

TOLANI MARITIME INSTITUTE

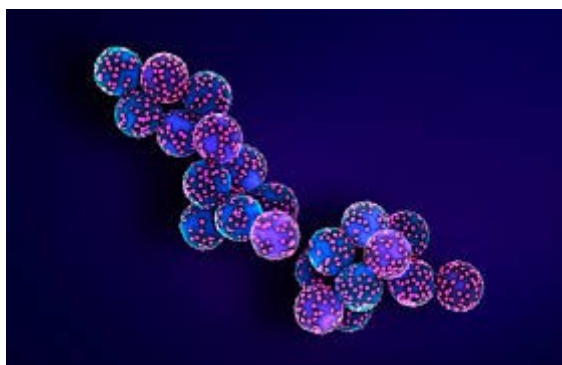


Attitude - Skill - Knowledge

THEME: SUSTAINABLE INNOVATION FOR ENHANCING INDUSTRIAL GROWTH

SUBTHEME: INNOVATIVE MATERIALS AND THEIR APPLICATION

TOPIC: PROTECTION OF BOOT TOPPING OF SHIP USING NANOCAPSULES



BY

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ABSTRACT

The boot topping is the area immediately above and below the mean water level, has been a major concern for corrosion engineers. Sea waves, winds and other factors alternately wet and dry exposed metal surfaces of the ship's hull. The part of the side shell permanently submerged can be protected due to lack of oxygen and the part of the hull well above the water line can be effectively protected from corrosion. But protecting the boot topping with traditional methods has been proved unsatisfactory and expensive. Hence, newer methods have to be used to protect and maintain the boot topping of the side shell.

Nanotechnology is the next revolution in the corrosion mitigation industry. The nanocoating industry is conservatively estimated to be \$2billion in 2012, growing to over \$8billion by 2024. In the coating sector, high transparency, new functionalities and high quality performance are increasingly important requirements. Nanocoatings display significant performance advantages over traditional coatings as well as being more cost-effective in medium to long term. In this paper, we restrict ourselves to the application of nanocapsules on the boot topping of a ship, its advantages over the traditional epoxy based and petroleum based paints and the cost benefits of this revolutionary technology.

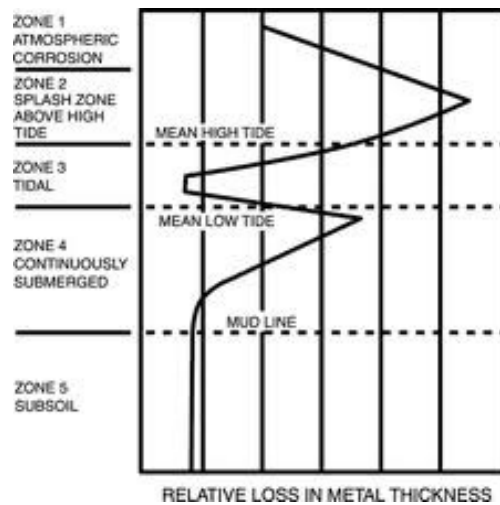
KEYWORDS

- Nanocapsules
- Boot topping
- Corrosion
- Epoxy paints.

INTRODUCTION

Corrosion of steel structures in marine environments is a problem that has to be considered during both design and maintenance and the corrosion rate of the boot topping of a ship is particularly severe. The spray and boot topping above the mean

high tide level is the most severely attacked region due to continuous contact with highly aerated sea water and the erosive effects of spray, waves and tidal actions.



The criteria for a successful protection of the boot topping of a must contain the following:

- Isolation of the metal surface – metal must be isolated and separated from the environment, essentially the brackish sea water.
- High electrical resistance- the coating should be resistant to electrolytic corrosion.
- Bio-fouling resistance – isolate metal from sea life, fungus and scale attack.
- Longevity – The coating should ideally last virtually the entire life expectancy of the ship.

Nanocapsule is the next revolution in the preventing of corrosion. An extremely thin layer of polyaniline nanocapsules can be applied over the metal surface along with the traditional paints used to resist corrosion in the side shell of the ship. This can form an effective barrier between the metal surface and the external environment to reduce the corrosion to remarkable levels.

With the economy in the red and companies aiming for a higher profit margin, an investment has to be made in cutting edge sciences such as nanotechnology. After all,

using outdated techniques and technologies is suicidal in the current economic situation. Corrosion is a major concern for the shipping industry and ranks high in the causes for lower efficiency and higher operating costs. A coat of nanocapsules can do wonders for the shipping industry and this is a definitive way forward to reduce corrosion, specifically in the splash/spray zone of a ship.

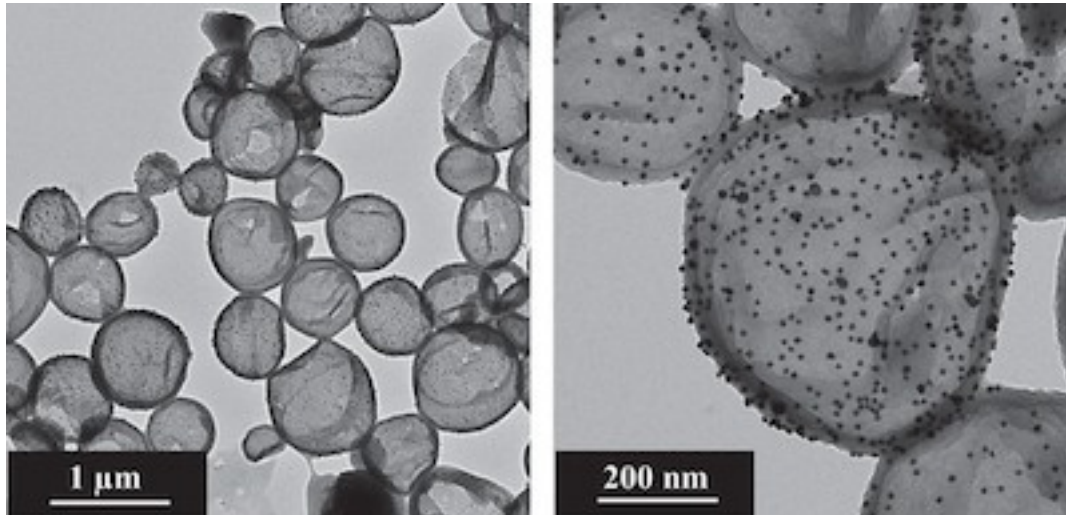
NANOCAPSULES

Nanocapsule is an innovation which is set to change the way the shipping industry will prevent corrosion of its ships. Nanocapsule is a material with self-healing, anticorrosive and antifouling capabilities.

The Nanocapsule is a spherical structure with two layers. The outer layer releases anti-corrosion payloads and when the corroding agent withdraws, the inner layer reseals the outer layer to restore the anti-corrosive abilities.

The nanocapsule is made of polyaniline, a conductive polymer to contain anticorrosive substance. The nanocapsule is bonded with a metal surface and metal nanoparticles are added to the capsule to generate electrical contact between the metal surface and any potential corrosive agent, that being sea water in case of ship's hull.

As the corrosion starts, there is a drop in the electrical potential in the coating. This provides a reliable signal for the nanocapsules to open and start releasing the anti-corrosive payloads. On contact with salt water, the polymer capsules become porous, allowing anticorrosive contents to escape, blocking the oxygen reduction process of the metal. Instead the inner layer forms a weak oxide to prevent the corrosive elements to affect the metal layer. When the corroding agent withdraws, the inner layer undergoes a reduction process and the outer layer gets oxidizes to reseal the capsule, hence retaining the anti-corrosive properties of the capsule.



Nanocapsules under a microscope

The reason why the nanocapsules can be applied only on the spray zone of the ship is that it cannot function if the corroding agents do not withdraw. If the nanocapsules are applied on the bottom shell of the ship, the outer layer will not be able to reseal itself. This will cause a continuous discharge of the anti-corrosive payload, effectively reducing the lifetime of the nanocapsules drastically.

The nanocapsule coat can bind with the epoxy paint matrix. This will result into fewer coats of paint that need to be applied, less of toxic paint leaching into the sea water, lower costs of repainting the side shell of the ship during dry docking, and of-course, the most important advantage being higher resistance to corrosion.

ADVANTAGES OF USING NANOCAPSULES

The disadvantage of using epoxy paints is that they tend to be brittle. Along with this, epoxy paints do not give any indications of rusting of the metal paints underneath. They also tend to add a considerable amount of weight to the ship due to multiple coats being applied.

Though nanocapsules currently cannot eliminate epoxy paints entirely, there are major advantages of using them together.

- Nanocapsule technology can be used to fight marine fouling efficiently. The properties of the nanocapsule can be fine-tuned to suit the anti-fouling requirements to a particular sea route. This will allow a constant release of agents that fight fouling that allows reliable antifouling performance during the entire service period.

- In a condition where the nanocapsules cannot guarantee effective resistance against bio-fouling, it is possible to overcoat the existing antifouling paints.
- Nanocapsules can be applied with extremely low dry film which will reduce the overall thickness of the paint by 15%
- Nanocapsules are highly reactive and can protect the side shell of the ship actively. The nanocapsules can also be used as a binder component which gives a self-polishing effect.
- The nanocapsules have self-polishing and self-smoothing ability which results into a low hydrodynamic drag coefficient resulting in lower fuel consumption.
- The nanocapsules can increase the service period effectively up to 5 years.
- There is a considerable saving on purchase and application of the paint by 18%-20% on the total dry docking cost of paint work if a coat of nanocapsule is applied.
- As it can effectively form a fibre composite with the paint matrix, there is no need to obtain specially designed paints.
- Nanocoating reduces the number of coats of epoxy paint that has to be applied and this reduces the leaching effects of the paint.
- It reduces the loading of toxic material in paint and it results in a more environmental friendly paint.
- In an event where the paint surface might be scratched, nanocapsules can re-bond if the scratch is fine. The self-healing property of the nanocapsules will make the application of localized coat of fresh paint unnecessary.

Nanocapsules have started to gain traction and a company named Hemple has already developed nanocapsule based paints and uses Globic NTC paints that have the advantages already stated.

METHOD OF APPLICATION

Firstly, these nanocapsules are incorporated in sol-gel matrix to form a solution. This solution can be then applied on the surface of the hull. And after that 2-3 coats of solvent free or coal tar epoxies can be applied so that the nanocapsule coating is not exposed.

The reason for adopting nanocapsules is that it offers greater protection of the side shell of the ship for a lesser cost in the long run.

To explain the above statement, we take an average sized bulk carrier. Let the wetted surface area for the ship be about **8000m²**

For epoxy paints to retain their effectiveness, four coats of it are applied.

The average cost of epoxy paint is about **\$6.50** per sq. meter.

The density of epoxy paint is about **1200 kg/m³**

The thickness of every coat of epoxy paint = **0.000125m**

Hence, the weight of the total epoxy coating would be = $8000 \times .000125 \times 1200 \times 4$
= **4800kg**

The total cost of the paint would be = $8000 \times 4 \times 6.50 =$ **\$208000**

The service time of epoxy paint is 5 years

Therefore, cost of epoxy paints per year = **\$52000 (including maintenance)**

If nanocapsules are applied,

Reduction of thickness in the epoxy coat = 15%

Estimated cost of nanocapsules = **\$15 per square meter**

The total weight of the paint coating would be = $8000 \times .000125 \times 1250 \times 4 \times .75 =$ **3600Kg**

The cost of paint would be = $.75 \times 208000 + 15 \times 8000 =$ **\$276000**

The service time of epoxy paint with nanocapsule coating will be about **8 years**

Hence, the cost per year of this coating would be = **\$34500**

The estimated cost saved per year = **\$17500**

Additionally, weight reduced is **1200Kg**

This weight can either be utilized to increase fuel efficiency, or to increase the dead weight of the ship.

If this weight is used as additional deadweight,

Assumed freight rate of a region **\$150** per tonne and the ship makes 30 trips a year, the increase in income would be = $1.2*150*30 = \mathbf{\$5400}$

CONCLUSION

With polyaniline as core material, nanosize capsules can be prepared. These nanocapsules can be incorporated in sol-gel matrix, which provides a uniform coating of self-healing material. Healing effect can be observed within 8 hours of damage. Hence, we were able to conclude that these nanocapsules embedded self-healing coating enhance the corrosion resistance of coated steel and also there is a reduction in cost of paint if nanocapsule coating is used instead of epoxies. It also helps in increasing dead weight capacity due to its light weight. Hence it is advisable to use nanocapsules along with epoxy paints to increase resistance to corrosion at nearly the same cost of conventional paints.

The development of nanocapsules is in its nascent stage but its application is wide range. In years to come, it is expected that nanocapsules will eliminate paints completely. Further research can be done in colour changing nanocoatings to indicate the precise location of corrosion and combined with nanocapsules; it just might be possible to eliminate corrosion of structures completely.

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