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Surface preparation of non-metallic materials for thermally sprayed coatings

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Content:

1 Scope of validity

The leaflet contains recommendations (work instructions) for the correct substrate preparation of non-metallic base materials for thermally sprayed coatings. It also contains general information on safety in the workplace and environmental protection.

2 Introduction

When metals, carbides, oxides, plastics and mixtures of these materials are thermally sprayed onto non-metallic base materials, the adhesion mechanism depends on different types of bonding.

This is why surface preparation is of particular importance. Base material surfaces must be prepared perfectly in order for a satisfactory bond to be produced between the base material and the sprayed coating.

Non-metallic materials such as plastic, graphite, ceramics and semiconductors are becoming increasingly important in the field of engineering for a variety of reasons (lightweight, specific electrical properties, chemical resistance and cost). Functional components made from plastic, graphite and ceramics are already being used in place of expensive metallic base materials both for mass-produced components and for one-off components that are subject to high levels of stress. If the surfaces of non-metallic base materials are not equal to the requirements to which they are subject, then thermally sprayed coatings can enhance the surface, for instance as

Protective coatings to withstand

- Wear and mechanical effects
- Corrosion and chemical effects
- Heat and thermal effects

Coatings with specific electrical properties

- Electrical insulators, dielectrics
- Electrical conductors
- Particular electron emission

Coatings with specific surface effects

- Surface enlargement
- Specific surface structure
- Decorative surfaces

Coatings with specific material properties

- Catalytic converter effect
- Surface activity
- High-temperature resistance
- Solderability

3 Non-metallic base materials

Non-metallic base materials can be subdivided into the following groups:

Table 1. Categories of non-metallic base materials.

Ceramics	Plastics	Natural	Others
Silicate ceramics Earthenware, glass ceramics, [illegible]lite,	Thermoplastics (plastomers) PE, PVC, PU, etc.	Wood and wood products (cardboard, paper) Cellulose	Graphite
Oxide ceramics [illegible] Al_2O_3, ZrO_2, etc.	Elastomers EPDM, PP, etc.	Stone	Semiconductors
Non-oxide ceramics AlN, SiC, Si_3N_4, etc.	Duroplasts (duromers), filled and unfilled Epoxy resin, melamine, etc.		Glass

4 Surface preparation

In addition to cleaning / degreasing the base material, proper preparation of the substrate may also necessitate a more thorough chemical / physical, thermal or mechanical surface treatment. The interval between surface preparation and subsequent thermal spraying should be kept as short as possible. This requirement applies in particular to chemical / physical and thermal preparation.

4.1 Cleaning using washing agents in aqueous solutions

The cleaning processes are as follows:

- Immersion or spraying process with or without the use of ultra sound.

With immersion or spraying processes, mechanical aids are usually also required in order to sufficiently remove adherent foreign matter.

The cleaning effect is enhanced with ultrasound. In the event that ultrasound cannot be used, then mechanical aids (e.g. brushes) must be reverted to. Mildly alkaline (pH 9 to 10.5) phosphate cleaners with a high tenside content should preferably be used for this purpose. Silicate cleaners and organic neutral cleaners are suitable only to a limited extent. Subsequent rinsing with deionised water and drying with oil-free, dry compressed air are absolutely essential.

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4.2 Cleaning using organic solvents

The possible cleaning processes are as follows:

- Immersion process with or without the use of ultrasound and
- steam degreasing.

The following solvents can be used:

Table 2. Organic solvents.

Solvent	Boiling point °C
2-propanone (acetone)*	56,2
Dichloromethane (methylene chloride)#	39,6
Ethanol*	78,3
Methanol*	64,7
Tetrachloroethylene (perchloroethylene)#	120,8
1,1,2-trichloroethylene#	87,4
1,1,2-trichloro-1,2,2-trifluoroethane (R 113)#	47,6
1,1,1-trichlorethylene (methyl chloroform)#	74,0
Isopropanol (isopropyl alcohol)*	82,3

*Easily inflammable

Hazardous to health

When organic solvents are used, the principles for preventing hazards in accordance with GefStoffV (German Hazardous Substances Directive) [1] must be observed. Where possible, relevant processes and substances should be replaced by less dangerous ones acc. to GefStoffV. Furthermore, the regulations in the German Operational Safety Regulation (BetrSichV) [2] regarding flammable liquids and the explosion protection regulations for cleaning systems must be observed. Caution should be exercised when spraying. Even with cleaning agents that are less readily inflammable (those with a very high flash point), it must be borne in mind that a spray mist can be ignited.

The use of chlorinated hydrocarbons (CHCs) for cleaning purposes has been strictly regulated in order to protect the environment and for health and safety reasons. In accordance with the 2nd Federal Immissions Control Act (BImSchV) [17], apart from a small number of exceptions CHCs must no longer be used other than in enclosed systems. Immersion cleaning and steam degreasing are commonly-used processes.

4.3 Chemical / physical surface preparation

The following processes are common: etching, seeding, ion etching. There are numerous chemical preparation methods for plastics, and the specialist books [e.g. 3] can be used as a source of information on them.

4.4 Thermal surface preparation

Thermal preparation should dry, clean or chemically / physically activate the surface. Depending on the base material this can be done using naked flames, radiated heat, low temperatures or corona discharge.

4.5 Mechanical surface preparation

4.5.1 Machining processes

In certain cases milling, turning, grinding or brushing may be the only required preparation. However, care must be taken in this case to ensure that the material properties are not adversely affected.

Adverse effects can arise as a result of:

Voltages being introduced, the surface being compacted, oxidation processes. In the case of plastics: exposure of pores, damage to fibre inserts, etc.

4.5.2 Shot blasting

Shot blasting should be performed to clean and roughen the surface. Variables affecting the result of shot blasting include the nature and the type of the blasting abrasive as well as the operating parameters for the blasting process such as its duration and throughput, the distance between the gun and the surface, the angle and speed of impact of the blasting abrasive and lastly the degree of coverage (see also DIN 8200 [4]). These parameters should be set accordingly for the component and the base material that is being blasted, and if necessary should be optimised by test blasting.

The resulting roughness (depth of roughness and surface character) can be determined by visual and tactile comparison with the help of roughness comparison samples, e.g. acc. to DIN EN ISO 8503 (Parts 1 and 2) [6]. The measured values for depth of roughness can be determined with the aid of electrical surface profiling devices (see DIN EN ISO 4288 [5]).

4.5.2.1 Blasting agents

An overview of the possible blasting agents that might be suitable can be found in Table 3. To select suitable blasting agents see also DIN 8200 [4], DIN 8201 Parts 4 and 5 [7], DIN EN ISO 11124 [9] and DIN EN ISO 11126 [10], especially with regard to grain shape, grain size and distributions of grain size), and [8].

Table 3. Blasting agents

Corundum Al_2O_3	+ (A)	+	o (A)	o (A)
Zirconia alumina	+ (A)	+	o (A)	o (A)
Silicon carbide	+ (A)	+	o (A)	o (A)
Iron and steel	o (A)	o	o (A)	–
Non-ferrous metal	o (A)	+	o (A)	–
Slags	o (A)	+	o (A)	o (A)
Glass	+ (A)	+	o (A)	o (A)
Plastic	–	–	o (A)	–
Nutshells	–	+	o (A)	–
*Quartz sand	Because of the danger of silicosis, this is only still used for special purposes and with a certificate of exemption in accordance with DIN 8201 – Part 5, [7]			
Suitability: + suitable; o suitable to a certain extent; – unsuitable, (A) depending on the hardness and surface sensitivity of the base material.				

4.5.2.2 Shot blasting systems

A shot blasting system is designated according to the method or the carrier agent that is used to accelerate the blasting agents to the required speed for blasting. The shot blasting system used should be chosen according to the base material, the requisite blasting agent and technical aspects.

In shot blasting the carrier agents (e.g. compressed air, sludges or liquids) used for acceleration purposes are often of particular importance since they are also often used for cleaning or cooling purposes.

4.5.3 Adhesion-promoting intermediate layers

Adhesion-promoting intermediate layers provide for better adhesion of the thermally-sprayed topcoat. Thermoplastic buffer layers allow hot spray particles to penetrate through to the surface and thus create a form-fitting connection. Numerous, generally less ductile polymers (not elastomers) on plastics can be prepared using a coarse-blasting process to achieve the desired surface magnification and activation. Furthermore, the type or structure of the intermediate layer can deliver a favourable residual stress state (continuous transfer of material properties).