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Thermal spraying — Spraying and fusing of self-fluxing alloys

Projection thermique — Projection et fusion d'alliages autofondants

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 240, *Thermal spraying and thermally sprayed coatings,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 14920:2015), which has been technically revised.

The main changes are as follows:

— materials which can and can’t be used for fusing have been clarified;

— grit blasting material has been defined;

— spray methods and their influence coating quality have been specified.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Thermal spraying — Spraying and fusing of self-fluxing alloys

1 Scope

This document specifies the procedure for thermal spraying of self-fluxing alloys that are simultaneously or subsequently fused to create a homogeneous, diffusion-bonded coating.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13507, *Thermal spraying — Pre-treatment of surfaces of metallic parts and components for thermal spraying*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Influence on the substrate and design

4.1 Substrate

Due to the heat transfer into the substrate metal when fusing the coating, in order to bond the coating with the substrate by diffusion, the following possible effects of such heating on the substrate metal shall be considered:

a) scaling;

b) the need to stress relieve;

c) an irreversible transformation of the mechanical and/or metallurgical properties.

Martensitic steels are susceptible to stress cracking and alloys containing significant amounts of C, Al, Ti, Mg, S, sulfides, P and nitrogen can create porosity in the coating and can render the substrate metal liable to stress cracking.

When “self-fluxing alloys” are utilized with fusing, there are additional restrictions on the coatable base materials. Austenitic steels (both non-magnetic and stainless as well as chromium-nickel steel) can be fused without any structural transformation during sintering. Other metals must have melting points which should be well over 1 200 °C.

Ferritic steels (magnetic) can only be utilized if they are not higher-alloyed heat-treatable steels. This means that the alloying constituents should not exceed upper limiting values. Empirical values for the upper limiting values on alloying constituents are: C = 0,5 %; Cr = 5 %; Ni = 4 %; W = 3 %; Mo = 3 %.

4.2 Design

If pre-machining is carried out prior to spraying and fusing of a coating, there will usually be a reduction of the design dimensions. Consideration shall be given to the effect of such a reduction on the loading of the component, as the coating does not contribute to the strength of the component. Consideration shall be given to the fact that the sprayed and fused coating will have differing physical properties to the substrate material.

The fatigue strength, the deformation resistance and other properties of the component can be affected by the application of the coating.

Due to the heat input during fusing, unacceptable deformation of the component can occur. Measures to prevent distortion or deformation can be used, such as to erect or hang the parts along their centre-of-gravity axis or by using supporting jigs.

5 Spray material of the self-fluxing alloy

5.1 Selection

The properties of the coating are determined by the selection of the spray material and the spray and fuse procedure, for example:

a) hardness;

b) resistance to wear and/or corrosion;

c) machinability;

d) suitability for the foreseen application.

5.2 Composition

The chemical composition of the spray material and the structure of the coating determine its metallurgical and technological properties as well as its machinability.

For substrate alloys, which can create a martensitic structure, see 7.3.5.

Table A.1 contains reference values for the expected hardness of the fused coating.

6 Preparation of the component

6.1 General

6.1.1 Surface cleanliness

All components to be coated shall be free from surface contamination such as oil, grease, rust and other dirt. Particular attention shall be paid to porous components, because oil and grease can exude out of the pores during the preheating or coating process.

6.1.2 Removal of prior surface treatments

To ensure a quality control of the parts, it is possible to do a dye penetrant inspection operation before surface preparation, if cracking sensitive alloys are used. It is important to make sure all traces of penetrant material are removed before further processing.

6.1.3 Pre-machining requirements

Any prior surface treatments (e.g. nitriding, galvanic or other protective coatings) shall be removed before the preparation of the surface to be coated.

6.1.4 Surface preparation requirements

If the area to be coated and the bordering areas of the component are to be machined, then this preparation shall be suitable for the coating process. Recommendations for suitable designs are given in ISO 12679.

Where the coating is required to terminate at a point other than the end or edge of the component, the depression shall be machined to provide an angle of 30° to 40° at each end, blending smoothly with the adjoining surface. Alternatively, if the coating can be continued around a chamfered and/or rounded edge, the risk of spalling of the coating will be reduced.

Where the coating shall finish to a square edge, the component shall be left longer than the proposed finished overall size and the excess shall be machined off after finishing the coating process.

6.2 Methods of surface preparation

6.2.1 Surface preparation requirements

Surface preparation shall be carried out in accordance with EN 13507.

The surface to be coated should be grit blasted using suitable angular grit in accordance with ISO 11124-1 or ISO 11126-1.

The choice of the grit blasting material can influence the bond strength of the coating. The preferred grit blasting material is sharp-edged steel grit or chilled iron. Ceramic grits can be used, but if a ceramic grit is used and becomes embedded in the blasted surface, coating defects can occur after fusing. The embedded ceramic can degas at fusing temperatures which will lead to the creation of pores in the fused coating.

6.2.2 Surface preparation inspection

The grit blasting operation shall be confined to the area to be coated. The adjacent areas shall be masked, so that the surfaces will not be damaged and will not be coated later. The masking material shall resist the grit blasting and shall not contaminate the prepared surface to be sprayed.

6.2.3 General masking of surface preparation

Masking material, intended to prevent the adherence of spray particles, shall be able to withstand preheating, spray particle impact and temperatures.

6.2.4 Plug masking for surface preparation

Drilled holes and other orifices, which are required not to be grit blasted and coated, shall be plugged. Plugs of steel or rubber are recommended for this purpose; they shall be shaped and positioned in such a manner as not to mask any part of the surface to be prepared. After grit blasting the plugs shall be replaced with pieces of carbon suitably shaped to prevent ingress of the coating material. They shall protrude with their top surface to be caught for subsequent machining.

6.3 Cleanliness

After preparation, the surface to be coated shall not be contaminated with oil, grease, water or fingerprints. In the case of contamination, the surface shall be completely re-prepared.

7 Spray and fusion process

7.1 Spraying with simultaneous fusion

7.1.1 Procedure

This operation of spraying with simultaneous fusion is carried out manually using an oxy/acetylene torch, which is fitted with a hopper for the spray powder.

A suitable self-fluxing powder is fed from the hopper into the gas stream and heated by the flame, accelerated and sprayed to the component, where it is simultaneously fused to the substrate metal. Using this continuous process a coating is created, whose properties depend on the self-fluxing powder used.

7.1.2 Particle size and particle size range of the powder particles

The suitable grain size and the particle size range depend on the design of the powder feed system. In order to avoid powder feed restrictions and blockages, the powder size range recommended by the torch supplier shall be used.

7.1.3 Coating thickness

A limitation on deposit thickness is dependent on the chosen alloy, the required coating quality, and the acceptable residual stresses, which will increase with deposit thickness.

NOTE Spraying and fusing of thicker coatings demands higher skill from the executing operator.

7.2 Spraying with subsequent fusion

7.2.1 Procedure

For spraying and subsequent fusion, the procedures of spraying and fusion are separated. Both procedures can be manual or mechanized. Usually, spraying is carried out using powder flame spraying (PFS), high velocity oxygen fuel (HVOF) flame spraying and wire or cord spraying (WFS).

A suitable self-fluxing material is transported into the fuel gas oxygen jet, heated and accelerated by the flame and sprayed onto the component until the desired coating thickness is achieved.

Fusion of the deposit is a separate operation, which shall be carried out as soon as possible after spraying using one of the following methods:

a) manually, using an oxy/acetylene torch with suitable capacity;

b) by inductive heating;

c) by fusion in a furnace under vacuum or in an inert gas atmosphere;

d) with a laser beam;

e) by another heating processes.

7.2.2 Particle size and particle size range of the powder particles

The suitable grain size and the particle size range depend on the design of the powder feed system. To avoid powder feed restrictions and blockages, the grain size and the powder size range recommended by the spraying equipment supplier shall be used.

7.2.3 Coating thickness

A limitation on deposit thickness is dependent on the chosen alloy, the required coating quality, and the acceptable residual stresses. Usually, the coating thickness is limited to 1,6 mm with 1 mm being preferred.

The deposit should be approximately 25 % thicker in the as-sprayed state to allow for shrinkage during fusion. If the coating needs to be applied onto complex geometries or with thickness limitations, a preferred application method can be via HVOF spraying. The use of this process tends to reduce the amount of shrinking allowance detailed in 7.3.3.

7.3 Spraying technique — Procedure

7.3.1 General

The thermal spraying of the coating shall be started immediately after the surface preparation and before any visible deterioration of the surface has set in (moisture, coat, oxidation, etc.).

7.3.2 Preheating

The surface to be sprayed shall be pre-heated immediately before spraying. The pre-heating temperature depends upon the composition of the substrate. When preheating, contamination or local overheating of the surface shall be avoided.

7.3.3 Spraying

Spraying shall be continuous until the coating reaches the required thickness including the shrinkage allowance of 20 % to 25 %. After spraying there shall be no visible evidence of defects, such as cracks, lifting of the deposit, blisters, spalling on edges or at the end of the coating. If defects are detected, the sprayed coating shall be removed completely, and the preparation and the thermal spraying shall be repeated.

7.3.4 Fusing the deposit

The deposit shall be heated to a temperature within the melting range of the selected self-fluxing alloy and fused. The heating shall be such that the interface between the self-fluxing alloy and the substrate reaches the fusing temperature to ensure a complete melting of the coating and rapid diffusion.

Fusing can be performed manually or be mechanized using an oxy-acetylene torch, or can be mechanized by induction heating, laser beam or in a vacuum or shielding gas furnace.

The heating rate and the duration within the temperature range depend upon the composition of the coating alloy and of the size and complexity of the component. Prolonged heating within the fusion range shall be avoided to prevent excessive diffusion between the coating and the substrate and to avoid deformation of the component and/or of the coating.

When the correct fusion temperature is reached, it is indicated by the appearance of the coating, which exhibits a marked increase in reflectivity, generally known as a “wet shine”, and is visible when employing manual or partly mechanized fusion. The fusion area of the sprayed surface shall exhibit this wet shine. If heated by a torch or induction coil, the heat source should be moved progressively over the surface of the part to continue this wet shine. Usually when melting in a furnace, this wet shine is not visible. In case of doubt, the suitable fusion temperature shall be determined by tests. Exceeding the ideal temperature point can lead to dripping of the coating and to damaging the furnace. The appearance of a local hot spot during fusion indicates a local coating or bonding defect. In this case, the coating shall be rejected.

7.3.5 Cooling

After fusing, to avoid undue stresses, creating cracks and/or distortion, cooling shall be retarded. This can be achieved by packing the component in an insulating material or by a controlled cooling in a furnace.

If substrates are coated, which are subjected to a martensitic change when cooling down from the fusion temperature, specialized cooling procedures will be necessary. A subsequent heat treatment can be necessary to restore the technological and mechanical properties of the substrate metal.

8 Final machining

Machinability depends upon the properties of the self-fluxing alloy. Information regarding machining of fused coatings is given in ISO 14924.

If the recommendations in ISO 14924 are not sufficient to solve the machining task, advice from a manufacturer of machining tools should be sought.

Because adjacent areas or the whole component will also be brought to high temperature to fuse the coating, the coating and fusion process and further heat treatments, if necessary, should be completed before carrying out the final machining of other areas.

9 Hardness testing

9.1 General

The spray material is often selected with respect to the achievable hardness rather than according to the chemical composition.

Table A.1 shows examples of expected hardness values. If necessary, a different alloy not listed may be agreed upon between the customer and the supplier, which meets the required hardness and the valid supply specifications. In case of doubt, test coatings shall be produced to meet the defined hardness range using the selected powder.

9.2 Standard hardness test

9.2.1 Test piece properties: 50 mm × 50 mm × 6,0 mm to 6,5 mm made out of unalloyed carbon steel.

9.2.2 Test piece preparation: edges of test piece should have a 2 mm chamfer.

The powder sample shall be representative of chosen batch.

9.2.3 Spray technique: use spray torch with foreseen parameter setting for the application and spray a deposit of uniform thickness of 1,0 mm to 2,0 mm.

9.2.4 Fusing technique: fusing shall be carried out using the expected procedure for the application (see 7.3.4).

9.2.5 Cooling: the test piece shall be cooled by packing in insulation material, by controlled cooling in a furnace or in still air to below 500 °C.

9.2.6 Preparation for hardness test:

— Level the underside of the test piece first by grinding or linishing (test piece can be deformed).

— Machine the test face to a smooth and even finish to get a test area of about (20 × 20) mm (grinding or milling with hard metal tool), so that a minimum coating thickness of 1 mm remains.

A minimum of seven readings, 8 mm apart, shall be taken. Discard the highest and lowest readings and take an average of the remaining five. The mean value and/or the range can be taken as a requirement into the supply specification.