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**Thermal spraying — Recommendations  
for thermal spraying**

*Projection thermique — Recommandations pour la projection thermique*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12679 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

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## Introduction

Thermal spraying encompasses processes used in the production of coatings and free-standing bodies for which spray materials are surface-melted, melted off or melted and then propelled onto suitably prepared workpiece surfaces. The workpiece surfaces are not surface-melted. In order to achieve specific coating properties, the spray coating can undergo additional post-treatment, either thermal or otherwise, for example, sealing.

Thermally sprayed coatings serve to improve the surface properties of a workpiece by manufacturing or repair operations. This can be done, for example, in relation to wear, corrosion, heat transfer or heat insulation, electrical conductivity or insulation, appearance and/or for restoring the part to working order. In certain cases, a spray coating can render a surface solderable.

Chiefly due to their bonding mechanism, thermally sprayed coatings without thermal post-treatment can be distinguished from coatings applied with other processes, such as deposition welding, brazing, physical vapour deposition (PVD) or chemical vapour deposition (CVD).

The advantages of thermal spraying are the following.

- The workpieces to be coated are only slightly heated so that distortion and any other undesired structural changes to the parent material are avoided. This does not apply if the coatings are thermally treated during or after the spraying process.
- The application is not dependent on the size of the workpiece or component. The operation can be stationary or mobile depending on the spraying process.
- Even geometrically complex components can be coated using the appropriate spray set-up.
- The untreated surface of spray coatings generally provides a good bond coat for painting.
- Depending on the spraying process and spray material, different coating thicknesses can be applied, although a coating thickness of approximately 10 µm is currently considered to be the lower limit.

Process-related disadvantages are as follows:

- the bond strength of thermally sprayed coatings without thermal post-treatment derives from adhesive forces only;
- the bond strength can be influenced due to an expansion mismatch between the coating and substrate material, especially in the case of a high operation temperature;
- spray coatings are micro-porous;
- the thicker the spray coating, the higher the residual stresses in the coating, and the degree of multi-axial stress thus increases;
- spray coatings without additional thermal post-treatment are sensitive to edge pressure, localized and linear loads and to impact stresses;
- there are restrictions in relation to the geometric dimensions, for example, for the inner coatings of workpieces whose inner diameter is too small.

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# Thermal spraying — Recommendations for thermal spraying

## 1 Scope

This International Standard includes general guidelines for the workmanlike production of metallic, metal-ceramic, oxide-ceramic and plastic coatings, by means of thermal spraying on metallic and non-metallic parent materials.

This International Standard provides recommendations for an appropriate and practical spray set-up, faultless manufacturing, monitoring, quality assurance and for non-destructive and destructive tests on the component and accompanying specimen. It describes details about negative effects which can occur. It also gives advice on how to prevent such effects.

Permissible coating loads and evaluation categories for quality are not the subject of this International Standard, as they are dependent on the operating conditions.

This International Standard can be used for contract purposes.

## 2 Normative references

The following referenced documents are indispensable for the application 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.

ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 14231, *Thermal spraying — Acceptance inspection of thermal spraying equipment*

ISO 14232, *Thermal spraying — Powders — Composition and technical supply conditions*

ISO 14918, *Thermal spraying — Approval testing of thermal sprayers*

ISO 14919, *Thermal spraying — Wires, rods and cords for flame and arc spraying — Classification — Technical supply conditions*

ISO 14920, *Thermal spraying — Spraying and fusing of self-fluxing alloys*

ISO 14921, *Thermal spraying — Procedures for the application of thermally sprayed coatings for engineering components*

ISO 14922-1, *Thermal spraying — Quality requirements of thermally sprayed structures — Part 1: Guidance for selection and use*

ISO 14922-2, *Thermal spraying — Quality requirements of thermally sprayed structures — Part 2: Comprehensive quality requirements*

ISO 14922-3, *Thermal spraying — Quality requirements of thermally sprayed structures — Part 3: Standard quality requirements*

ISO 14922-4, *Thermal spraying — Quality requirements of thermally sprayed structures — Part 4: Elementary quality requirements*

ISO 14923, *Thermal spraying — Characterization and testing of thermally sprayed coatings*

ISO 14924, *Thermal spraying — Post-treatment and finishing of thermally sprayed coatings*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

#### 3.1

##### **shot-peening effect**

pressure strengthening by grit-blasting

#### 3.2

##### **sound pressure level**

mean value of emitted sound

NOTE Sound pressure level is measured in decibels (dB).

#### 3.3

##### **etching**

removing of surface material

NOTE Etching can be applied using liquid agents (wet chemical etching) or using gases in a recipient (dry etching, plasma etching). The etching agent reacts chemically with the substrate.

#### 3.4

##### **ion-etching**

material removed by shooting the surface with high-energetic particles like ions

NOTE The ions cut off material at the impact point. The procedure is used in plasma technology application (vacuum coating technology).

#### 3.5

##### **corona discharge**

dielectric discharge in air after exceeding the break-down field intensity; air molecules will be ionized by generating short-living ozone

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### 4 Parent material

Virtually every kind of solid-state material can be coated by means of thermal spraying, provided its surface is suitably prepared. The achievable bond strength of the coating to the substrate is dependent on the spray material, spraying process and the physical and technological properties of the parent material used. The bond strength, amongst other things, is particularly influenced by the thermal conductivity of the parent material in comparison to the conductivity of the spray coating and the state of the parent material's surface. In general, hardened materials need a bond coat to give adequate bond strength. The possible coating thickness may be limited, depending on the bonding material being used. Certain surface-hardening processes, e.g. "nitriding", may leave gaseous inclusions which would prevent proper bonding.

A variety of plastics, as well as glass and paper, can be thermally sprayed when using the appropriate spraying process and a surface treatment method adapted for the respective material.

As the workpieces to be coated by means of thermal spraying are generally only slightly heated, undesired structural changes to the parent material and changes to the component's geometry due to distortion are avoided to the greatest possible extent. However, distortions resulting from intensive grit-blasting during surface preparation, especially with thin-walled parts or as a result of residual compressive stresses on the surface of the substrate caused by process-related shot-peening effects, can occur. If coatings are thermally treated during spraying (processes with simultaneous fusing) or subsequently, undesired structural changes and significant geometric changes can occur.

For purposes of quality assurance during the manufacturing process, the parent materials and components to be coated should be stored in such a way that damage and/or undesired changes to the shape or surface are avoided.



## 5 Component geometry

The application of thermal spraying is independent, to the greatest possible extent, of the size of the workpiece or component to be coated. This is mainly true for flame and arc spraying. For plasma and HVOF (high-velocity oxygen fuel) spraying, closed-off spray booths are normally required due to the high noise and dust emissions. As a result, there may be restrictions to size of the component.

Certain prerequisites concerning the practical set-up shall be considered when using thermal spraying. If these rules are followed, even complex geometric parts can be coated with expertise. The most important rules can be summarized as follows:

- the area to be coated shall be accessible to the spray gun with all its electrical and/or gas connections, and the necessary spray distance and spray angle shall be maintained;
- sharp edges should be avoided; they cannot be covered with a spray coating;
- narrow radii should be avoided, otherwise turbulence in the spray jet can occur, which can lead to unsatisfactory coatings in terms of bond strength and density;
- problems with turbulence and undesired, loose particles sticking to the walls occur especially when spraying in narrow bores or blind holes;
- to prevent the coating from spalling, it has proved advantageous to pull the coating around rounded or chamfered edges;
- the arguments listed for thermal spraying, i.e. accessibility, sharp edges, narrow radii, bores and blind holes, also apply to grit-blasting when preparing the surface to be sprayed.

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## 6 Spray materials

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### 6.1 General <https://standards.iteh.ai/catalog/standards/sist/f2e30d80-49dd-4917-911e-39d0eb8ae8f8/iso-12679-2011>

The spray materials used for thermal spraying cover a wide range of very different materials. It is virtually possible to spray any material which can be produced as a solid wire, cored wire, rod, cord or powder, and which does not sublime in the arc or plasma or decompose when passing through the flame. In the special case of molten-bath spraying, the material is processed in its liquid state.

Generally, the following spray materials can be used for thermal spraying:

- metals and metal alloys;
- metal ceramics;
- hard phases embedded in a matrix material;
- oxide ceramics, plastics, as well as various hybrid materials.

### 6.2 Selection of spray materials

An important task for the designer and/or person responsible for the spray technology is the selection of the spray material which is most suited to the application. Fundamental to the selection are the demand's profile of the coating, the subsequent operating conditions and the most suitable spraying process. Corrosion and/or wear loads, for example, can determine the demand's profile. The operating conditions in a tribological system can be determined by an increased operating temperature or by operating temperatures which fluctuate in level and, in some cases, also in speed. The most suitable spraying process distinguishes itself in terms of its ability to fulfil coating requirements, such as density, bond strength, porosity, purity, etc. Here, the relevant process data, such as temperature level in the flame, in the arc or in the plasma, the dwell time of the spray particles in the hot zone and the particle velocity in flight and on impact on the substrate, play a decisive role.

The most important spray materials have been standardized. The following are specified in standards: chemical composition of the material and its supply form as powder with its special features based on the manufacturing process, particle shape and particle size distribution, or as wire, rod or cord.

The following International Standards apply:

- for powder: ISO 14232;
- for wires, rods and cords: ISO 14919.

### 6.3 Supply, handling and storage

The supply form and its constancy from batch to batch, especially with spray powders, plays a fundamental role in ensuring a uniform quality for the finished coating. For this reason, it is recommended that manufacturing, supply and distribution be assessed and monitored by a suitable quality-management system. Details concerning such a procedure are described in EN 12074.

## 7 Gases for spraying

Industrial gases are used in all thermal spraying processes. Depending on the spraying process, these gases or their mixtures are employed as a fuel, combustion accelerator, plasma gas, shroud gas, propelling or atomizing gas, powder-feed gas, or for cooling the part to be coated or even the spray gun.

The physical and chemical characteristics of the industrial gases used for thermal spraying differ quite markedly from each other. Paying attention to these parameters, a gas or gas mixture, which fulfils the process and material requirements, can be selected for any thermal spray application.

The following gases are mainly used:

- as a fuel gas: acetylene (C<sub>2</sub>H<sub>2</sub>), propane (C<sub>3</sub>H<sub>8</sub>), propylene (C<sub>3</sub>H<sub>6</sub>), ethene (C<sub>2</sub>H<sub>4</sub>), hydrogen (H<sub>2</sub>), natural gas;
- as a plasma gas: argon (Ar), helium (He), hydrogen (H<sub>2</sub>), nitrogen (N<sub>2</sub>) and their mixtures;
- as a combustion accelerator: oxygen (O<sub>2</sub>);
- as a shroud gas: argon (Ar), nitrogen (N<sub>2</sub>);
- as a propelling or atomizing gas: compressed air, nitrogen (N<sub>2</sub>), argon (Ar);
- as a powder-feed gas: argon (Ar), nitrogen (N<sub>2</sub>);
- for cooling: compressed air, carbon dioxide (CO<sub>2</sub>).

Depending on the spraying process and the purpose of the application, varying high-purity levels are demanded of the gases. The gas producer is responsible for the gas purity whose level shall then be maintained at the user's premises during the filling process, transport and withdrawal, and in the pipeline system.

In general, it is sufficient to indicate the purity of the gases used in thermal spraying with numerical values according to the number of "nines" before and after the point (4,6 = 99,996 %). Typical gas purities for thermal spraying are:

- |            |     |
|------------|-----|
| — Ethene   | 3,5 |
| — Oxygen   | 3,5 |
| — Hydrogen | 3,0 |
| — Nitrogen | 4,6 |
| — Argon    | 4,6 |
| — Helium   | 4,6 |

For plasma spraying in particular, the purity of the gases has a big influence on the lifetime of the nozzle electrode system.

## 8 Liquid fuels for spraying

In several applications, the high-velocity flame spraying process is applied using liquid fuels, e.g. kerosene, *N*-paraffin, test benzene or petroleum. A low sulfur content has to be kept due to environmental reasons. Flash point, evaporation point and purity have to be considered, as well as additional instructions from the equipment supplier.

## 9 Spray equipment

### 9.1 General

The thermal spray equipment includes the spray device with all the electrical and gas supply and regulating equipment, possibly the handling system, plus the peripheral installations such as exhaust and filter systems, spray booth and soundproofing. Modern installations often include additional equipment for monitoring spray parameters and motion sequences by means of video cameras.

### 9.2 Spray device

The spray device is defined in ISO 14917 as the equipment required for thermal spraying.

Guidelines can be found in ISO 14231 for the qualification of the spraying installation including the transport system for the spray material. ISO 14231 can also be consulted when monitoring the state of the thermal spraying installation.

### 9.3 Mechanical equipment, rotating devices, handling systems, robots

In addition to the spray parameters for melting and melting off and for the transport of the spray material, the distance, setting angle and relative motion between the gun and workpiece have a decisive influence on the quality of the spray coating. In order to maintain these parameters as closely as possible, a mechanized spraying process should be used wherever possible rather than a manual one.

A handling system should fulfil the following requirements:

- capable of movements, speed and positioning with accuracy values appropriate to the application;
- sufficient static and dynamic loading capacity;
- stabilization of spray distance;
- non-susceptibility of control and regulation systems to influences from spray operation, for example, when igniting the plasma burner, and in relation to spray dust and heat from the flame, arc or plasma jet;
- simple and straightforward setting and programming of the handling system or rotating device.

### 9.4 Essential auxiliary equipment

Auxiliary equipment essential for thermal spraying includes equipment for cooling the burner system and possibly the energy supply, too, for cooling the workpiece and/or the coating, for detecting, removing by suction and transporting the spray dust, collecting the spray dust in a suitable filter system which, at the same time, releases the exhaust air mixed with the combustion or plasma gas residue into the atmosphere, safely and in compliance with environmental regulations. The spray booth and sound-proof chamber are also essential components of the auxiliary equipment.

The peripheral equipment, especially for detecting and removing the spray dust, can also influence the quality of the spray coating by acting upon the spray jet and the safe discharge of rebounded spray particles. For this reason, this equipment should always be kept in good working order.