purpose of application of coating is the value enhancement of the substrate by improving its appearance, corrosion resistant property, wear resistance, etc.

When compared the non coated coupling with the silicone coated coupling, the difference in component life will changes the rate of services. The improved component life and component wear and corrosion services are last longer and hence reduce the rate of service of the coupling.

12. CONCLUSIONS

Surface modification of commercial PDMS matrixes with self-stratifying hydrogel-promoting polymers markedly improves theresistance towards the settlement of fouling on traditional Fouling Release coatings, particularly slime and algae fouling. TheHydrogel Silicone technology has also shown superior performance compared to other commercial ternatives by reinforcing the fouling release properties of the PDMS films. Static, dynamic, static/dynamic and real life tests have proved that this new technology is able to keep a fouling free surface even at conditions of low speed and low activity. On a large ontainer vessel, the latter can potentially translate into annual savings of up to 7775 tonnes of fuel a, equivalent to 24550 tonnes of CO2, 490 tonnes of SOx and 780 tonnes of NOx (FORCE Technology, 2008).

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