

Corrosion Control of Steel Ships

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ABSTRACT

Corrosion control is a costly and persistent problem across every class of surface ship, and as ships age, the maintenance costs and effort required to extend their service lives increases. Paint coatings have holidays, low abrasion resistance and poor bond strength. Corrosion initiated at scratches and holes easily lifts the paint film, accelerating attack of the underlying steel. Paint over corrosion only masks an ongoing problem. In contrast, metallic zinc coatings have excellent abrasion resistance and superior bond strength. Furthermore, metallic zinc coatings offer both barrier protection and cathodic protection to steel. The ultimate corrosion protection is to use a metallic zinc base layer with a paint topcoat. The paint adds an extra layer of barrier protection to the zinc, while the zinc protects the paint from underfilm corrosion at scratches and holes. Effective corrosion control significantly reduces maintenance costs and provides the lowest cost of ownership for a vessel. Application of metallic zinc coatings for steel ships will be presented with case studies.

Key words: Duplex coatings, Hot dip galvanizing, Thermal sprayed zinc, Corrosion, Ships

INTRODUCTION

Commercial ships cover a wide range of vessels including tankers, bulk carriers, cargo ships, tugs, fishing boats, passenger ferries and cruise ships. Across all sectors commercial ships contribute significantly to the global economy. Maintenance costs for commercial ships are twofold. First there is the direct cost of corrosion maintenance and second, there is the lost revenue when the ship is not working. Direct maintenance costs for corrosion control of commercial ships is estimated to be \$5.4 Billion annually.¹ The indirect cost of downtime needed

for the corrosion maintenance repair adds another \$5.2 Billion for a total cost of \$10.6 Billion per year.

Much of this cost is due to simple steel corrosion that could be significantly mitigated with painted metallic zinc coatings. Zinc provides very effective corrosion protection for steel by acting first as a barrier coating, keeping corrosive elements away from the steel, and secondly as a sacrificial anode.² Painted metallic zinc coatings provide improved corrosion protection performance. A painted metallic zinc coating is called a 'Duplex' coating.³ The paint adds an extra layer of barrier protection to the zinc, while the zinc protects the paint from underfilm corrosion at scratches and holes.

The process of hot dip galvanizing to apply zinc to steel was patented in 1836 and has been used successfully to protect steel from corrosion for almost two centuries. The most famous case is the Brooklyn bridge, a magnificent granite pier suspension bridge that spans the East River and joins Manhattan with Brooklyn.⁴ Completed in 1883, the bridge deck is suspended from 1,520 vertical cables and 400 diagonal stays made from galvanized steel wire ropes. The duplex galvanized steel cables have been maintenance-free now for 137 years.

Thermal spray zinc is another century old process, patented in 1909, that is used to protect steel from corrosion.⁵ Inspired by the successful completion of the Forth Road bridge in Scotland, the Norwegian Public Roads Administration has specified duplex thermal spray zinc coatings for steel bridges since 1965. Many of the steel bridges crossing rivers and ocean fjords are now 50 years old with little or no corrosion maintenance and some are predicted to reach their 100 year design life maintenance-free.⁶

Offshore windmills are subjected to the most severe climate conditions experienced by engineering structures. Due to accessibility issues, offshore maintenance costs can be 75 to 100 times more expensive than onshore maintenance.⁷ Duplex metallic zinc coatings have been used successfully to provide maintenance-free corrosion protection to offshore windmills over their 25 year design life. Detailed inspections of existing towers after 19 years at sea show that the galvanized steel landing platforms and duplex thermal spray zinc coated towers have no red rust or red rust staining. Areas where the paint has been abraded from the surface of the towers, such as on welded brackets, also show no rusting, as the zinc is still in place to protect the steel.⁸

Technology transfer of duplex metallic zinc coatings is now taking place to the commercial shipping industry, primarily on fishing boats. Mostly owned and operated as a small business, boat owners are keenly interested to maximize their time at sea fishing, while reducing maintenance costs.

METALLIC ZINC COATINGS

Hot-dip galvanizing produces a zinc coating by completely immersing the steel part in a bath (kettle) of molten zinc.⁹ Surface preparation for galvanizing is a three-step process involving degreasing, pickling and fluxing. While in the galvanizing kettle, the molten zinc metallurgically reacts with the iron in the steel to form a distinct coating structure approximately 100µm (4mils) thick, shown in Figure 1. The hot-dip galvanized coating structure consists of a series of iron-zinc layers with a top surface layer of pure zinc. The intermetallic layers are tightly bonded to (25MPa (3,600 psi)) and harder than the base steel, offering excellent abrasion resistance. The zinc-iron alloy layers, metallurgically bonded to the steel, become an integral part of the steel rather than just a surface coating.

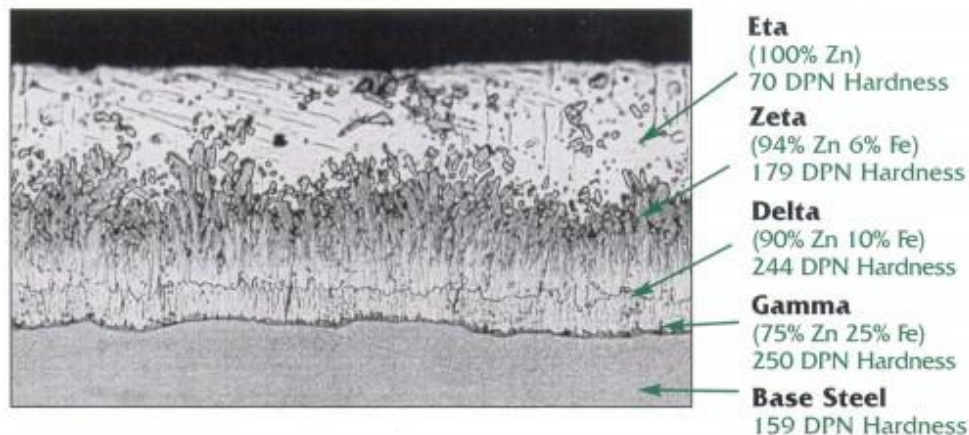


Figure 1: The hot-dip galvanized coating structure

However, since galvanizing must be performed in a factory setting and not on site, steel structures are limited to the size of the galvanizing kettle. Any structures on a ship that can be removed, such as rails, winches, hatches and cranes, can be sent for galvanizing and then reinstalled on the ship.

For the thermal spraying of zinc, surface preparation by grit blasting serves two functions; one is to clean the steel, and the other is to develop a sharp angular profile needed to anchor the coating to the steel. Two different techniques can be used for thermal spraying of zinc, either flame spraying or electric arc spraying, with either pure zinc or a zinc 15% aluminum alloy.¹⁰ Flame spraying uses an acetylene-oxygen flame to melt a zinc or zinc alloy wire that is continuously fed into this flame. In arc spraying, two zinc or zinc alloy wires are brought together at an angle between 30 and 60°, and an imposed voltage difference between them creates an electric arc, which melts the zinc. With both techniques, a gas flow, of either compressed air or a special gas, then atomizes and propels the molten metal droplets toward the steel substrate. Thermal spray zinc coatings can be applied at the factory or in the field, need no curing time and have no structure size limitations.

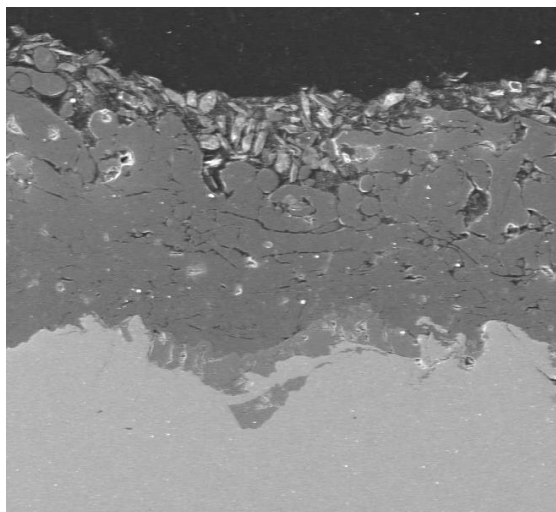


Figure 2: Thermal spray zinc coating structure