SHIP PRODUCTION COMMITTEE
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EDUCATION AND TRAINING

November 1993
NSRP 0408

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1993 Ship Production Symposium

Paper No. 24: Thermal Spray for Corrosion Control: A Competitive Edge for Commercial Shipbuilding

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
NOV 1993	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The National Shipbuilding Research Program 1993 Ship Production Symposium Paper No. 24: Thermal Spray for Corrosion Control: A Competitive Edge for Commercial Shipbuilding	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tower Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**9**	

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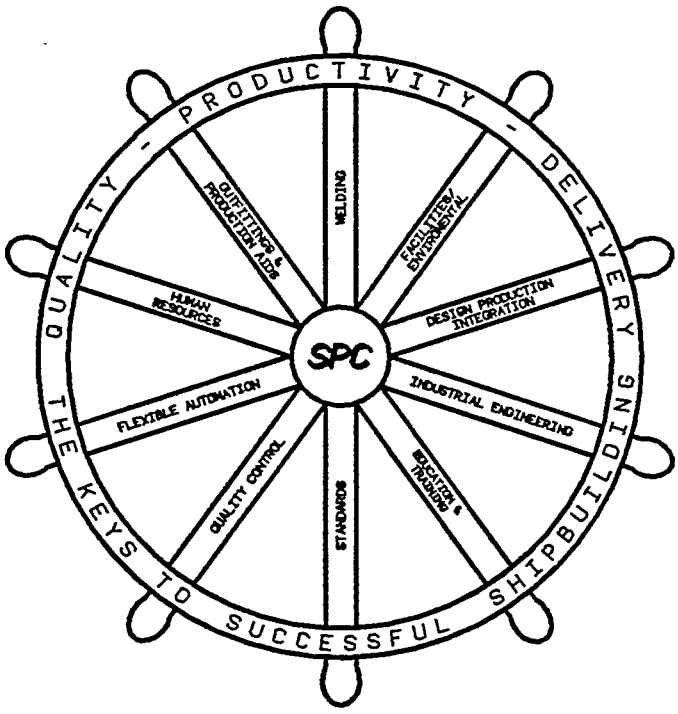

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Thermal Spray for Corrosion Control: A Competitive Edge for Commercial Shipbuilding

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ABSTRACT

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 galvanization (as in galvanizing) . With this dual protection mechanism, steel is protected from corrosion even when the coating is damaged.

The thermal sprayed aluminum coating system has proven to be the most cost effective corrosion protection system for the marine environment. However, unti 1 recently the initial cost of application has limited its use for general application. Today a new arc spray technology has reduced the application cost of thermal spraying aluminum to below that of painting. Commercial shipbuilders could use this technology to enhance their market position in the marine industry.

INTRODUCTION

It is time to put thermal spray aluminum technology to work. The 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 Navy [1]s David Taylor Research Facility at Annapolis, Maryland. A series of fault and no-fault tests were conducted, using the Navy paint system as a standard. These tests, conducted over a five year period proved the thermal sprayed aluminum coating system provided corrosion protection better 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 fifteen 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, weather decks, oil tanks, bilge tanks, ballast tanks, sanitary spaces, sewage holding tanks, fresh water tanks, fuel tanks, steam valves, etc. have provided testimonial 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 one currently available that allows the thermal spraying of aluminum to be performed cheaper than painting. Additionally, the results are of higher quality and provide the longest service life.

IMPLEMENTING THE THERMAL SPRAY PROCESS

A thermally sprayed aluminum coating, unlike paint, is resistant to abuse, and will therefore 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 automated processes could be utilized. Welding over the aluminum coating will not normally effect the steel's physical and chemistry properties, however, it does effect the welding characteristics; so welding over the thermal sprayed coating is not a good idea. The weld areas should be masked or the thermal sprayed coating can be removed with the same methods used to remove paint or galvani.zi.ng by grinding, sand blasting, or water blasting.

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 a cost reductions in surface preparation and sealer application. The combination of these process improvements have made the thermally sprayed aluminum coating a viable cost alternative to paint coatings.

Surface Preparation

The high cost of surface preparation for the flame spray process is due to the fact that 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 ultra clean practices are required to maintain surface cleanliness until it is coated.

Arc spray is much more forgiving to surface cleanliness requirements, and requires blasting standards similar to painting, with the exception that arc spraying requires blasting with an angular grit to achieve a anchor tooth pattern of 50um (2 roils) or more. The optimum surface preparation condition for both painting and

arc spraying is metal that has been cleaned to 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 24-36. The cost of these grits in bulk quantities is about $.066/kg ($.03/lb), as compared to $.66/kg ($.30/lb) for the aluminum oxide grit which is required for the flame spray process (Table I).

	PAINT/ARC	FLAME
COPPER SLAG $.066/KG ($.03/LB) 73 KG/M² (15 LBS/FT²	4.83 (.45)	4.83(.45)
ALUMINUM OXIDE $.66/KG ($.30/LB) 29.28 KG/M² (6 LBS/FT²		19.39 (1.80)
LABOR	10.76 (1.00)	13.45 (1.25)
TOTAL US $	15.59 (1.45)	37.67 (3.50)

per square meter (square foot)

Table I: Typical surface preparation costs

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. This is because the high energy of the electric arc causes the spray material to super heat and bond to the steel at strengths three to four times that of flame spray (Table II). The coating is also **more** ductile (softer) and will withstand more abuse.

ARC (wire)
316-421 KG/CM² (4.5K-6K LBS/IN²)
FLAME (wire)
105-246 KG/CM² (1.5K-3.5K LBS/IN²)
K=1000

Table II: (Typical) bond strengths for arc wire and flame wire processes

Sealer Application

Sealers are required for the thermal sprayed aluminum coating. The sealer enhances the performance of the coating by filling its pores, and 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, making it more desirable to apply a thin coating system rather than a multiple layer thick coating system.

A thin sealer allows a considerable cost savings, and a reduction in volatile organic compounds (VOC) emitted to the atmosphere. The British, whom has more experience in thermal spraying ships, discourage a thick sealer system and specify a single coat wash primer system in their standard. The U.S.

Navy specifies a thin coating sealer system for high temperature steam valves; this application in itself verifies that the single coating practice satisfies the sealing requirements. 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 paint. Blisters do not form on a thin sealer system to cause this problem.

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, and applied just thickly enough to provide color, is all that is required and recommended.

The Are 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 changed from an average of 3.4 kg/hr (7 1/2 lbs/hr) to over 15.8 kg/hr (35 lbs/hr). This has been accomplished through inventions that allow the arc spraying of aluminum wire with diameters of up to 4 mm (5/32 inch). Other representative spray rates and coverages are shown in Table III . 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.

WIRE SIZE MM (IN)	AMPS	MELT RATE PER HOUR KG/HR	(LBS/HR)	COVERAGE PER HOUR 250um/FT² (10mil/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 III: (Typical) arc wire spray rates

Improvements in arc spray equipment design and reliability have lowered costs of operations, and significantly increased labor efficiency, see table IV for process comparison. Training personnel to perform thermal spraying can be completed in just a couple 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.

	PAINTING	FLAME SPRAY	ARC SPRAY
ENERGY	X	.13	.01
SURF PREP	1.45	3.50	1.45
SEALER*	X	.70	.70
PRIMER*	1.35	X	X
COLOR#l*	1.35	1.35	1.35
COLOR #2*	1.35	X	X
METALSPRAY*	X	2.75	1.83
TOTAL US $/FT²	**5.50**	**8.43**	**5.34**

*INCLUDESLAEOR AND MATERIAL

Table **IV**: Process cost comparison

CONCLUSION:

Through the use of thermal spray, the United States shipbuilding industry could enhance their market position. Marine products could be guaranteed for more than twenty years against corrosion. Coating costs could be lower and environmental hazards could be reduced. Volatile organic compounds, a hazard in paints, could be reduced by more than ninety percent, or possibly eliminated. Because corrosion allowances would not be needed structural steel thicknesses could be reduced, increasing pay load and reducing fuel costs. Double hull technology would be enhanced by the long term protection of thermally sprayed coatings; which have been validated by both laboratory and field applications.

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

It is time to put the thermal sprayed aluminum technology to work in providing corrosion protection to our marine products and to provide a market edge for the United States shipbuilding industry. The coating will provide more than twenty years of corrosion protection for marine products, three to five times the life of a standard paint system. It can be applied on any size component in the field or in the shop, and the thermal sprayed aluminum coating system is now cheaper than painting and environmentally safer.

ACKNOWLEDGEMENTS

The high deposition arc spray process was developed with the assistance and valuable experience and knowledge input from employees of Puget Sound Naval Shipyard. Funding was provided by Naval Sea Systems Command and David Taylor Research Center. Legal services for Patent applications were provided by the Navy Patent Office.

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