Thermally Sprayed Metal

Metallising

Introduction

Sprayed metal coating using zinc, aluminium or alloys is used to protect steel against corrosion in aggressive environments. The metallic coating may be used as sole corrosion protection or in combination with organic coating systems (paint).

Scope

To describe the thermally sprayed metal process detailing the materials, heating sources, surface preparation of steel and the thickness of metallising.
Furthermore to explain best practice related to the painting over metal sprayed steel, like adhesion and appearance of the metallising before being painted, surface preparation to ensure good adhesion of the coating system, etc.

Description of metal spraying

Thermal metal spraying is the process where a metal is molten by a heat source followed by atomized into small droplets by compressed air and propelled to the substrate.



The metal for spraying may be in powder form or wire. Typically zinc, aluminium or their alloys are used. This is also called TSZ or TSA.

- Pure zinc
- Pure aluminium (for exposure to high temperatures)
- Zinc-aluminium alloy usually with 85% by weight zinc and 15% by weight aluminium

Various processes exist using different heat sources like flame, electric arc or plasma. Plasma is not treated in this article.

Before spraying the metal the substrate must be cleaned and prepared in such way that the adhesion of coating and substrate is optimized.

The steel substrate must be abrasive grit blasted to Sa 3, ISO 8501-1, and with an angular surface profile corresponding to grade Medium-Coarse G, ISO 8503 or BN10-BN11, RUGOTEST No. 3.

Flame spraying:
The coating metal is led to the spray gun either as powder or more often as wire. To the spray gun are also connected oxygen-acetylene hoses for the burner to melt the metal and a compressed air hose for spraying the metal. Despite the hoses and wire, the spray gun may be manipulated by one hand.

Arc spraying:
The coating metal is led as two wires to the spray gun. The two wires are connected to a rectifier, so an electric arc is formed between the wire ends, which melt and is blown by compressed air onto the steel.

From the paint coating's point of view there is no difference between the processes except when aluminium is used for high temperature protection. In that case, arc spraying is preferable due to better adhesion obtained between steel and aluminium.

Thickness of metallisation
Typically, the coating thickness range will be 40-200 micron/1.6-8 mils for zinc and zinc-aluminium alloy and 80-300 micron/3.2-12 mils for aluminium.
When top coated with paint, more than 100 micron/4 mils metal-sprayed coating is seldom specified.

An exception is when aluminium is used at temperatures up to 550°C/1022°F. In that case, 175-200 µm/7-8 mils arc sprayed aluminium is often used.

Key parameters influencing the performance of the coating

- **Temperature to melt the metallic particles**. Electric arc achieves significantly higher temperature than flame spraying. A higher temperature is beneficial to facilitate contact between metallisation and steel surface and achieve a good adhesion.

- **Spray Technique**. Distance to the substrate, spray angle and spray speed will have an influence on the conditions the particles being deposited on the steel surface. For instance long spray distance will reduce the speed of particles impacting with the substrate, particles will also arrive cooler over the steel (dry spray) leading to a reduced adhesion of the metalisation.

Painting metal sprayed substrate

Two philosophies exist on how metal sprayed coatings are to be painted:

- Norsok M501 eds. 6 distinguish between metallising with aluminium (system 2A) and zinc (system 2B).
  - 2A:
    Norsok recommends to only seal the aluminium metallising for service in CX environment. Following a number of cases of premature coating breakdown on metal sprayed aluminium in offshore service, a theory has been made that acidic aluminium chloride may be formed under the paint film (when overcoated with a full paint system). It is therefore recommended that for marine environments, metal sprayed aluminium surfaces should only be coated with a sealer. For more detail see ref 1.

- 2B:
  For zinc metallising Norsok's recommendation is 125µm epoxy + 75µm topcoat rather similar to ISO 12944.

- ISO 12944-5:2018 treats metallising with aluminium , zinc and alloys equally. The standard recommends to coat the metallising with a 160-240µm barrier system for C4, C5. See tables below for details. Application of a full paint system is done to protect the metal sprayed coating and the steel, so the metal sprayed coating is only brought in action when the paint coating is degraded.
  In CX environment aluminium metallising should only be sealed similar to Norsok 2A.

ISO12944-5: Categories C4/C5, Durability High and Very High

System No.	Corrosivity category	Sealer coat			Subsequent coat(s)	Paint system		Durability	
		Binder type	No. of coats	NDFT in µm	Binder type	No. of coats	NDFT in µm	h	vh
TSM 4.01	C4	EP, PUR	1	NA	EP, PUR	2	160	X	
TSM 4.02		EP, PUR	1	NA	EP, PUR	2	200	X	X
TSM 5.01	C5	EP, PUR	1	NA	EP, PUR	2	200	X	
TSM 5.02		EP, PUR	1	NA	EP, PUR	2	240	X	X

NA = Not applicable

The sealer shall fill the metal pores. It shall be applied until absorption is complete. There should not be measurable overlay of sealer on the metallic coating after application.

Systems in corrosivity category C2 and C3 are only considered relevant where special stresses are present in the form of high mechanical or thermal impact. Use DFT as for the relevant system for carbon steel.

Special care should be taken when overcoating thermal-sprayed aluminium in a chloride environment as premature failures have been documented. See also Reference [13].

In addition to polyurethane technology, other coating technologies may be suitable, e.g. polysiloxanes, polyaspartic and fluoropolymer [fluoroethylene/vinyl ether co-polymer (FEVE)].

NOTE For abbreviations see Table A.1.

ISO12944-9: Category CX

	Blast-cleaned carbon steel: Sa 2½; Surface profile: medium (G)							Hot-dip-galvanized steel or steel with thermal-sprayed zinc coating[a]
Type of environment according to 4.1	CX (offshore)		Splash and tidal zones CX (offshore) and Im4			Im4		CX (offshore)
Type of primer	Zn (R)[b]	Other primers	Zn (R)[b, c]	Other primers		Other primers		
NDFT (µm)	≥40	≥60	≥40	≥60	≥200	—	≥150	
Minimum number of coats[d]	3	3	3	3	2	1	2	2
NDFT of paint system (µm)	≥280	≥350	≥450	≥450	≥600	≥800	≥350	≥200
Minimum pull-off test value (before ageing) determined in accordance with ISO 4624, Method A or B[e] (MPa)[f]	5	5	5	5	5	8	5	5

[a] The thickness of the metallic coating shall be in accordance with ISO 1461 (hot-dip galvanized) or ISO 2063 (all parts) (thermal sprayed metal) and the metallic coating shall be prepared as specified in ISO 12944-4. Overcoating of thermal sprayed aluminium (TSA) is not recommended due to the risk of the overcoat flaking and corrosion of the TSA occurring. For TSA, a sealer coat only is recommended.

[b] Zn (R) = Zinc-rich primer as defined in ISO 12944-5.

[c] This coating system with an organic Zn (R) primer can also be used for Im4 service if a Zn (R) primer is desired. In this case, the NDFT of the complete system can be reduced to ≥ 350 µm.

[d] The number of coats does not include a tie coat, which might be needed when a Zn (R) silicate primer is used, for instance.

[e] It is required that the force built up is controlled and linear as described in ISO 4624, e.g. by using an automatic hydraulic test equipment

[f] Push-off adhesion testing is not permitted.

Surface preparation before painting
The appearance of the coating must fulfil the following requirements:

- Lumps and extremely coarse coating must be removed
- Oxidized and powdery coating must be removed
- Coating contaminated with compressed air impurities such as oil and water must be removed

Spray dust must be removed by vacuum cleaning

Metal-sprayed coatings should be overcoated as soon as possible to avoid formation of zinc and aluminium salts (corrosion products) from the very active surface. If done so, no further surface preparation is required.
If already exposed, high pressure hosing and removal of zinc/aluminium salts by stiff brushes, or in severe cases by abrasive sweep blasting, is required.

Sealing
Metallised substrates are (even more than zinc silicates) prone to "popping" when overcoated, and should therefore be painted in a similar way, i.e. using a special sealer coat or flash coat technique.

The higher the metal thickness, the more porosity and the higher tendency to popping.

Sealing is the application of a low viscosity, low solids paint or varnish intended to fill pores. Sealing may be done with dedicated sealer products or heavily diluted paint – usually the same material to be applied as barrier coating The sealer impregnates the porous metal sprayed coating with no measurable overlay, improves appearance, reduces dirt retention, and finally yet importantly allows the sprayed metal to actively protect the steel by galvanic action. Sealing may, however, be insufficient in polluted environments or when ultimate requirements to decorative properties are required.

Standards

- ISO 2063.- Thermal Spraying – Metallic and other inorganic coatings – Zinc, Aluminium and their alloys for the protection of iron against corrosion.
- ISO14919.- Thermal Spraying - Wires, rods and cords for flame and arc spraying – Classification; Technical supply conditions
- ISO14713.- Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures

References:

1. Knudsen and T. Rogne, T. Rossland :" Rapid degradation of painted TSA". NACE, Corrosion 2004, paper no. 04023.
2. Hempel's Coating Reference Handbook, page S5
3. Handbook of Thermal Spray Technology, Edited by J.R Davis

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