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Thermal Spray for Commercial Shipbuilding

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Thermal spraying of steel with aluminum to protect it from corrosion is a technology that has been proven to work in the marine environment. The thermal spray coating system includes a paint sealer that is applied over the thermally sprayed aluminum. This extends the service life of the coating and provides color to the end product. The thermal spray system protects steel both through the principle of isolation (as in painting) and galvanizing. With this dual protection mechanism, steel is protected from corrosion even when the coating is damaged. The thermal-sprayed aluminum coating system has proved the most cost-effective corrosion protection system for the marine environment. Until recently, however, the initial cost of application has limited its use for general application. Arc spray technology has reduced the application cost of thermal spraying of aluminum to below that of painting. Commercial shipbuilders could use this technology to enhance their market position in the marine industry.

Keywords arc spray, corrosion protection, shipbuilding

1. Introduction

Thermal spray aluminum technology has been proven to provide more than 20 years of maintenance-free service in the marine environment and can now be applied at a cheaper cost than painting. The technology was extensively analyzed by the U.S. Navy's David Taylor Research facility at Annapolis, MD (Ref 1). A series of fault and no-fault tests were conducted, using the Navy paint system as a standard. These tests, conducted over a 5-year period, proved that the thermal-sprayed aluminum coating system provided better corrosion protection than painting, even when the coating was so severely damaged as to expose bare steel. These same tests also proved that flame wire and arc wire processes produce coatings that provide acceptable corrosion protection.

For more than 15 years, the Navy has been applying thermal spray aluminum coating to high-corrosion areas aboard ships and to dry-dock facilities. Actual field applications, such as on weather decks, oil tanks, bilge tanks, ballast tanks, sanitary spaces, sewage holding tanks, freshwater tanks, fuel tanks, and steam valves, have testified to the success of the technology.

All the thermal spray processes produce coatings that will protect steel in the marine environment for long periods of time. The arc spray process is the only currently available process that allows the thermal spraying of aluminum to be performed at lower cost than painting. Additionally the results are of higher quality and provide longer service life.

2. Implementing the Thermal Spray Process

Unlike paint, a thermally sprayed aluminum coating is resistant to abuse and therefore will not be damaged by normal fabrication practices. This allows the coating to be applied during the construction process. The most cost-effective production practice, with the highest quality of work, would be obtained by thermal spraying subassemblies and individual parts in the shop, where accessibility would be better and where automated processes could be used.

Welding over the aluminum coating will not normally affect the physical and chemical properties of the steel; however, because it does affect the welding characteristics, welding over the thermal sprayed coating is not advised. The weld areas should be masked, or the thermal-sprayed coating can be removed by the same methods used to remove paint or galvanizing (e.g., grinding, sandblasting, or water blasting).

3. Application Cost Reduction

The introduction of the arc spray process to corrosion protection applications has reduced the cost of thermal spraying and has also facilitated cost reductions in surface preparation and sealer application. The combination of these process improvements has made the thermally sprayed aluminum coating a viable cost alternative to paint coatings.

3.1 *Surface Preparation*

Surface preparation for the flame spray process is expensive because it requires a double blast operation. The first operation, performed with any blasting material, cleans the steel. The second blast operation establishes the required anchor tooth and further cleans the material to a white metal finish. Aluminum oxide grit or chilled iron grit is normally specified for this second blast. Even with these precautions, ultraclean practices are required to maintain cleanliness until the surface is coated.

Arc spray is much more forgiving in terms of surface cleanliness requirements. Its blasting standards are similar to those of painting, with the exception that arc spraying requires blasting with an angular grit to achieve an anchor tooth pattern of 50 μm (2 mils) or more. The optimum surface preparation condition for both painting and arc spraying is metal that has been cleaned to

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white or near white. This cleanliness requirement can be achieved with mineral slag grit material such as garnet, copper slag, and nickel slag in sieve sizes of 24 to 36. The cost of these grits in bulk quantities is about $0.066/kg ($0.03/lb), compared to $0.66/kg ($0.30/lb) for the aluminum oxide grit that is required for the flame spray process (Table 1).

The arc spray process provides a higher-quality coating with the single surface preparation method than the flame spray process does on the dual blasting method. Thus, the high energy of the electric arc causes the spray material to superheat and bond to the steel at strengths three to four times that of flame spray (Table 2). The arc-sprayed coating is also more ductile and will withstand more abuse.

Table 1 Surface preparation costs

Expense	Cost, U.S. $/m² ($/ft²) Paint/arc spray	Flame spray
Blast media		
Copper slag $0.066/kg ($0.03/lb)(a) 73 kg/m² (15 lb/ft²)(b)	4.83 (0.45)	4.83 (0.45)
Aluminum oxide $0.66/kg ($0.30/lb)(a) 29.28 kg/m² (6 lb/ft²)(b)	. .	19.39 (1.80)
Labor	10.76 (1.00)	13.45 (1.25)
Total	**15.59 (1.45)**	**37.67 (3.50)**

(a) Cost. (b) Amount required

Table 2 Bond strength

Process	Bond strength kg/cm²	lb/in.²
Arc wire	316-421	4500-6000
Flame wire	105-246	1500-3500

Table 3 Arc wire spray rates

Wire size mm	Wire size in.	Current, A	Melt rate kg/h	Melt rate lb/h	Coverage per hour, 250 μm/ft² (10 mil/ft²)
2.38	3/32	300	10	22	88
3.17	1/8	400	12.7	28	112
3.96	5/32	500	15.8	35	140

Table 4 Process cost comparison

Item	Cost, U.S. $/ft² Painting	Flame spray	Arc spray
Energy	...	0.13	0.01
Surface preparation	1.45	3.50	1.45
Sealer(a)	...	0.70	0.70
Primer(a)	1.35	...	...
Color No. 1(a)	1.35	1.35	1.35
Color No. 2(a)	1.35	...	...
Metal spray(a)	...	2.75	1.83
Total	**5.50**	**8.43**	**5.34**

(a) Includes labor and material

3.2 *Sealer Application*

Sealers are required for the sprayed aluminum coating. The sealer enhances coating performance by filling pores and by isolating the aluminum from the environment. Without a sealer, the life expectancy of a thermally sprayed aluminum coating would be decreased by a factor of three or more. A thin-coat sealer performs better than a thick coating, thus making it more desirable to apply a thin coating system rather than a multiple-layer thick coating system.

A thin sealer saves considerable cost and reduces volatile organic compounds emitted to the atmosphere. The British, who have more experience in the thermal spraying of ships, discourage a thick sealer system and specify a single-coat wash primer system in their standard (Ref 2). The U.S. Navy specifies a thin coating sealer system for high-temperature steam valves, thereby verifying that the single-coating practice satisfies the sealing requirement. A thick paint sealer can blister and create a pocket for moisture to gather. This stagnant water deteriorates the thermal spray coating under the blister, leaving the steel without protection at that point. Blisters do not form on a thin sealer system.

For marine applications where color is not needed, a single-coat sealer system is the preferred method. For example, a Mare Island Formula 150 primer thinned with an equal amount of solvent will provide the required protection. When a specific color is specified, a thinned second-coating material applied over the original sealer—just thickly enough to provide color—is all that is required and recommended.

3.3 *Arc Spray Process Improvements*

The spray rate of the arc spray process has significantly reduced the labor required to apply the thermal-sprayed coating. Spray rates for aluminum have risen from an average of 3.4 kg/h (7.5 lb/h) to more than 15.8 kg/h (35 lb/h). This has been accomplished through inventions that allow the arc spraying of aluminum wire with diameters of up to 4 mm (5/32 in.). Other representative spray rates and coverages are shown in Table 3. Deposit efficiency has also improved with the spraying of larger-diameter wires; the efficiency is now more than 75%, which is equal to or better than the deposit efficiency of the flame spray process.

Improvements in arc spray equipment design and reliability have lowered operation costs and significantly increased labor efficiency (Table 4). Training personnel to perform thermal spraying can be completed in just a couple of days; this includes learning the skills to maintain the equipment. Operations are simple: The equipment turns on and off with one switch, and spraying is started immediately without preheating of the substrate material.

4. Conclusions

Through the use of thermal spray, the U.S. shipbuilding industry could enhance its market position. Marine products could be guaranteed for more than 20 years against corrosion. Coating costs could be lower and environmental hazards reduced. Volatile organic compounds, a hazard in paints, could be reduced by

more than 90% or possibly eliminated. Because corrosion allowances would not be needed, structural steel thicknesses could be reduced, increasing payload and reducing fuel costs. Double hull technology would be enhanced by the long-term protection of thermally sprayed coatings, an advantage that has been validated by both laboratory and field applications.

High-deposition arc spray technology has helped to lower the cost of thermal spraying to below that of painting, while providing the highest-quality coating. The process is forgiving in terms of surface cleanliness requirements, allowing it to be used as a normal production practice with few special precautions. The process can be operated manually or automated using conventional or robotic equipment, and does not require special skills; almost anyone can be trained to operate and maintain the equipment.

Thermal spray aluminum technology can protect marine products against corrosion, thus offering a market edge for the shipbuilding industry. The coating will provide more than 20 years of corrosion protection—three to five times the life of a standard paint system—and can be applied on any size component in the field or in the ship. The thermal spray aluminum coating system is now cheaper than painting and environmentally safer.

Acknowledgments

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References

1. B.A. Shaw and A.G.S. Morton, "Final Report, Five Year Evaluation of Flame and Arc Sprayed Aluminum, Zinc, and 85/15 Zinc/Aluminum," Marine Corrosion Branch, David Research Center, Bethesda, MD, DTNSRDC-SME-87-11, 1987
2. "Code of Practice for Protective Coating of Iron and Steel Structures Against Corrosion," BS5493, British Standard Institution, 1977