Use of Thermally Sprayed Aluminum in the Norwegian Offshore Industry

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Thermal spraying with aluminum is not a new method for corrosion protection. For many years, thermally sprayed metal coatings have been widely accepted for giving very long protection lifetimes. Experience in Norway (on bridges, for example) and numerous tests in Europe and the US,1 show that the lifetime, or the time to the first necessary maintenance work, of thermally sprayed aluminum (TSA), combined with a paint coating system, can be more than 50 years.

Development of the Norwegian oil fields in the North Sea started with the Phillips Ekofisk Field in 1972, and it has progressed rapidly since then. TSA was almost not in use at all in the offshore industry until 1984-85.2 During construction, it was used only in a few special areas that would have very difficult or impossible access for maintenance during the operation of the platform (e.g., the flare boom). However, the increased application costs for TSA could be justified by the expected decrease in the cost of future maintenance. (For a comparison of the costs of TSA coatings and conventional systems, see "Offshore Protection: Painting for a 20-Year Life" in the April 1996 issue of PCE.3)

Several platforms built during the last six years, and most of those now under construction, have TSA as one of the corrosion protection coating systems. The real breakthrough came with the development of the Shell Draugen Field in 1991 where the whole underside of the platform, the lifeboat stations, and the flare boom were coated with TSA. The Sleipner Riser Platform (Statoil) and the Troll Gas development (Shell) also are using TSA as the main corrosion protection system.

The Basics

TSA Application Methods

The term "thermally sprayed aluminum" (TSA) covers several application methods. Electric arc spraying and flame spraying are the most suitable methods for the corrosion protection of steel structures.

Electric arc spraying is performed by feeding two electrically conducting aluminum metal wires towards each other. An electric arc is produced at the point just before the wires meet. The arc melts the metal wires, and a high-pressure air line is used to spray the fine droplets onto the steel surface, which has been previously cleaned and prepared.

In flame spraying, a metal wire is melted in a gas flame and then air-sprayed onto the steel surface.

Electric arc spraying is by far the more commonly used method in the Norwegian offshore industry, and the terms TSA coatings and metalizing in this article refer to electric arc thermally sprayed aluminum.

Surface Preparation

Before coating, the steel surface is blast-cleaned to Sa 3 according to ISO 8501, Preparation of Steel Substrates Before Application of Paints and Related Products - Visual Assessment of Surface Cleanliness.

Coating Systems

The prepared surface is coated with 200-400 microns AlMg5 (aluminum-magnesium alloy), which then usually is painted with an organic coating, such as epoxy, urethane or acrylic.

The choice of organic coating depends on the temperature to which the surface is exposed. For low temperature use, a sealer is applied to the TSA surface to seal the pores of the metal coating. This usually is followed by two coats of paint. For high temperature use, a heat-resistant sealer coat only is applied. The requirement for adhesion varies, but the latest specifications usually state a minimum requirement of 7 MPa and an average of 12 or 14 MPa.

Why Use TSA Coatings?

TSA coatings find use in a variety of environments, including the following:

- Atmospheric areas - The main reason for using TSA coatings in areas subject to atmospheric exposure is to reduce the need for future maintenance. Maintenance costs for existing constructions have been increasing rapidly due to the fact that many painted platforms in the North Sea are now about 20 years old and require extensive surface preparation maintenance. This, combined with longer design lifetimes for many recent installations (e.g., flare booms, crane booms, and steel underdecking), has generated increased interest in TSA coatings as a way to reduce future maintenance costs.
- Submerged areas - The use of TSA coatings reduces the requirement for sacrificial anodes. Bare steel has a current requirement of 120 milliamps per square meter (mA/m2) compared with 10 mA/m2 for a TSA coating.4 Test results are available showing current requirements reduced to as low as 1-2 mA/m2 for a TSA coating with sealer.6
- Special areas (pipe work and tanks) - TSA coatings reduce the possibility of chloride stress corrosion cracking in super duplex (stainless) steel.5

Table 1

Installation	Area	Gun	Metal	Approximate Area m^2	Year
Karsto	Gas pipeline	Arc	Zn	50,000	1983-84
Heimdal	Flare boom	Flame	$AlMg_5$	-----	1984
Gallfaks A/B/C	Flare boom Lifeboats	Arc Flame	$AlMg_5$ Zn	----- -----	1984-87
Veslefrikk	Flare boom Burner boom	----- Flame	----- Al	----- -----	1989
Gyda	Flare boom	Flame	Al	1,800	1988
Snorre	Flare boom Burner boom Derrick Crane boom	Arc	$AlMg_5$	-----	1990
Oseberg A/C	Flare boom Lifeboats	Arc Flame	$AlMg_5$ Zn	1,600 -----	1987
Draugen Topside	*Typical areas	Arc	$AlMg_5$	20,000	1992
Zeepipe	Gas pipeline	Arc	$AlMg_5$	20,000	1992
Sleipner Riser Topside	The main corrosion protection system	Arc	$AlMg_5$	40,000	1992
Embla Topside	Welding areas on super duplex pipes	Arc	$AlMg_5$	-----	1992
Troll Phase 1 Platform	The main corrosion protection system	Arc	$AlMg_5$	100,000	1993-94
Troll Phase 1 Land	Gasleading pipes/tanks and the adjacent steel structures	Arc	$AlMg_5$	105,000	1993-95
Europipe	*Typical areas	Arc	$AlMg_5$	7,000	1993-94
Heidrun Template	Internal conductor guides	Arc	$AlMg_5$	1,000	1992
Heidrun TLP Subsea	Tethers Risers	Arc	Al Al	8,000 5,000	1993-94 1994-96
Heidrun Topside	*Typical areas	Arc	$AlMg_5$	25,000	1993-94
Troll OLJE Topside	Flare boom Crane boom Insulated pipes and tanks	Arc	$AlMg_5$	3,000	1993-94

*Typical Areas: Flare booms/crane booms/crane pedestals/steel under cellar decks/piping and vessels under thermal insulation, etc.

Use on Offshore Constructions

In the Norwegian offshore industry, approximately 400,000 m2 of steel surface has been coated with TSA. This figure is based on available information7,8 and the authors' own estimates. It includes land installations that are allied to the oil and gas industry as well as platforms under construction. Table 1 gives an overview of where TSA coatings have been used for corrosion protection in the Norwegian offshore industry.

Experience in Use: Does the Coating Perform as Expected?

The available experience from operation is limited because most of the applied coatings have had too short a time in use, or they are not yet installed. However, one use of a TSA coating system is the flare boom on the ELF Heimdal platform, which has been in operation for approximately 10 years. It is coated with AlMg5 applied by flame spraying. The AlMg5 surface is overcoated with an aluminum silicone paint. ELF Petroleum reports very good results, with the coating still 100 percent intact and no need for maintenance.

What Effect Has TSA Had on the Norwegian Offshore Industry?

The large-scale introduction of TSA coatings is one reason why the larger Norwegian offshore building yards have constructed permanent halls for surface preparation work. Many of these halls have filter units to extract the dust created during the metalizing process. (Approximately 30 percent of AlMg5 ends up as dust.)

With such large amounts of TSA coatings being applied, as indicated in Table 1, it is not sufficient to rely on just a few specialty metalizing firms. The entire surface coating trade has had to upgrade its personnel for the application of TSA coatings. This work has centered primarily on acquiring skilled personnel within the industrial paint trade, which, in turn, has led to an enormous increase in competence in this area of Norwegian industry.

Work Health and Safety

The TSA coating process does not involve the use of solvents or other health-hazardous organic substances, but electrical arc spraying does create other significant health hazards, including

- noise (up to 110 dB),
- dust (approximately 30 percent of metal wire is turned into respirable dust),
- ultraviolet and infrared radiation, and
- formation of ozone (O_3) and nitrogen oxides (NO_2 and NO). (For more information on this topic, see "Thermally Sprayed Metal Coatings for Corrosion Protection: Health and Safety Considerations" in the September 1996 issue of PCE.9)

Metalizing operators must protect themselves against these hazards with personal protection gear, such as ear protectors, an air-line respirator/mask, and clothing to cover all exposed skin. This protection equipment must be suitable for the conditions created by electric arc spraying. For example, the quality and air tightness of respirators/masks are very important. In addition, the metalizing halls must have the necessary ventilation for the extraction of dust to minimize any risk of explosion due to the nature of the very small particles produced.

However, it is not these health hazards that lead to absence from work. Chronic strain injury is the most common cause of absence. The manual application of TSA coatings involves repetitive and prolonged movement under physical strain, which easily can lead to injury. Therefore, it is important to automate/mechanize the application process as much as possible to reduce these injuries. Also, development of lighter, more user-friendly spray guns would be advantageous.

Environment

The aluminum (Al) dust created in the metalizing process reacts quickly with the oxygen in the air to form aluminum oxide (Al_2O_3). The limits for atmospheric pollution of aluminum oxide have decreased in recent years. Today, the limit is 10-15 mg/m3. Use of the "best known technology" for extraction/filtering also is required.

Aluminum dust is respirable and hazardous to health in the same way as other respirable dusts due to the small particle size. Therefore, it is important that dust waste not be dispersed by wind.

However, aluminum, the third most abundant element in the earth's crust, is found in rocks and minerals, and it is dissolved in water.11 Due to its abundance in the earth, and in its inert state as aluminum oxide, it is not considered harmful to the environment.

How Has the Introduction of TSA Affected Steel Design?

The spraying equipment gives physical limits to the application of TSA coatings. An operator can use a brush for painting in areas with difficult access, but for TSA, there is no alternative. Even a spray gun with an angle-head nozzle has considerable limitations. This is one of the reasons why traditional angled profiles for stiffening of decks and bulkheads have been replaced by bulb profiles. This and other changes to the steel construction have been designed into the structure when it is known that TSA is to be used for protection, thereby improving the access capability for TSA applicators.

If this same focus on steel design had been applied to structures before painting, then the lifetime for the coatings as corrosion protection would have been improved significantly because of changes in application and coating thickness. A large part of the usual damage to paint is a result of sharp steel edges, uneven weld surfaces, and unsuitable steel construction design. The introduction of TSA has caused the designers to consider the protection system at the design stage, which has resulted in a generally better design for surface preparation, and this also has led to an improvement for the application of traditional paint systems.

Advantages of TSA Coatings

Among the various advantages of TSA coatings are the following:

- long lifetimes with minimum need for maintenance,
- resistance to mechanical damage,
- no health hazard from solvents or other organic substances,
- no drying/curing times after application,
- coatings exposed to dry atmospheres can withstand temperatures up to the melting point for aluminum (660 C),
- coating has sacrificial anode effect on steel in marine environments, which means the coating will corrode in preference to the steel substrate (hence, any small areas of bare steel will receive limited cathodic protection and be protected against corrosion10), and
- the application process can be mechanized.

Disadvantages of TSA Coatings

Disadvantages associated with TSA coatings include the following:

- high initial costs compared with painting (i.e., higher standard of surface preparation required and more expensive application),
- very expensive repair work (e.g., after the installation of new welded supports),
- pre-treatment to Sa 3 and high surface roughness/sharpness normally required,
- possible chronic strain injury to manual operators,
- high level of personal protection required (against noise, dust, ultraviolet/infrared radiation, ozone and nitrogen oxide gases),
- signs of surface rust can occur when coating thickness is less than approximately 150 microns, and
- the process creates large amounts of aluminum and aluminum oxide dust, which can be explosive if not handled properly due to its reactive nature and small particle size.

Future Use of TSA Coatings

In the future, the choice of coating type will depend much more on the life cycle cost associated with the coating. Construction costs and future maintenance costs in production will be taken into consideration. Important questions include the following:

- What is the lifetime for which the installation is designed?
- Are these areas requiring high temperature-resistant coatings?
- Are there coated areas that are impossible (very difficult/expensive) to maintain?

The most important parameter will be the design lifetime for the installation. If it is less than 25 years, then life cycle cost assessments will not favor the use of TSA for general corrosion protection, and it will be used only for protection at high temperatures and for special areas that are difficult to access.

Another important factor that can affect coating choice for offshore use and maintenance is the possibility that future health and environmental requirements may restrict the use of solvent-based paint products and zinc-containing paints to the extent that their large-scale use may be almost impossible. TSA coatings then would be a serious alternative to traditional paint systems, even for applications with short design lifetimes.

These considerations can be summarized as follows:

Platform Design Lifetime < 25 Years

- Flare booms
- Steel with operating temperatures of 60-450 Celsius

Platform Design Lifetime > 25 Years

- Flare booms
- Crane booms
- Crane pedestals
- Steel under cellar decks, including piping, etc.
- Steel with operating temperatures of 60-450 Celsius
- Piping and vessels that are thermally insulated
- Lifeboat stations

Summary

TSA coatings have not been introduced to the Norwegian offshore industry in order to take over from the traditional painting systems, but to exist as an additional coating type with good special properties.

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