

NONDESTRUCTIVE EVALUATION (NDE) FOR THERMAL-SPRAY COATINGS

Robert A. Sulit, Force Engineering Advisor (N43A)
Naval Surface Force, U.S. Pacific Fleet
San Diego, CA 92155

and

Vincent D. Schaper, Welding Engineer (2803)
David W. Taylor Naval Ship R&D Center
Annapolis Laboratory
Annapolis, MD 21402

THERMAL-SPRAY DEFINITION AND CLASSIFICATION¹

Thermal spray is the process of depositing metal, alloy, and ceramic coatings on properly prepared substrate materials so that they solidify on and bond mechanically, chemically, and metallurgically to the substrate materials. Thermal-spray coatings are applied to improve surface-wear characteristics, to provide resistance to heat, oxidation, and chemical environments; to restore dimension to the original equipment manufacturer's (OEM) specifications; to reduce erosion wear; and to improve corrosion control.

The authorized use of the thermal-spray processes in the Navy are specified in acquisition and OEM drawings for new equipment; in Technical Repair Standards or TRS's for the naval shipyards.

There are several different thermal-spray processes, they can be conveniently classified by the heat source and the physical form of the material being sprayed. The oxy-fuel or the combustion systems are capable of thermally spraying metal, alloy, and ceramic powders in powder guns; wire in wire guns; and ceramic materials when they are packed into rods or cords and sprayed in wire guns. The electric-arc gun sprays wire materials; and the arc-plasma and the "Union Carbide proprietary" detonation-gun processes sprays powder materials only.

The oxy-fuel temperatures of around 3500°F to the 15K to 30K°F temperatures of the arc-plasma processes gives a full range of thermal sources to melt and atomize all known materials. In addition to the high-temperature capacity, the thermal-spray equipment is designed to propel the atomized spray materials onto the substrate at high velocity. The coating materials must have a plastic range of at least 100 to 150°F.

The impact velocity of the sprayed material on to the substrate is directly related to the coating density, hardness, and bond or tensile strength of the coating to the substrate. The oxy-fuel powder-spray gun has an impact velocity of about 80 to 100 ft/sec and produces the lowest density, hardness, and bond of the thermal-spray processes. The oxy-fuel and electric-arc wire gun have an impact velocity ranging from 1600 to 2000 ft/sec when spraying at atmospheric pressures; about 2200 to 2400 ft/sec, equivalent to

the detonation gun, when arc-plasma spraying at partial vacuum of about 50 torr (50 mm of Hg).

Although the heat required for thermal spraying is generally supplied by fuel gas or electricity, one material, a mixture of nickel and aluminum, has been developed to provide additional heat when sprayed. When heated in the gun, nickel and aluminum combine chemically releasing a significant amount of exothermic energy which is added to the heat produced by the gun. The result increases the bond strength as much as ten-fold when used in an oxy-fuel powder-spray gun approaching that obtainable with the arc-plasma spray process.

The wide range of coating materials and thermal-spray processes gives the materials engineer the opportunity to design a coating system to maximize equipment and component service life, restore dimensions, improve the wear, and decrease erosion and corrosion characteristics of hull, mechanical, and electrical (HME) components; these coatings can be applied during original equipment manufacture or during their repair and overhaul. The simpler combustion gun and wire processes are used at intermediate maintenance activities (IMA), i.e., tenders, repair ships and shore IMA's (SIMA's); the arc-plasma system is used at industrial activities as naval shipyards.

SERVICE APPLICATIONS

Wear Coatings and Restoration of Dimensions -
Thermal-spray coatings can be applied to buildup worn or mis-machined parts and to improve abrasion resistance. They are not intended to fill gouges or similar localized damage without building up the entire area. Thermal-spray deposits do not restore properties such as tensile strength or resistance to fatigue stresses. However, under compressive loading conditions, they can exceed the original properties. MIL-STD-1687 (SH) approves the following thermal-spray coatings:²

a. Repair of seal (packing) areas of shafts used in oil and fresh water systems to obtain original dimensions and finish.

b. Repair of bearing interference fit areas of shafts to restore original dimensions and finish (except for motors and generators where chrome plating is permissible).

c. Buildup of pump shaft wear ring sleeves to original dimensions.

d. Repair of miscellaneous static fit areas, such as those on electric motor end bells, to restore original dimensions, finish and alignment."

CORROSION CONTROL

The Navy has been using wire sprayed aluminum (WSA) as a high performance marine corrosion-control system for a wide range of shipboard components and spaces on the weather decks and interior spaces. The WSA-preservation system consists of a 0.007 to 0.010 inch of WSA applied over a clean white substrate abrasive blasted with angular grit as aluminum oxide to a 0.002 to 0.003 inch "anchor-tooth" and then sealed with an appropriate organic paint or primer. Large scale use of the WSA-preservation system began with the preservation of steam valves in 1977 and it is now being used routinely in the maintenance and overhaul of many shipboard components and spaces where the conventional paint systems have not been effective. WSA is also being used in new ship construction.

NONDESTRUCTIVE EXAMINATION

We know of no NDE technique suitable for assessing the quality of thermal-spray coatings in the shop and production environment. Current quality assurance procedures being used are:

1. Process control, i.e., spray within the process parameters which have been previously qualified through destructive examination.

2. Coupon analysis, i.e., preparing and spraying a coupon in like manner to that of the production component and conduct destructive tensile, hardness, and/or metallographic examination of the coupon sample.

NDE REQUIREMENTS

Need NDE techniques, equipment, and procedures suitable for intermediate- and depot-level shop repair work and their quality assurance personnel to quantitatively evaluate:

1. Substrate preparation

a. Cleanliness - no contamination as grease/oil, dirt, and oxidation of the substrate.

b. No embedded abrasive blasting material and debris.

c. Anchor-tooth profile in the substrate.

2. Bond or adhesion of the thermal-spray coating to the substrate including areas where bond is below that specified for the coating system.

3. Bond or adhesion between adjacent layers of a multicoat system as nickel-aluminum bond coat topped with an alumina-titania ceramic wear coat.

4. Cracks and "bad volume" under the surface which could result from equipment malfunction, use of bad spray materials, and/or spraying outside the coating parameters.

REFERENCES

1. A PLASMA FLAME SPRAY HANDBOOK, Naval Ordnance Station, Louisville, KY, Report No. MT-043, March 1977.
2. MIL-S-1687(SH), Thermal-Spray Processes for Naval Machinery and Ordnance, 24 Nov. 1980.