

SUSTAINABLE COATINGS FOR ABOVE GROUND STORAGE TANKS

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ABSTRACT

Above ground storage tanks display a large surface area that can often be covered in unsightly rust. A long-term coating is needed to reduce maintenance costs as scaffolding and tarping a tank for coating typically costs more than the actual blasting and re-painting costs. Thermal spray zinc (TSZ) duplex coatings have been shown to be highly durable. In a life cycle comparison with paint, the durability of metallic zinc coatings eliminates the repeat burdens of maintenance painting, significantly reducing the total cost of ownership of a structure. Furthermore, zinc coatings have significantly lower life cycle impact in terms of global warming potential, acidification potential, and photo-chemical ozone creation potential, providing a more sustainable corrosion maintenance strategy. A thermal spray zinc duplex coating applied with three aerial work platforms can eliminate the need for scaffolding and tarping and provide an economical and sustainable coating system with a service life typically exceeding 50 years.

Key words: Thermal sprayed zinc, duplex coatings, corrosion

INTRODUCTION

Controlling corrosion of steel is expensive. The direct costs of corrosion maintenance are estimated to be over 3% of GDP every year.¹ Metallic zinc coatings provide 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 Should the zinc coating be compromised, accidentally by a scratch or on purpose with a drilled hole, the zinc will provide anodic protection to the exposed steel. Metallic zinc coatings can be pure zinc or zinc-based alloys and will be referred to generically as zinc coatings in the paper. Zinc coatings can be efficiently applied by thermal spraying, which involves projecting particles of semi-molten zinc onto the surface of the steel using compressed air. With thermal sprayed zinc (TSZ) coatings, there is no size limitation to the part to be coated, and the technology is fully portable, allowing easy field applications.

The lifetime of a zinc coating will be greatly extended by overcoating it with an engineered paint system. The paint enhances the barrier protection of the zinc, while the anodic properties of the zinc protect the paint film from underfilm corrosion creep at scratches and holes. The paint can be a single or multilayer paint system. Painted metallic zinc coatings, called 'Duplex' coatings, provide improved corrosion protection performance.³

Paint only corrosion protection coatings for steel often do not last as long as the structure they are protecting, which means that maintenance costs add significantly to the life cycle cost. Metallic zinc coatings have been shown to drastically reduce overall life cycle costs compared to paint only corrosion protection systems.⁴ Duplex coatings will have even longer lifetimes between maintenance. Many steel bridge structures protected with duplex coatings have been corrosion free for 50 years and are projected to last the entire design life of the structure with no maintenance.⁵

Sustainable products reduce or avoid the depletion of natural resources. Sustainability can be measured by Life Cycle Assessment (LCA), which is a decision-making tool to identify environmental burdens and evaluate the environmental consequences of a material, product, process or service through production, use, and end of life.⁶ The measured life cycle may be from cradle to gate (typical for basic raw materials and commodities such as zinc metal) or cradle to grave (typical for products such as zinc coated steel).

LCA has been standardized by the International Organization for Standardization (ISO) and forms the conceptual basis for a number of management approaches and standards that consider the life cycle impacts of product systems. Compared to paint, zinc coatings have been shown to have significantly lower life cycle impact in terms of embodied energy, global warming potential, acidification potential, and photo-chemical ozone creation potential. The results are often expressed as an Environmental Product Declaration.^{7, 8}

THERMAL SPRAYED ZINC

Thermal spraying of zinc coatings is a well-established process for the corrosion protection of steel. One technique used to apply the TSZ coating to the steel is flame spraying.⁹ As for all coatings, the steel surface needs to be prepared for thermal spraying. Grit blasting of the steel surface, rather than shot blasting, is required to provide adequate mechanical adhesion of the zinc coating to the steel.

Flame spraying uses an oxy-fuel combustion flame to partially melt pure zinc or zinc-15% aluminum alloy wire that is continuously fed into this flame. The process is shown schematically in Figure 1. A stream of gas, generally compressed air, then propels the semi-molten metal particles in the direction of the steel surface. The particles impact and freeze on the steel surface to build up a coating to the desired thickness.

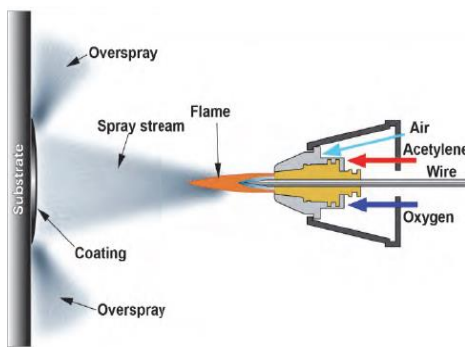


Figure 1. Flame spraying process schematic (source: Ref. 9)

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The TSZ coating is produced by impacting semi-solid particles on a roughened steel surface. This produces a metallic layer with minimal porosity and oxides on the individually solidified particles. Coating thickness is dependent on the time of spray. Porosity typically makes up 5-7% of the coating volume. The overall coating has characteristics similar to solid metallic zinc, including a Vickers hardness of around 70. The surface profile of thermal sprayed zinc provides excellent paint adherence for duplex coatings.

DUPLEX COATINGS

The service life of TSZ coatings will be extended if protected with a paint coating system. Even more importantly, the service life of the paint system will also be extended if it is applied over a zinc coating rather than over a steel substrate. The paint enhances the barrier protection of the zinc, while the anodic properties of the zinc protect the paint film from underfilm corrosion creep at scratches and holes.³ The significant extension of the expected life of the duplex coating compared to the sum of the expected lives of the zinc coating or the paint system used by themselves is known as a synergistic effect. The synergy effect is defined by a factor in the equation:

$$\text{Duplex service life} = \text{synergy factor} \times (\text{zinc life} + \text{paint life}).$$

For example, in an industrial environment, with a synergy factor of 2, and an expected life to first maintenance of 30 years for zinc and a life to first maintenance of 10 years for paint would give an expected protective coating system life of 80 years $[2 \times (30+10)]$.¹⁰ Synergy factors vary, depending upon the climate. Typical synergy factors found as a result of global corrosion testing have been compiled in Table 1.

Table 1
Synergy Factors for determining life of duplex coatings

Environment	Synergy Factor
Sea Water / Immersion	1.5 – 1.6
Industrial / Marine	1.8 – 2.0
Mild Climate	2.0 – 2.7

It can be seen that synergy effects in industrial and marine environments range from 1.8-2.0, whereas in less aggressive climates they can range from 2.0-2.7. The basic reason for this synergy is that zinc supports the paint when it begins to fail and prevents corrosion creep and other mechanisms of paint failure from proceeding anywhere near as rapidly as they would occur with a steel substrate that does not have the protection of the intermediate metallic zinc coating.

SUSTAINABLE ZINC COATINGS

The most apparent benefit of using zinc coatings for protecting steel against corrosion is the significant increase in usable life of the steel structure. Extending the life of the structure reduces the replacement rate and the use of natural resources.