INTERNATIONAL STANDARD

ISO 14917

Second edition
2017-03

Thermal spraying — Terminology, classification

Projection thermique — Terminologie, classification

Reference number
ISO 14917:2017(E)

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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 documents 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*.

This second edition cancels and replaces the first edition (ISO 14917:1999), which has been technically revised.

Introduction

Requests for official interpretations of technical aspects of this document should be directed to the Secretariat of ISO/TC 107, *Metallic and other inorganic coatings*, via your national standards body; a listing of these bodies can be found at www.iso.org.

Thermal spraying — Terminology, classification

1 Scope

This document defines processes and general terms for thermal spraying. It classifies thermal spraying processes according to type of spray material, to type of operation and to type of energy carrier. It specifies abbreviations for spray processes, sprayed coatings, and manufacturing steps.

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.

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*

ISO 17836, *Thermal spraying — Determination of the deposition efficiency for thermal spraying*

3 Terms and definitions

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

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

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

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

3.1
thermal spraying
TS
process in which surfacing materials are heated to the plastic or molten state, inside or outside of the spraying gun/torch, and then propelled onto a prepared surface

Note 1 to entry: The substrate may undergo some localized surface melting in the particle impact area only.

Note 2 to entry: To obtain specific properties of the deposit, a subsequent thermal, mechanical or sealing treatment may be used.

4 Process variations

4.1 Classification according to the type of spray material

Distinction of the following variations:

— wire spraying;

— rod spraying;

— cord spraying;

— powder spraying;

— suspension spraying.

4.2 Classification according to the operation

4.2.1 Manual spraying

All operations typical of the spraying process are manual.

4.2.2 Mechanized spraying

All operations typical of the spraying process are mechanized.

4.2.3 Automatic spraying

All operations typical of the spraying process are fully mechanized including all handling, e.g. workpiece loading and unloading, and are integrated in a programmed system. Also, monitoring and controlling of the entire spraying process can be included according to the closed loop method.

4.3 Classification and abbreviations for thermal spraying, coatings and their technological properties, post-treatments

4.3.1 Thermal spraying, coatings and properties

See Table 1.

Table 1 — Thermal spraying, coatings and properties (abbreviations in capital letter)

Abbreviation	Item	Specified in section	Specified in a standard
TS	Thermal spraying (in general)	3.1	—
BC	Bond coat	6.4.3	—
TC	Top coat	6.4.4	—
SF	Self-fluxing alloy		ISO 14920/ISO 14232
DE	Deposition efficiency	6.3.16	ISO 17836
R_H	Tensile adhesive strength	6.5.1	ISO 14916

4.3.2 Condition of spray coatings and post-treatments

See Table 2.

Table 2 — Condition of spray coatings and post-treatments (abbreviations in small letters)

Abbreviation	State	Specified in standard resp. described in section
as	as sprayed	6.4.1
f	fused	ISO 14920
sm	linished	ISO 14924
m/c	machined	ISO 14924
s	sealed	ISO 14924

4.3.3 Classification according to the energy carrier and/or to the type of spray material — Abbreviations for spray processes and special surfacing processes by welding

In classification according to the energy carrier, sub-classifications are necessary due to different spray materials. Figure A.1 provides a master chart of the spray processes with sub-classifications. See also Tables 3 and 4.

Table 3 — Classification and abbreviations of spray processes (abbreviations in capital letters)

Standard spray processes		Process abbreviations	Process description in section
TS by means of gaseous or liquid fuels	**Flame spray processes**		5.1
	Wire flame spraying (Combustion wire spray)	WFS	5.1.2
	Cord flame spraying	CFS	5.1.2
	Rod flame spraying	RFS	5.1.2
	Powder flame spraying	PFS	5.1.3
	High velocity flame spraying		5.2
	High velocity oxy-fuel spraying	HVOF	5.2.1
	High velocity air fuel spraying	HVAF	5.2.1
	High velocity flame suspension spraying	HVFSS	5.2.3
	Detonation spraying (Detonation gun spr.)	DGS	5.2.4
TS by means of expansion of highly pressurized gases without combustion	Cold spraying (Cold gas spraying)	CGS	5.3
TS by means of electric arc or gas discharge	Arc spraying (Arc wire spraying)	AS	5.4
	Atmospheric plasma spraying	APS	5.5.1
	Atmospheric plasma suspension spraying	APSS	5.5.2
	Vacuum plasma spraying/ Low pressure plasma spraying Controlled atmosphere plasma spraying	VPS (Europe) LPPS™ (US, Asia)[a] CAPS	5.5.3
TS by means of electric arc or gas discharge (only few users)	Water-stabilized plasma spraying	WSPS	5.6.1
	Inductively coupled plasma spraying	ICPS	5.6.2
	Plasma transferred wire arc spraying	PTWA	5.6.3

[a] LPPS™ is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Table 4 — Classification and abbreviations of special surfacing processes by welding (abbreviations in capital letters)

Special surfacing processes by welding		Process abbreviations	Process description in section
Surfacing by means of a bundled beam of light	Laser cladding	LC	5.7
Surfacing by means of electric arc or gas discharge	Plasma transferred arc surfacing	PTA	5.8

5 Process descriptions

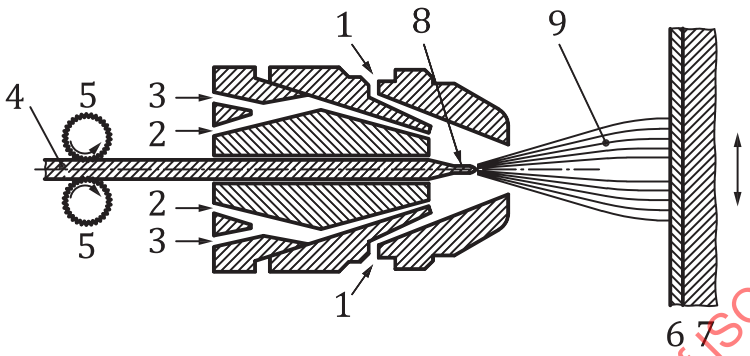
5.1 Flame spraying

5.1.1 General

Flame spraying is a process in which a surfacing material is heated in an oxy-fuel gas flame and then propelled onto a substrate. The material may be initially in the form of powder, rod, cord or wire. The hot material is projected onto the substrate by the oxy-fuel gas jet alone or with the additional aid of an atomizing gas, e.g. compressed air.

5.1.2 Wire flame spraying (Combustion wire spray)

In wire flame spraying, the metal wire (solid or cored wire type) to be deposited is supplied to the gun continuously. It is heated to the molten state by the oxy-fuel gas flame and propelled onto the prepared substrate surface by the additional aid of an atomizing gas, e.g. compressed air. See Figure 1.



Key

1 compressed air
2 fuel gas
3 oxygen
4 wire cord or rod
5 wire feed mechanism
6 spray deposit
7 substrate
8 melting wire tip
9 spray stream

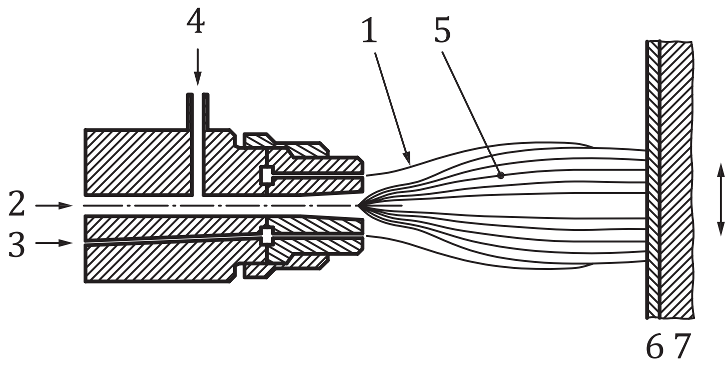
Figure 1 — Wire flame spraying

The fuel gases predominantly used are acetylene, propane and hydrogen.

Variations are rod flame spraying (RFS) where cut lengths of material rod are used, and cord flame spraying (CFS) where cords of surfacing material are used.

5.1.3 Powder flame spraying

With this method, the material to be sprayed is supplied to the gun in powder form and heated to the plastic or partially or completely molten state in the oxy-fuel gas flame. It is propelled onto the prepared substrate by the expanding fuel gas. In some cases, an additional gas jet may be used to accelerate the powder particles. See Figure 2.



Key

1 flame
2 fuel gas
3 oxygen
4 powder and carrier gas
5 spray stream
6 spray deposit
7 substrate

Figure 2 — Powder flame spraying

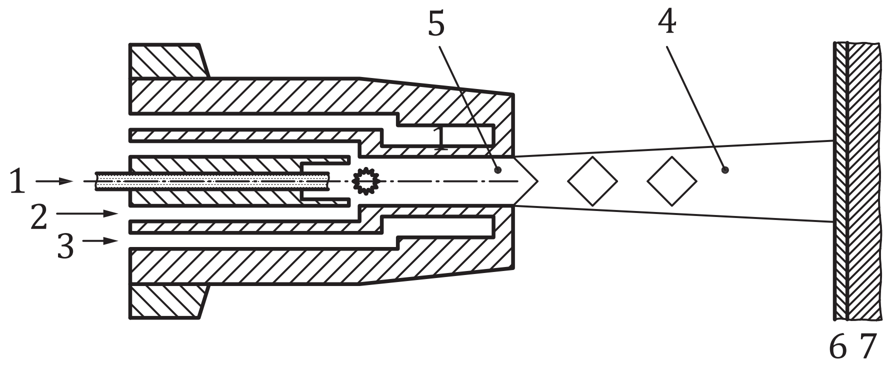
5.2 High velocity flame spraying

5.2.1 High velocity flame spraying with gaseous fuel

In high velocity flame spraying, continuous combustion is obtained in the combustion chamber which, in conjunction with the expanding nozzle, produces an extremely high velocity in the gas jet. The spray material is injected axially into the combustion chamber or radial into the high velocity gas stream. Pressurized air or nitrogen is commonly used as shroud gas.

The location of the powder injector will result in a different dwell time in the flame, which will affect the particle velocity and temperature. Coatings of high density and adhesion are produced by the high kinetic energy imparted to the spray stream. See Figure 3.

Fuel gases like acetylene, propane, propylene, methyl-acetylene-propadiene and hydrogen can be used in conjunction with oxygen (HVOF) or air (HVAF) in order to create the combustion.



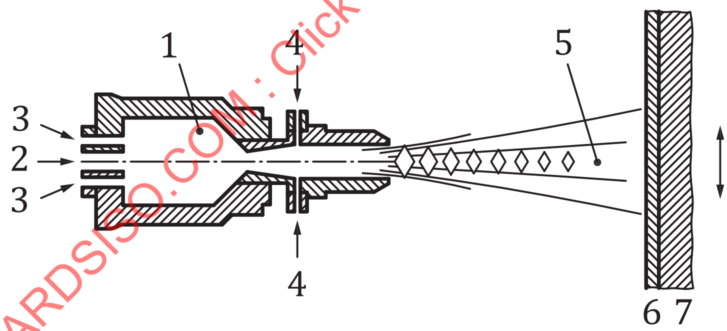
Key

1 powder and carrier gas
2 oxygen fuel resp. air fuel
3 burner cooling (water or air)
4 spray jet
5 combustion
6 spray deposit
7 substrate

Figure 3 — High velocity flame spraying with gaseous fuels

5.2.2 High velocity flame spraying with liquid fuel

In high velocity flame spraying with liquid fuel like kerosene, N-paraffin[1)], etc., higher combustion pressure is created as compared to spraying with gaseous fuel. The spray powder is radially injected at a position where the combustion gases are already fully expanded and somewhat cooled down. This creates coatings of higher density and higher adhesive strength values. Occasionally, residual compressive stresses may be created in the coating. See Figure 4.



Key

1 combustion chamber
2 liquid fuel
3 oxygen/air
4 powder and carrier gas
5 spray stream
6 spray deposit
7 substrate

Figure 4 — High velocity flame spraying with liquid fuel

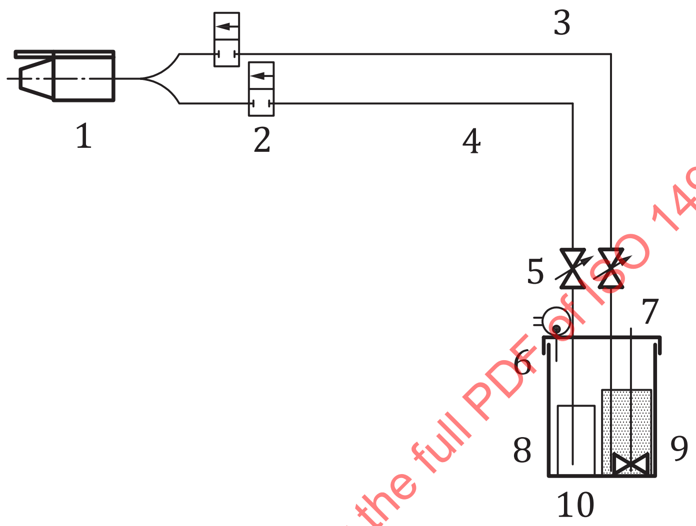
5.2.3 High velocity flame suspension spraying

Suspensions represent an alternative feedstock material. Use of suspensions focuses mainly on APS and HVOF spraying. Their use is currently emerging. Suspensions are mostly based on water and alcohol

1) N-paraffin is in common use in US.

and contain finely dispersed powders with grain sizes ranging from nanometres up to about 5 µm to 10 µm. Thus, materials can be used which would otherwise not be sprayable in this size. These are predominantly oxides, such as alumina, zirconia and titania.

Injection of the suspension (radially or axially) into the spray gun depends on its construction principles; axial injection can be more easily realized for HVOF processes. The general principle is that the liquid is fragmented through an atomization process into small droplets. The liquid is then evaporated and the resultant particles are melted or partially melted and accelerated onto the substrate where they will form the coating. These fine particles show a different behaviour concerning splat formation as compared to traditional thermal spray materials. See Figure 5.



Key

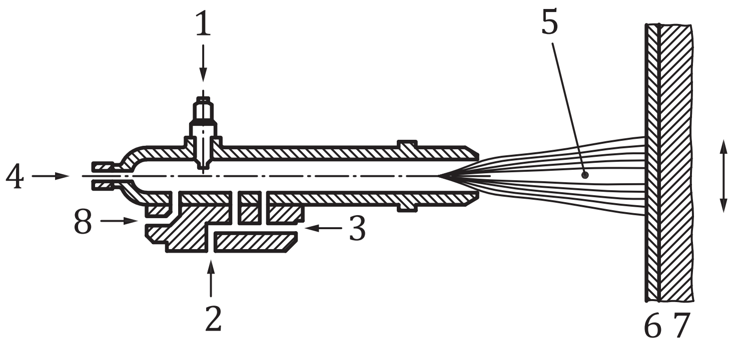
1 HVOF torch
2 electrovalve
3 suspension line
4 flushing liquid
5 switching vale
6 compressed air
7 stirring device
8 flushing liquid (water)
9 suspension
10 pressurized reservoir

Figure 5 — Suspension spraying in the case of HVOF spraying

5.2.4 Detonation spraying

In detonation spraying, the gun contains a chamber into which certain quantities of a powder are injected. The gas mixture in the chamber is detonated at controlled intervals at frequencies of a few Hertz. This creates a hot, high velocity gas stream that heats the powder to its plastic or partially or completely molten state and accelerates the particles as they leave the gun barrel.

The detonation gun consists of the barrel and the gun chamber. The injected gas and powder mixture are ignited by an electric spark. The resulting shock wave generated in the barrel accelerates the particles, which are further heated in the flame front and are propelled in a directed jet onto the prepared substrate. Nitrogen is used to flush clean the gun chamber and barrel after every detonation. See Figure 6.



Key

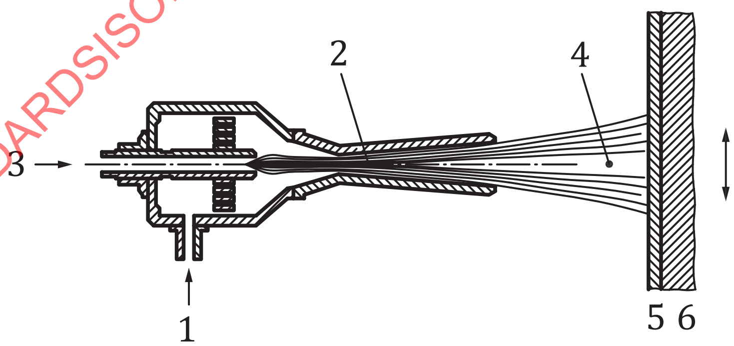
1 ignition
2 fuel gas
3 oxygen
4 powder and carrier gas
5 spray stream
6 spray deposit
7 substrate
8 flush gas nitrogen

Figure 6 — Detonation spraying

5.3 Cold spraying (Cold gas spraying)

In the cold spraying process, a gas (nitrogen or helium) is accelerated to supersonic velocity in a de-Laval type nozzle. The acceleration is driven by letting the gas expand from very high pressure (up to 50 bar) to the surrounding atmosphere. The spray material is injected into the gas jet in powder form upstream of the nozzle and then propelled with high kinetic and relatively low thermal energy onto the substrate. Above a certain particle velocity which is characteristic of the respective spray material, the particles form a dense and solid adhesive coating upon impact. External heating of the gas jet, e.g. in an electric-heated continuous heater, increases the flow velocity of the gas and also the particle velocity. The related rise in particle temperature assists the deformation upon impact. However, the gas temperature is clearly below the melting temperature of the spray material, which means the particles cannot be melted in the gas jet.

Consequently, drawbacks like oxidation and other phase transformations can be avoided. Figure 7 shows the process schematically.



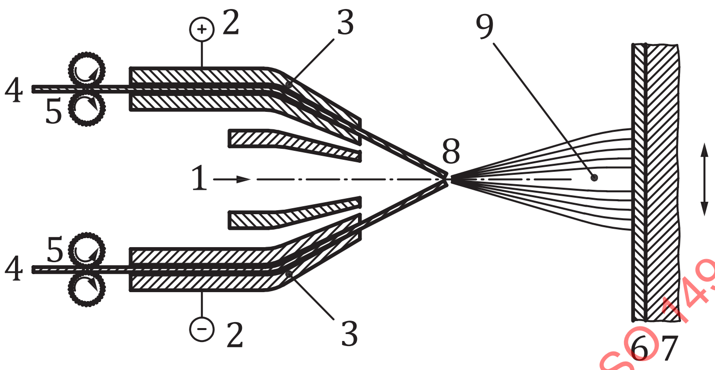
Key

1 process gas
2 de Laval nozzle
3 powder and carrier gas
4 spray stream
5 spray deposit
6 substrate

Figure 7 — Cold spraying

5.4 Arc spraying processes — Arc spraying

Arc spraying utilizes an electric arc between two wires to melt their tips; the wires may be of identical or dissimilar composition or formed as cored wires. A jet or jets of gas, normally compressed air, atomize the molten metal and project the particles onto the prepared substrate. Instead of air, nitrogen or blends of nitrogen with other gases are used as atomizing gas to reduce oxidation or to set defined oxygen content of the coating material. See Figure 8.



Key

1 atomizer gas
2 voltage
3 contact tubes
4 wires
5 wire feed mechanism
6 spray deposit
7 substrate
8 melting wire tips
9 spray stream

Figure 8 — Arc spraying

In special cases, an inert gas, utilized as a gas sheath around the arc and spray stream, can be applied to prevent or reduce penetration of air into the hot gas and particles stream. By that way, the porosity and oxidation in the coating can be reduced.

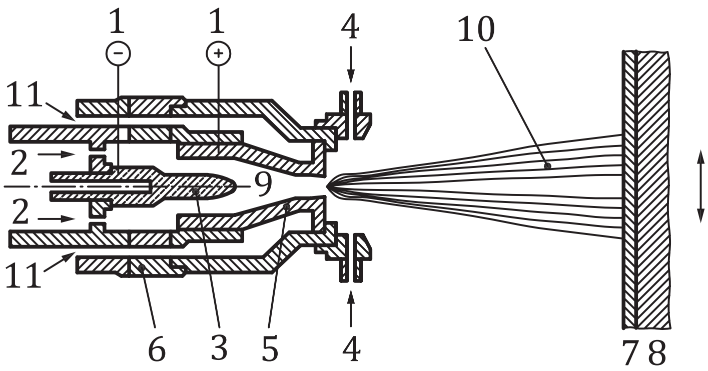
5.5 Plasma spraying processes

5.5.1 Atmospheric plasma spraying

In atmospheric plasma spraying, a plasma jet is used to heat the spray material to its plastic or partially or entirely molten state and project it onto the prepared surface of the substrate. The powder may be injected by means of carrier gas into the plasma jet inside (internal feed) or outside (external feed) the nozzle.

The plasma is produced by an arc established between the electrode (cathode) and the nozzle (anode) with partial or total ionization of the plasma gas. Recent designs of atmospheric plasma guns include an electrically insulated part between the electrode and anode or as part of the anode in order to increase the arc length. Secondly, multiple arcs are generated in modern designs by having either multiple electrodes, a segmented anode or both.

The high velocity of the plasma jet emerging from the nozzle is generated by the thermal expansion of the gas. The plasma gases commonly used are argon, hydrogen, helium, nitrogen or mixtures of these gases. See Figure 9.



Key

1	voltage	7	spray deposit
2	plasma gas	8	substrate
3	cathode (electrode)	9	plasma
4	powder and carrier gas	10	spray stream
5	anode (nozzle)	11	cooling water
6	insulator		

Figure 9 — Atmospheric plasma spraying

In special cases, an inert gas, utilized as a gas sheath around the plasma jet, can be applied to prevent or reduce penetration of air into the hot gas and particles stream. By that way, the porosity and oxidation in the coating can be reduced.

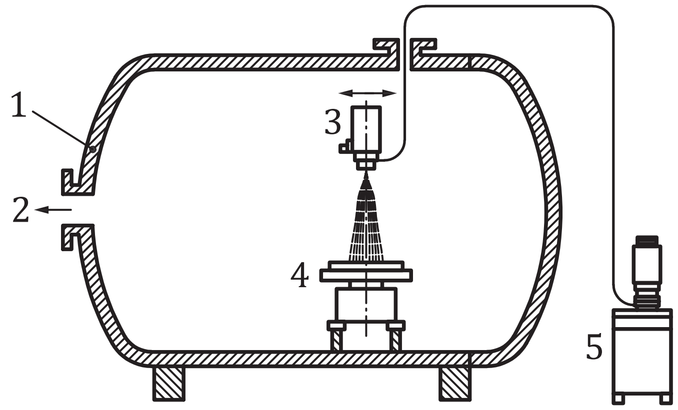
5.5.2 Plasma suspension spraying

Advantages of plasma suspension spraying are analogous to those of high velocity suspension spraying as described in 5.2.3. However, the injection of the suspension will only be applied radially into the spray jet. For further details, see 5.2.3.

5.5.3 Plasma spraying in chambers

Plasma spraying may also be carried out in a sealed chamber containing a defined gas atmosphere.

The plasma gases commonly used are argon, helium, hydrogen, nitrogen or mixtures of these gases. Manipulation of plasma gun and work-piece is done via suitable handling systems. Powder is continuously fed into the gun from external feeder units suitable for the specified conditions. See Figure 10.



Key

1 chamber
2 to vacuum pump
3 plasma gun
4 work-piece manipulator
5 powder feeder

Figure 10 — Plasma spraying in a chamber

Vacuum plasma spraying (VPS or LPPS™[2)]) is a special method of plasma spraying, where the pressure in the chamber is reduced. In order to reduce the oxygen partial pressure, the pressure is reduced to a vacuum level of 1 Pa to 0,1 Pa (10^{-2} mbar to 10^{-3} mbar) prior to spraying. Spraying takes place at a pressure range according to the specific application.

Plasma spraying in chambers can also be applied in a controlled atmosphere (CAPS) or at elevated pressure.

A substrate and deposit cooling system by jets of liquid gas sprayed in the form of fine droplets can also be applied. In other applications, a transferred arc is applied to heat up the work-piece prior to spraying.

5.6 Other plasma spraying processes

5.6.1 Water-stabilized plasma spraying

In water-stabilized plasma spraying, the plasma gas is generated from liquids, e.g. water, ethanol or methanol. Between a graphite cathode and a rotating, water-cooled anode, an arc is established. The liquid is introduced into the chamber with a swirling motion to stabilize the arc and produce the plasma jet. The continuously regenerated sheath of liquid provides thermal, as well as electrical, insulation against the chamber wall and, at the same time, serves as a coolant. Some part of the stabilizing liquid evaporates and the high temperatures present in the chamber provide its dissociation and ionization. The spray powder is introduced into the high velocity plasma jet outside the nozzle, heated to the plastic or partially or completely molten state and projected onto the prepared substrate. See Figure 11.

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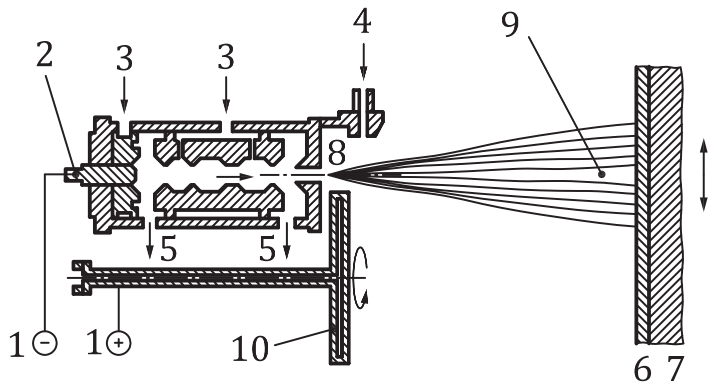


Key

1	voltage	6	spray deposit
2	cathode	7	substrate
3	liquid inlet	8	plasma
4	powder and carrier gas	9	spray stream
5	liquid outlet	10	anode

Figure 11 — Water-stabilized plasma spraying

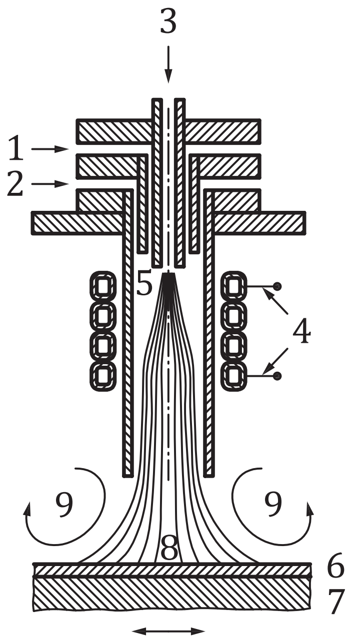
5.6.2 Induction plasma spraying — Inductively coupled plasma spraying

The induction plasma spraying process presents a special case of plasma spraying processes. The energy coupling is done by heating in the area of the induction coil (4). There are no electrodes in case of inductively coupled plasma. Therefore, the plasma is relatively free of pollution. The plasma transfers its energy by heat conductivity and convection to the gas streaming through a large diameter pipe. This allows the creation of a large volume plasma. Nearly every type of gas (also oxygen) can be applied. Often, a molecular gas will be supplied to the shroud gas (2). For the thermal spraying process, a carrier gas-powder stream (3) will be axially supplied to the plasma stream.

In atmospheric induction plasma spraying, the plasma jet is created in an atmospheric environment. Figure 12 shows schematically the basis of the atmospheric induction plasma spraying process.

This plasma has a relatively low flow velocity with a laminar profile. Therefore, very little turbulence will occur in the surrounding air (9).

In vacuum-induction plasma spraying, the plasma flows through a nozzle of the plasmatron into the reactor (flange-mounted or incorporated) with a reduced pressure value near to atmospheric pressure. Even due to the small differences in pressure, plasma velocity will increase, it can reach a multiple of the supersonic velocity.



Key

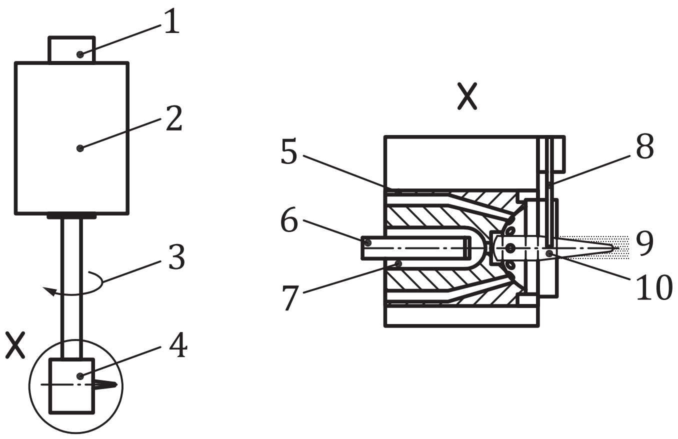
1	process gas	6	spray deposit
2	shroud gas	7	substrate
3	powder and carrier gas	8	spray stream
4	induction coil	9	surrounding air
5	plasma core		

Figure 12 — Induction plasma spraying — Inductively coupled plasma spraying

5.6.3 Plasma transferred wire arc spraying

The plasma transferred wire arc (PTWA) process presents another special plasma spraying process. The function is shown schematically in Figure 13.

The nozzle unit contains a tungsten cathode, an air cooled pilot nozzle of copper and an electrically conductive wire type spray material, which is fed perpendicular to the pilot nozzle. The plasma gas, usually a mixture of argon and hydrogen, is fed through drilled holes which are located tangentially to the circumference of the cathode fixture (not shown in the figure). The process is started by a high voltage discharge, which ionizes the plasma gas between the pilot nozzle and the cathode. The created plasma streams with hyper sonic speed through the nozzle's muzzle and expands along the axis of the nozzle. By that way, the plasma jet runs through the nozzle, where it heats the spray wire, which is continuously fed perpendicular to the nozzle, where the electric circuit is closed. The tip of the wire will be melted due to the high temperatures of the plasma. The melted material is atomized by a pressurized air jet and projected onto the substrate. Usually, a coating produced by this process contains a porosity of less than 2 %.



Key

1 wire feeder
2 main housing
3 rotating spindle
4 torch head
5 atomizing gas
6 cathode
7 plasma gas
8 spray wire (+)
9 molten particles
10 plasma

Figure 13 — Plasma transferred wire arc spraying

5.7 Laser cladding

Laser cladding can be carried out by the one step method or the two step method. The main difference is given by the different melting location of the powder. In the case of the two step method, the powder is melted in the laser beam. In the case of the one step method, the melting of the powder takes place in the melt pool. The two step method is more sensitive and the coating thickness is typically 0,3 mm to 0,8 mm.

In the case of the one step method, the powder starts melting in the laser spot and reduces the heat available. This effect lowers the heat input to the substrate and the dilution.

Different types of laser can be used; however, diode laser is mainly used due to transportation of the beam via a glass fibre cable. Thus, working can be nearly independent from the location of the power source and laser head.

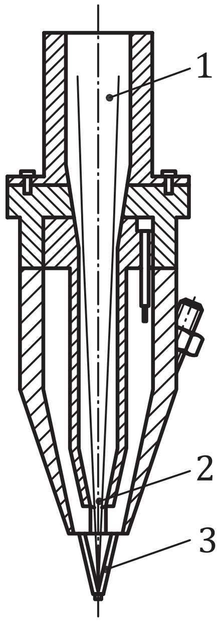
The process of laser cladding is characterized by the injection of a powder into the laser beam using a suitable powder nozzle. The powder particles are projected to a melt pool on the substrate by the carrier gas and/or by gravity. They are partially or entirely melted by laser radiation. The result is a fully dense, metallurgically bonded coating, usually 0,5 mm to 3 mm thick. Due to a relatively low heat input into the substrate material and a controlled motion of the laser spot, the substrate will be melted at the surface only. The dilution between the spray material and substrate material will typically be less than 5 %.

Usually, a shielding gas serves for the protection of the melt pool.

In special cases, metal matrix composites with carbides can be fed simultaneously to the melt pool generated by the laser beam. The aim is to keep the carbides intact with minimal dissolution and to melt the matrix material only. If the difference between the melting temperature of the matrix and the carbides is high enough, the aim can be achieved due to the low heat input of laser cladding.

Laser cladding is defined as a (hard) surfacing process and therefore, it typically belongs to the area of welding processes. Nevertheless, due to its application, in terms of this specification, laser cladding shall be included within the area of thermal spraying.

For details, see Figure 14.



Key

1 laser beam

2 shroud gas

3 powder

Figure 14 — Laser cladding

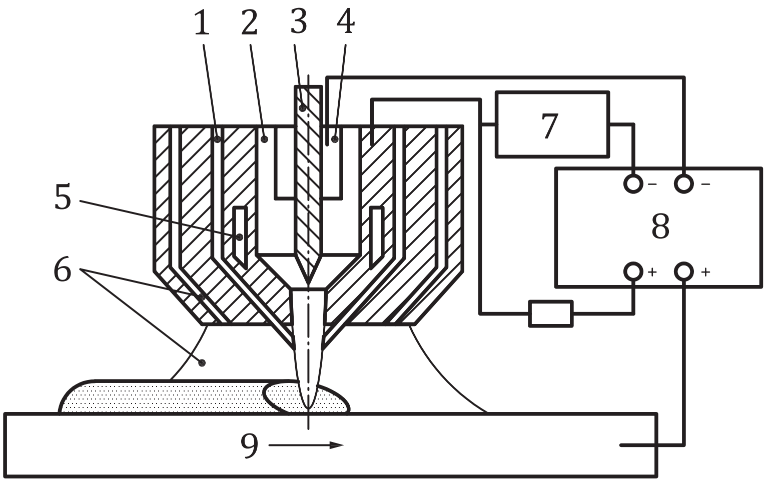
5.8 Plasma transferred arc surfacing (PTA)

In the PTA process, the surface of the work-piece is surface melted only. The process includes two arcs. A direct current arc is generated between a tungsten cathode (−) and a surrounding water cooled copper anode (+). Between these two non-consumable electrodes, a stream of inert gas (e.g. argon, helium or argon-helium mixtures) is ionized and forms a plasma jet. The copper electrode is bounded by a small outlet which constricts the plasma jet and increases its speed. Thus, this high-density plasma arc serves as the heat source and the metal powder as the surfacing material.

The powder is supplied to the torch by means of a carrier gas, heated in the plasma jet and deposited on the work-piece surface where it melts completely in the melt pool on the substrate.

This melt pool is created by the second direct current arc which is generated between the non-consumable tungsten electrode (−) and the work-piece (+) and this current arc serves for the transferred arc. The energy supply of the two arcs can be controlled separately. A true metallurgical bond between the substrate and the coating is generated, where the heat-affected zone in the substrate remains very small due to the precise control of the level of current for the transferred arc. For details, see Figure 15.

The entire process takes place in the atmosphere of a shroud gas (e.g. argon or argon-hydrogen mixture).



Key

1 powder and carrier gas
2 plasma gas
3 cathode
4 cathode fixture
5 cooling system
6 shroud gas
7 high frequency ignition
8 double inverter power source
9 welding direction

Figure 15 — Plasma transferred arc surfacing

6 Thermal spraying — Terms

6.1 General terms

6.1.1 Coatability

A component is considered to be completely or partially coatable by a given manufacturing process and application of a suitable spray material when the functionality of the applied coating satisfies the requirements stipulated in the particular case.

NOTE The coatability is influenced by parent metal, spray material, design and manufacturing. Coatability exists when the stipulated surface requirements can be reached by applying a suitable design, a suitable parent metal, a suitable spray material and a suitable manufacturing procedure applying a given spray process.

6.1.2 Coating suitability

A property of a substrate material that allows it to be coated by a particular technique.

NOTE The coating suitability is influenced by the chemical composition, technological and physical properties, metallurgical structure, surface conditions (surface hardened, nitrided, chromated or painted) and the wettability of the substrate.

6.1.3 Spray suitability — Sprayability

A property of the spray material that facilitates its application by a specified spraying process.

NOTE The spray suitability/sprayability is influenced by the chemical composition, the physical properties, and the manufacturing process of the spray material (wire, rod, cord, powder). The main features for spray suitability are the morphology, particle size range, its distribution, and the flowability in the case of powder, where the feeding behaviour is the main feature for wires, rods or cords. The spray suitability influences decisively the spray deposit and the coating structure.

6.1.4 Coating functionality

A property of the coating and its design provided it works satisfactorily under the required service conditions.

NOTE The functionality of the coating is influenced by a number of factors including, but not limited to, location of surface to be coated, prevention of edge pressure and sharp edges and narrow radii to be coated, thickness of the coating, substrate material, stress between coating and substrate, differences in expansion coefficient, temperature, temperature cycling, and risk of parent metal corrosion.

6.1.5 Coating feasibility

A manufacturing property, which makes possible applying an intended thermal spray coating properly to a particular component using the chosen manufacturing conditions and a suitable spray material.

NOTE The coating feasibility is influenced by factors such as surface preparation prior to spraying, spray process, types of spray and auxiliary materials, spray equipment, doing the spray work (sequence of sprayed layer, coating structure, preheating, cooling, precautions taken in unfavourable weather conditions), personnel skill, and post-treatment (fusion, diffusion, annealing, machining, and sealing).

6.1.6 Accompanying specimens

The accompanying test piece is a work specimen, that has to be coated under conditions as similar as possible to those of the original part.

6.2 Thermal spraying equipment, terms

6.2.1 Spray gun, torch

Unit with which the spray material is heated to the plastic or molten state, accelerated and projected onto the prepared substrate surface.

6.2.2 Spray nozzle

The spray nozzle is that part of the spray gun, which contains the outlet opening for the spray jet.

6.2.3 Supplementary nozzle

Supplementary nozzles are spray nozzles that influence directly shape, configuration and direction of the spray jet. They can also be applied for cooling purposes.

6.2.4 Contact tube

The contact tube is an electrically conductive part (electrical conduit) of the nozzle system of an arc spray gun to which wires are guided along electrical contacts toward a point of intersection and short circuiting at a desired angle.

6.2.5 Wire feed mechanism

The wire feed mechanism is a mechanically operated unit for a controlled supply of the spray material in the form of wire, rod or cord.

6.2.6 Powder feeder

Powder feeding units are systems for a controlled supply of spray material in the form of powder.

6.2.7 Powder injector

Powder injectors feed and guide spray powders into the gas jet. They may be integrated in the spray gun or mounted outside of it.

6.3 Process specific terms of thermal spraying, terms

6.3.1 Spray material

Coating material for thermal spraying aligned in form and/or composition to suit the applied process variations and type of application.

6.3.2 Carrier gas

Carrying gas for the injection of spray material in powder form into the hot gas jet or flame.

6.3.3 Atomizing gas

Gas for the atomization and acceleration of molten spray material in wire, rod or cord form.

6.3.4 Propellant gas

Gas utilized to accelerate the spray particles.

6.3.5 Spray jet

The stream of spray particles emerging from the spray gun.

6.3.6 Spray particles

Plastic or partially or entirely molten particles that emerge from the spray gun.

6.3.7 Splat

Thermal sprayed particle which is deformed and flattened and is sticking to the substrate or to the already sprayed deposited material.

6.3.8 Spray deposit

Spray material as deposited.

6.3.9 Spray distance

Distance between the nozzle face and the surface of the work-piece.

6.3.10 Spray angle

The angle between the centre line of the spray jet and the surface of the work-piece.

6.3.11 Spray velocity

The velocity of the spray jet itself relative to the substrate. The motion can be applied either by the spray gun and/or the work-piece.

6.3.12 Spray trace overlapping

The degree of overlapping of a spray trace with the previous one. An equal coating thickness can be achieved by applying a suitable overlapping of spray traces.

6.3.13 Spray spot

The area where the spray particles strike on the substrate. A distribution of the accumulation of spray particles in the spray spot can be determined by applying a point spray test (without any motion relatively between spray gun and the part).

6.3.14 Deposition rate

The weight of material deposited in a unit of time; the deposition rate is usually expressed as kilogram per hour (kg/h) or grams per minute (g/min).

6.3.15 Spray losses

Total loss of spray material resulting from evaporation, burn-off, projection outside the intended substrate area, and rebound, i.e. spray material not contributing to producing the desired deposit.

6.3.16 Deposition efficiency

The ratio of total weight of the spray deposit to total weight of spray material applied measured in %. Projection outside the intended substrate area is not taken into account. The determination shall be carried out according to ISO 17836.

6.3.17 Masking

Protective measure for areas of a work-piece that are not to be coated.

6.3.18 Sealing

The procedure to close pores by infiltrating with suitable substances (sealants).

6.3.19 Thermal treatment

Controlled heat treatment before, during and/or after the thermal spraying operation.

6.3.20 Fusing of sprayed deposits

Heating of sprayed deposits to temperatures in the melting range of the coating to obtain a homogeneous deposit, diffusion bonded within itself and with substrate, typically applied to self-fluxing alloys (see ISO 14920).

6.4 Coating specific terms

6.4.1 Sprayed coating

Deposit applied by thermal spraying.