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Hybrid-Biocomposite Material for Corrosion Prevention in Pipeline: a review

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One of the most challenging issues in the oil and gas industry is corrosion assessment and management in subsea structures or equipment. At present, almost all steel pipelines are sensitive to corrosion in harsh working environments, particularly in salty water and sulphur ingress media. Nowadays, the most commonly practiced solution for a damaged steel pipe is to entirely remove the pipe, to remove only a localized damaged section and then replace it with a new one, or to cover it with a steel patch through welding, respectively. Numerous literatures have shown that fiber-reinforced polymer-based composites can be effectively used for steel pipe repairs. Considerable research has also been carried out on the repair of corroded and gouged pipes incorporated with hybrid natural fiber-reinforced composite wraps. Currently, further research in the field should focus on enhanced use of the lesser and highly explored hybrid-biocomposite material for the development in corrosion prevention. A hybrid-biocomposite material from renewable resource based derivatives is cost-effective, abundantly available, biodegradable, and an environmentally benign alternative for corrosion prevention. The aim of this article is to provide a comprehensive review and to bridge the gap by developing a new hybrid-biocomposite with superhydrophobic surfaces.

Keywords: *marine corrosion, hybrid-biocomposite, superhydrophobic, oil and gas industry*

1. Introduction

Currently there is a wide range research interest of marine application and a pipeline structure has being developed. Bioompositein materials are now being considered and widely used as substitution for metals in many weights critical components in aircraft, aerospace, automotive, marine and other industries [1]. Environmental awareness and depletion of petroleum resource issuecs have triggered an enormous interest in utilising biocomposite as environmentally friendly and sustainable materials as an alternative materials to existing materials. Simultaneously the huge issue of corrosion try to be solved. Corrosion has become a gigantic problem for the nations. The impact of corrosion on the economy of a country can be manifested in billions of dollars spent annually to combat or control it. This corrosions issue attacks all industries including pipeline, bridge, ship, aircraft and power line. Corrosion generally occurs when mild steel comes in contact with oxygen and water. The presence of anodic and cathodic sites on steel surface and their reaction with water and oxygen transforms metal (iron) atom to ions, finally through a series of chemical reactions, hydrated ferric oxide forms (iron) rust. Another anaerobic (without oxygen) corrosion, micro-biological corrosion may occur if conditions favor the growth and multiplication of microbes, i.e., bacteria and fungi [2]. Renewable resource based derivatives are cost-effective, abundantly available, biodegradable, environmentally benign alternatives for corrosion resistant coatings, paints and inhibitors. With advancements in knowledge and updated instruments and techniques available, further research in the field may be focused on the enhanced use of the lesser and highly explored biomaterials for the development of anticorrosion agents in hand with “green” coating technology, for high performance high solids, hyper branched, water born, hybrid and composite coatings that may compete with their petro-based counterparts, both in the terms of cost and performance, in near future [3]. The renewable resources or natural biopolymers such as lignin, starch, cellulose, cashew nut shell liquid, rice husk, sucrose, caffeic acid, lactic acid, tannic acid, furan, proteins, glycerol, and vegetable oils contain hydroxyls, aldehydes, ketones, carboxyls, double bonds, ester, ether and other functional groups. These functional groups impart good adhesion and corrosion resistance performance to the substrate. Also, the performance can be further improved by chemical transformation, use of modifier (inorganic reinforcement, nano-

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Table 1 Environmental factors influence marine condition [4]

Factor	Effect on initial corrosion rate	Effect on steady state corrosion rate	Influenced by
Biological			
Bacterial	None	Reduces and probably controls rate	Temperature of seawater
Biomass/plant life			NaCl concentration
Animal life			Water velocity
			Suspended solids
			Pollutant type and level
			Percentage wetting
Chemical			
O_2	Directly proportional	None, if corrosion controlled by O_2 transfer rate	Seawater temperature
			NaCl
CO_2	Little effect	Little effect	
NaCl	Inversely proportional	Proportional	Unimportant in open oceans
pH	Little effect	Little effect	
Carbonate solubility	Little effect	Little effect	
Pollutants	Varies	Varies	Geographical location
Physical			
Temperature	Directly proportional	Proportional	Geographical location
Pressure			Not significant for shallow waters
Water velocity	Little effect	Little effect	Geographical location
Suspended solids		Little effect, if any	Geographical location
Percentage wetting	Proportional for tidal and splash zones	Proportional for tidal and splash zones	Location, weather patterns

material) and other methods.

2. Marine Corrosion

Depending on the exposure environment, marine corrosion mechanism may be divided into four categories

- Immersion;
- Splash/tidal zone;
- Atmospheric;
- Semi-enclosed space.

Seawater properties such as salinity, temperature, oxygen content, pH level and chemical composition can vary according to location and water depth [13]. Table 1 present the environmental factors that influence marine corrosion process [4].

2.1 Pipeline corrosion control

Efficient structures, design and materials selection is important for pipeline and all of this aspect are necessary for effectively reduce the cost of maintenance and longer the life span of the pipeline. Normally practice, there are four common methods used to control corrosion on pipelines are protective coatings and linings, cathodic protection, materials selection, and inhibitors. Coatings and linings are principal tools for defending against corrosion. They are often applied in conjunction with cathodic protection systems to provide the most cost-effective protection for pipelines. Cathodic protection (CP) is a technology that uses direct electrical current to counteract the normal external corrosion of a metal pipeline. CP is used where all or part of a pipeline is buried underground or submerged in water. On new pipelines, CP can help prevent corrosion from starting; on existing pipelines; CP can help stop existing corrosion from getting worse. While, materials selection refers to the selection and use of corrosion-resistant materials such as stainless steels, plastics, and special alloys to enhance the life span of a structure such as a pipeline. Corrosion inhibitors are substances that, when added to a particular environment decreases the rate of attack of that environment on a material such as metal or steel reinforced concrete. The use of corrosion inhibitors can extend the life of pipelines, prevent system shutdowns and failures, and avoid product contamination. Materials selection personnel must consider the desired life span of the structure as well as the environment in which the structure will exist.

3. Hybrid-Biocomposite

Since a past few decades, research interest has been shifting from traditional monolithic materials to natural fiber reinforced composite materials (NFRCM) or biocomposite materials in various applications. As reported by many researchers, recently due to a strong emphasis on environmental awareness worldwide, these biocomposite materials provide cheaper and abundant biological feed stocks with numerous advantages, such as cost effectiveness, low toxicity, inherent biodegradability and environment friendliness. Despite the advantages listed above, biocomposite materials suffer from some limitations such as poor moisture resistance especially absorption and low strength compared to synthetic fiber such as glass. To solve this, hybrid composites have proven to create a balance effect within the fiber incorporated in the composite material. The types of fiber can be natural fibers or man-made based synthetic fibers. Hybrid composites have proven to create a balance effect within the fiber incorporated in the composite material. The types of fiber can be natural fibers or man-made based synthetic fibers. The combination of renewable and synthetic materials appear to be the outstanding structural materials which come from natural fiber that is viable and abundant reinforcement for the replacement of expensive and non-renewable synthetic fiber [5]. Structural natural fiber composites, intended for indoor use, are usually made from low-cost adhesive which is not stable to moisture, while exterior-grade composites are made from a thermosetting resin that is higher in cost but stable to moisture [6]. Performance of structural natural fiber composite can be improved further by improving the properties of natural fiber especially agro-based fiber using chemical modification techniques [7] and [8].The study on hybridization of natural–natural fibers, natural-synthetic fibres and synthetic–synthetic fibers in a single matrix has been performed [9]. The use of lignocelluloses both agricultural and wood based [10,11] and [12] and wastes [13] as fillers and reinforcement in hybrid composite have shown promising effect on the improvement of mechanical properties of composite. As has been reported, the limitation of biocomposites is poor moisture resistance and to solve this issue regarding to corrosion control, the researcher is try to develop on hybrid-biocomposite materials with superhydrophobic surface which will be applied in pipeline and marine applications.

3.1 Superhydrophobic surfaces materials

Superhydrophobic surface is highly hydrophobic which is extremely difficult to wet. Superhydrophobic surfaces have evoked great interest in researcher for both purely academic pursuit and industrial applications [14]. In literature many articles have been published [15-17] In superhydrophobic surface, the surface morphology plays a crutial role effecting wettability. Roughing a surface cannot only enhance its hydrophocibility due to the increase in the solid-liquid interface (Wenzel, 1949) but also when air can be trapped on a rough surface between the surface and liquid droplet. Since air is an absolutely hydrophobic material with a contact angle of 180°, this air trapping will amplify surface hydrophobicity [19].

3.1.1 Marine applications of superhydrophobic materials

3.1.1.1 Anti-fouling applications

Biofouling of underwater structures and ships' hulls, in particular, increases operational and maintenance costs [20]. It can be reduced through underwater superhydrophobicity [21]. The reduction of the wetted surfaces minimized the probability of the biological organisms encounter a solid surface. The design of such surfaces should involve optimization between mechanical stability and minimal wetted area. The anti-fouling properties of superhydrophobic coatings have been investigated by Zhang *et al.*, [22]. Compared to normal substrates, which fouled within a day, almost no micro-organisms attached to the superhydrophobic surfaces in the first week after immersion.

3.1.1.2 Corrosion inhibition

The concept of preparing surfaces that repel water creates huge opportunities in area of corrosion inhibition for metals and alloy. Given their water repellency, superhydrophobic coatings form an important and successful method to slow down the breaking of the oxide layer of metals and thus prevent the metal surface underneath from futher corrosion. Several works have been carried out in order to study the corrosion resistance of metal coated

Table 2 Anti-corrosion using superhydrophobic coatings [14]

References	Substrate materials	Surface treatment	Test solution	Test method	Main results and issues
Shchukin et al. (2006)	Aluminum alloy	Layer-by-layer (LbL)	5% NaCl	Electrochemical impedance spectroscopy (EIS)	The nano reservoirs increase long-term corrosion protection of the substrate and provide effective inhibitor storage and its prolonged release on demand
Liu et al. (2007)	Copper	Myristic acid	Sea water	Polarization, EIS	The corrosion resistance of the material was improved remarkably
Yin et al. (2008)	Aluminum	Myristic acid	Sea water	Polarization, EIS	Film stability should be improved further
Barkhudarov et al. (2008)	Aluminum	Organosilica aerogel coating	5% NaCl	Neutron Reflectivity	The surface prevents infiltration of water into the
Zhang et al. (2008)	Aluminum	Hydroxide films	3.5% NaCl	Open-Circuit Potential Polarization	Good film adhesion and mechanical stability
Liu et al. (2007)	Zinc	PFTS	3% NaCl	Polarization	Higher corrosion resistance properties
Ishizaki et al. (2011)	Magnesium alloy	FAS	5% NaCl	Polarization, EIS	Superhydrophobic surface would be an effective strategy for improving the anticorrosion peer performance of various engineering materials
de Leon et al. (2012)	Steel	Polythiophene	3.5% NaCl	Polarization	Fabrication of the dual properties of superhydrophobic anticorrosion nanostructured conducting polymer coating follows a two-step coating procedure that is very simple and can be used to coat any metallic surface

with superhydrophobic surfaces.

3.1.1.3 Corrosion resistant coating

Superhydrophobic coatings on metallic substrates have shown, during the past two decades, remarkable corrosion resistance in highly aggressive media. Many techniques of preparing such surfaces, as well as various methods of characterization and analysis were apply, but the conclusion was the same and it states that superhydrophobic coatings prevent metallic substrates from corrosion. Table 2. summarized the previous research on anti-corrosion using superhydrophobic coatings.

4. Conclusions

Evaluating the environment in which a pipeline is or will be located is very important to corrosion control, no matter which method or combination of method is used. Pipeline corrosion control is an on-going, dynamic process. The keys to effective corrosion control of pipelines are materials selection, quality design and installation equipment, use of proper technologies with a non-destructive application, and on-going maintenance and monitoring by professionals.

References

1. P. K. Malick, *Fiber reinforced composites-materials*, 3rd ed., pp. 1-26, CRC Press and Taylor & Francis Group, Bota Racon, USA (2008).
2. F. Witte, J. Fischer, J. Nellesen, H. A. Crostack , V. Kaese, A. Pisch, F. Beckmann, and H. Windhagen, *Biomaterials,* 27, 1013 (2006).
3. H. Shih, *Corrosion Resistance*, pp. 449-473, In Tech (2012).

4. R. E. Melchers, *Proc. 7th International Conf. on Structural Safety and Reliability (ICOSSAŔ 98),* edited by N. Shiraishi, M. Shinozuka and, Y. K. Wen, vol. 3, p. 1143, Kyoto (1998).
5. A. Atiqah, M. A. Maleque, M. Jawaid, and M. Iqbal, *Compos. Part B-Eng.*, **56**, 68 (2014).
6. R. V. Da Silva, E. F. F. Aquino, L. P. S. Rodrigues, and A. R. F. Barros, *Matéria (Rio J.)*, **13**, 154 (2008).
7. M. M. Kabir, H. Wang, K. T. Lau, F. Cardona, *Compos. Part B-Eng.*, **43**, 2883 (2012).
8. M. Thiruchitrambalam, A. Alavudeen, A. Athijayamani, N, Venkateshwaran, and A. Elaya Peruma, *Mater. Phys. Mech,* **8**, 165 (2009).
9. S. Mishra, A. K. Mohanty, L. T. Drzal, M. Misra, S. Parija, S. K. Nayak, and S. S. Tripathy, *Compos. Sci. Technol.*, **63**, 1377 (2003).
10. F. Harnnecker, D. Santos Rosa, and D. M. Lenz, J. Polym. Environ., **20**, 237 (2012).
11. A. K. Mohanty, M. Misra, and G. Hinrichsen, *Macromol. Mater. Eng.*, **1**, 276 (2000).
12. H. Ku, H. Wang, N. Pattarachaiyakoop, and M. Trada, *Compos. Part B-Eng.*, **42**, 856 (2011).
13. M. A. Maleque, A. Atiqah, R. J. Talib, and H. Zahurin, *Int, J. Mech. Mater. Eng.*, **7**, 166 (2012).
14. M. A. M. Adel, M. A. Aboubakr, and A. Y. Nathalie, *Arab. J. Chem.*, **8**, 749 (2015).
15. P. Roach, N. J. Shirtcliffe, and M. I. Newton, *Soft Matter*, **4**, 224 (2008).
16. C.-H. Xue, S.-T. Jia, J. Zhang, and J.-Z. Ma, *Sci. Technol. Adv. Mater.*, **11**, 310 (2010).
17. B. Bushan and Y. C. Jung, *Prog. Mater. Sci.*, **56**, 1 (2011).
18. R. N. Wenzel, *J. Phys. Chem.*, **53**, 1466 (1949).
19. H. Ogihara, J. Xie, T. Saji, *Colloid. Surface. A*, **434**, 35 (2013).
20. C. S. Gudipati, J. A. Finlay, J. A. Callow, M. E. Callow, and K. L. Wooley, *Langmuir*, **21**, 3044 (2005).
21. A. Marmur, *Biofouling*, **22**, 107 (2006).
22. F. Zhang, S. G. Chen, L. H. Dong, Y. H. Lei, T. Liu, and Y. S. Yin, *Appl. Surf. Sci.*, **257**, 2578 (2011).