Novel Coatings for Improved Marine Growth Management of Subsea Structures

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Abstract

Marine growth is a combination of biological species that accumulate on surfaces and structures in subsea environments. This may have several negative implications including structural damage, accelerated corrosion and increased hydrodynamic drag. In this project, the use of certain coatings is investigated as a method of preventing or removing marine growth on subsea equipment and structures. From field deployments lasting approximately 3 months at the Royal Freshwater Bay Yacht Club (RFBYC) and Nedlands Yacht Club (NYC) in the Swan River, it has been established that some tested coatings are able to outperform non-coated control segments in terms of lower marine growth accumulation at the field sites considered. However, no coating was able to completely repel 100% of marine growth.

1. Introduction

Recent developments have been made in the oil & gas industry towards the greater utilisation of subsea equipment and processing. Marine growth is the accumulation of biological species including plants, animals and bacteria on subsea surfaces and structures. The detrimental effects of marine growth in terms of structural and corrosion biofouling and its negative hydrodynamic implications are well understood in industry, with it representing a significant obstacle in the progression of subsea processing and technology. The diversity and rate of marine growth accumulation varies significantly, depending on several environmental factors including location, water depth, temperature, pH, salinity and more.

In this project, the use of various novel coatings are investigated as a method of preventing or removing marine growth on subsea equipment. Seven different coatings of similar properties have been trialled in this project, with scope for further testing and refinement in future. Field tests have been conducted involving multiple deployments of test rigs comprised of several pipes supported by wooden frames. Field tests were undertaken at two sites in the Swan River – the Nedlands Yacht Club (NYC) and Royal Freshwater Bay Yacht Club (RFBYC). This test setup allows multiple different parameters to be trialled including coating type, thickness and application method, with control segments also included for comparison of results. Relating any marine growth observations in the Swan River to the intended offshore application sites may yield significant contrasts in marine growth diversity and accumulation behaviour. However, the selected deployment sites offer the benefit of close proximity to UWA and are deemed satisfactory for a preliminary study. Each deployment lasts for several weeks or months, with periodic checks (including underwater photography) to observe marine growth accumulation progress. Further laboratory testing has also been undertaken in the UWA Shenton Park field station and Crawley campus facilities. This CEED project has been completed over the course of a year, with the support of industrial partner Aurora Offshore Engineering as well as affiliation with Woodside Riverlab – a collaboration with the University of Western Australia.

2. Methodology

Field tests were implemented to investigate the effect of coatings on marine growth accumulation. Practical setups were designed and constructed to fulfil the criteria of being suitable to be deployed safely and left unattended for weeks at a time in a river (or marine) environment, securely positioned on the riverbed without being buried. It was also desirable to have a sufficient surface area for marine growth to interact with, and be easily replicable over several trials. The shape of surface features is important in microbiological binding behaviours (Edwards 2001). Pipe based designs were chosen over alternatives such as plates due to the lower likelihood of being buried as well as being a superior representation of subsea piping and tubular members characteristically used in subsea equipment.

Early deployments in the project consisted of lengths of single PVC pipes weighted with bricks coated with the different types of coatings. In the final deployment for the project, more emphasis was placed on obtaining a reliable result through replication. Eight test rigs were constructed as wooden rectangular frames (90cm x 55cm) with four 30cm legs and four attached bricks. Each test rig had four horizontal 500mm long by 75mm diameter PVC pipes spaced evenly apart along the width of the frame. Each pipe (thirty-two in total) had four 125mm segments spread evenly, three coatings and one control segment. Segments were randomly placed across the set of eight test rigs. A photo of the test rigs from the final deployment is displayed below in Figure 1.

Figure 1 Eight test rigs setup for final deployment

These rigs were split evenly between the two deployment locations in the Swan River, attached to jetties at the Nedlands Yacht Club (2.1m depth) and the Royal Freshwater Bay Yacht Club (3m depth). Each test rig was also orientated in different directions; this in addition to the thirty-two separate pipes (with four segments each) at two locations was designed to increase the validity of results from a biological perspective through replication. The final set of eight test rigs was deployed on 05/02/2018 and retrieved just under three months later on 01/05/2018.

Each coating was observed after retrieval to develop a general understanding of whether the coatings could remain intact and impervious to marine conditions and biological degradation. Extensive photography documented the deployment and retrieval of test rigs, as well as underwater photos and videos captured with a GoPro camera during the deployment period. As well as this, analysing each coating and control segment on every pipe from all test rigs allowed for marine growth accumulation to be observed, compared and quantified.

In order to produce reliable evidence of any findings, results of marine growth accumulation were quantified both in percentage surface area coverage as well as mass before and after deployment. Surface area coverage is documented and calculated by first photographing each retrieved pipe methodically from four angles – the top, bottom and two sides of the pipe circumference. These images from four angles could then be digitally stitched together to produce a composite image of the full external surface of the pipe. From these composite images, the surface of each segment (four on each of the thirty-two pipes) can be isolated and added with corresponding segments to allow each type of coating and control segment to be analysed separately (e.g. all eight coating A segments from Nedlands Yacht Club analysed together). A reliable percentage cover estimation method (Meese & Tomich 1992) was used to evaluate surface area coverage by generating 100 randomly placed points across each segment surface and manually categorising them as either 'No marine growth', 'small/thin marine growth' or 'large/thick marine growth'. In general, all thin algae and blue-green cyanobacteria or similar appearing marine growth are classified as 'small/thin'. Other more complex distinguishable species are classified as 'large/thick'– it is expected that these species will have the most severe impact on subsea equipment and structures.

Supplementary experimentation in addition to field tests included the attachment of small plastic caps as samples in order to perform high resolution X-ray microtomography (micro-CT) analysis of marine growth using scanning equipment at the UWA School of Biological Sciences. This was completed to attempt to identify the attachment mechanisms of prominent marine growth species on coatings. A laser scanner (SICK Ranger D50 Tomography Scanner) was also used to analyse a marine growth covered pipe from four angles. 3D rendered laser models may assist with future hydrodynamic studies or CFD modelling of marine growth on subsea structures. Twelve of the most prominent biological species were photographed on the test rigs after retrieval and stored for examination and identification. These may be useful in characterising the types of marine growth encountered in the experiment and within the Swan River.

3. Results and Discussion

From visual observation, it was easily observed that some coatings had accumulated less marine growth than control segments. This was reinforced by the percentage cover estimation method (as previously explained), with the key results presented below in Table 1 and Figure 2.

Table 1 Marine growth accumulation by surface area coverage

Rig 3-6 (P1-P16) - Royal Freshwater Bay Yacht Club							
Coating	**None (Control)**	**A**	**B**	**C**	**D**	**E**	**F**
No marine growth	1%	8%	41%	21%	18%	35%	14%
Small/thin marine growth	44%	47%	51%	50%	46%	38%	42%
Large/thick marine growth	55%	45%	8%	29%	36%	27%	44%
Rig 7-10 (P17-P32) - Nedlands Yacht Club							
Coating	**None (Control)**	**A**	**B**	**C**	**D**	**E**	**F**
No marine growth	0%	16%	70%	7%	27%	34%	30%
Small/thin marine growth	57%	52%	26%	69%	54%	59%	52%
Large/thick marine growth	43%	32%	4%	24%	19%	7%	18%

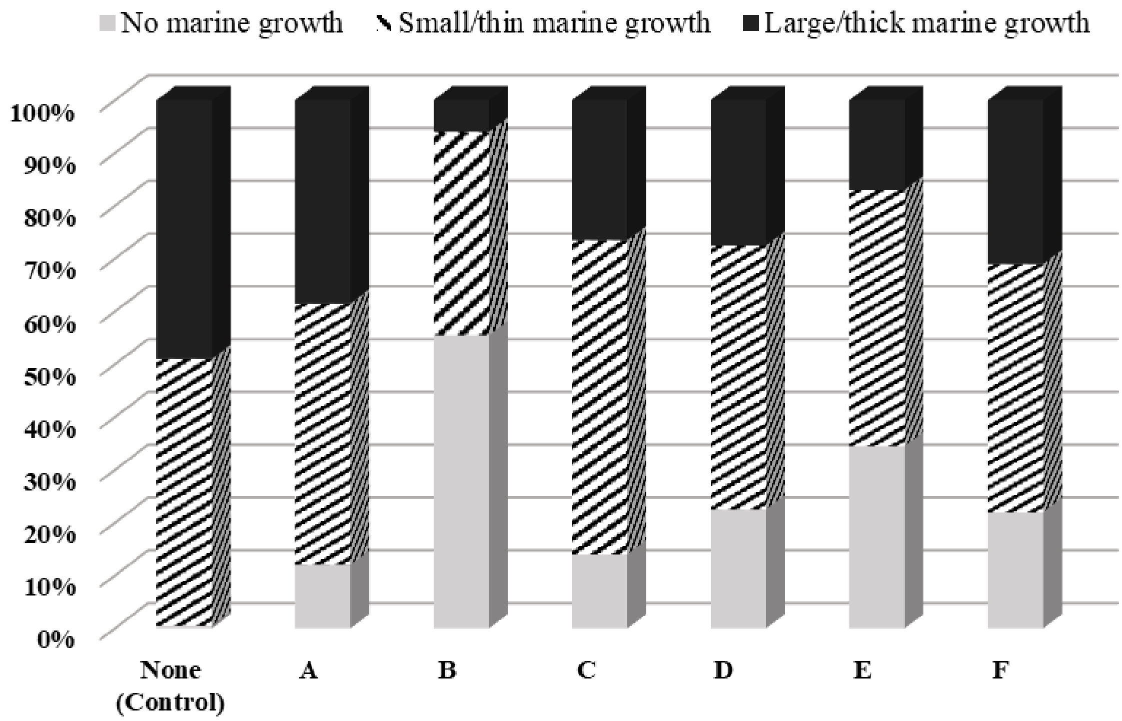

Figure 2 Chart of average marine growth coverage on pipe samples at both locations

All tested coatings outperformed control segments in terms of marine growth accumulation by surface area coverage. Coating B was found to be the overall best performing coating, with the lowest proportion of large/thick marine growth and lowest overall marine growth coverage in both locations. No coating segment was able to completely repel 100% of marine growth – the minimum marine growth coverage achieved was 30% with coating B at NYC. Mass before and after deployment were also measured, which supported the general indication of a greater presence of marine growth (especially large/thick marine growth) at the RFBYC field test location than at NYC. However this did not provide much meaningful evidence of varying coating effects on marine growth accumulation as each pipe contained four different segments (which could not be weighed individually). Statistical analysis including two-way ANOVA between site and coating supported the reliability of results. A p-value of 0.0154 was calculated for the coating data, indicating an existing relationship between coating choice and marine growth coverage at a 5% significance level. Overall, the results of this project represent a successful outcome, with further refinement potentially resulting in a commerically viable concept.

Another notable outcome from the project was the observation of the diversity and trends of marine growth accumulation in the local Swan River environment. Twelve of the most prominent species of marine growth were observed, photographed and stored as samples in order to provide more insight on the diversity of marine growth that test rigs have been exposed to in the Swan River. A wide range of marine growth species that colonised the deployed test pipes were identified and classified. This includes algae, blue-green cyanobacteria, *Ascidia sp.* (compound and solitary), *Balanus amphitrite* (barnacles), *Bryozoan sp.*, *Polychaete sp.* (bristle tube worms), *Porifera sp.* (sponges) and *Hydrozoan sp.*. In addition to these marine growth species, many larger species utilised the test rigs as habitation or shelter structures throughout the deployment period. This includes various fish, small crabs, seahorses, starfish, shrimp and other species. Species diversity and growth rates varied significantly seasonally throughout the year and also between yacht club sites, despite being only a few kilometres apart. As well as this, it was also observed that in general, marine growth accumulated in larger quantities on the bottom-sides of test rigs compared to the top-sides, with no obvious trends occuring horizontally planarly.

In the visual analysis of each coating segment it was observed that of the large/thick marine growth species found on the resistant coatings, the majority were of the plate-like *Byrozoan* species. This is significant as it suggests that particular coatings may be more effective at repelling some species more than others.

4. Conclusions and Future Work

From field testing, it has been established that despite not repelling 100% of marine growth, all coatings tested were able to outperform non-coated control segments in terms of lower marine growth accumulation as quantified by surface area coverage. Coating B is especially effective, resulting in approximately 6% coverage of large/thick marine growth compared to the 49% observed on the control segments. It can be concluded that there is clear potential for implementation in an industrial context. This represents a successful outcome for key project objectives.

In the short term, interest from industry experts will be consulted by presenting both the results of the full study with a logical plan for progressing and refining the concept further in order to gauge interest and compare results with currently available alternatives. More work including laboratory testing, field testing and modelling can also be completed to extend knowledge beyond this project. Additional field testing could potentially include trialling more varieties of similar coatings or parameter variations at more locations – preferably an ocean environment. Longer duration tests could also be conducted to observe or predict the durability of coatings across several months or even years.

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