appears to be largely due to corrosion products forming within the scribe. EDX analysis of the scribe immediately after damage exhibited a strong iron (Fe) signal resulting from the exposed substrate and corrosion products could be observed in the scribe by SEM.

In the case of the self-healing coating system, the initial width and depth at the areas evaluated were 124 and 144 µm, respectively. No formation of corrosion products within the scribe was evident after one day of salt fog exposure. After three days of salt fog exposure, some iron oxide staining of the coating along the scribe line was observed. The scribe width was observed to decrease by 54% to 57 µm (2.3 mils), while the depth was observed to decrease by 98% to 3 µm (0.12 mils) (Figure 3[b]).

It should be noted that the changes in the scribe dimensions are significantly greater relative to the control (compare Figures 3[a] to [b]). Furthermore, although EDX analysis of the scribe immediately after damage exhibited a strong Fe signal resulting from the exposed substrate, after three days of salt fog exposure, SEM analysis showed a distinct morphology change within the scribe that was inconsistent with the morphology characterized as corrosion in the control. EDX and elemental mapping analysis showed no significant deposition or formation of corrosion products within the scribe. Instead, a uniform distribution of salt deposit was observed on one edge of the scribe, likely trapped by polymerized healing agent, preventing it from reaching the substrate.

Technology Applications and Value

There is a substantial benefit to extending the life of coatings for offshore and onshore applications. In a recent report,[10] NACE International assessed the global annual cost of corrosion to be $2.5 trillion, which is equivalent to 3.4% of the global GDP (2013). The study further estimated that savings of up to 35% could be realized on the actual costs of corrosion-related maintenance (not including lost revenue due to downtime) over the life of an asset by simply implementing available corrosion control methods. NACE has also estimated the total cost of marine corrosion worldwide to be between $50 to 80 billion every year. A separate analysis based on data published in a previously referenced NACE article[11] has shown that increasing the paint service life by as little as 25% (e.g., from 12 to 15 years) could lead to a cost savings of 32.7%.[12] Note that the preliminary data reported here (Figure 2) suggests the potential of a far greater increase in service life as the performance of the self-healing coating after 1,000 h of salt fog exposure exceeds that of the control at 250 h. In addition to offshore applications, onshore assets exposed to harsh corrosive environments can also benefit from extending coating life. Although the cost to send maintenance crews to onshore sites is less drastic than offshore, there are still cost savings to be had with the reduction of coating upkeep necessitated by corrosion.

Technology Validation and Conclusions

This investigation has proven that after inflicting scribe damage to the coatings, the self-healing system incorporated into them releases a healing agent that forms a barrier at the site of damage, resulting in depth reduction of the scribe that significantly surpasses the damage response of the control system (compare Figures 3[a] and [b]). Although the self-healing process occurred within the first three days of salt fog exposure, it resulted in a maintenance of adhesion of the coating to the substrate after damage and germane protection of the substrate that led to a 65% decrease in the amount of corrosion creep observed after 1,000 h of ASTM B117 exposure (Figure 2[b]).

The focus of ongoing studies is to assess the robustness of this coating system by conducting a range of cyclic aging resistance tests specified by the oil and gas industry for offshore topsides qualification.

Overall, the results discussed in this article suggest that self-healing additives can be used to improve the performance of a coating system that is subject to mechanical damage, micro-cracking, and subsequent corrosion of the substrate while in service. While future work will further develop our understanding of the limitations and functionality afforded by the incorporation of self-healing additives into offshore protective coatings, what we have accomplished so far suggests that coatings exhibiting this kind of damage repair can significantly reduce maintenance costs by optimizing service life and reducing asset downtime.

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