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DVS – DEUTSCHER VERBAND FÜR SCHWEISSEN UND VERWANDTE VERFAHREN E. V.	Thermal spraying with suspensions	Technical Bulletin DVS 23[illegible]1

Inhalt:

1. Introduction

A new class of spray material – the suspension – is being used in thermal spraying, using the known technologies of atmospheric plasma spraying (APS) and high velocity oxy-fuel flame spraying (HVOF). By analogy with powder and wire flame spraying, it appears advantageous to include the type of spray material in the method name and use the abbreviation APS-S or HVOF-S.

As a rule, for the production of coatings, the conventional system technologies of APS and HVOF are currently used with appropriate modifications. This primarily concerns the feeding technology (suspension feeder) and the injection. To realise the technology in industrial practice, besides having functional hardware (e.g. suspension feeder units, injectors), it is also necessary to resolve all questions relating to the use of suspensions as a spray material. At the same time, suspension feed rates and deposition levels must allow coatings to be produced economically.

The use of suspensions for thermal spraying is currently in transition from development in the laboratory to industrial practice. As the process is developing rapidly, new features and enhancements can be expected on a regular basis. At the same time, a lot of the work currently being done in the commercial sphere (particularly application development) is being published late or not at all due to secrecy restrictions.

2. Scope

This technical bulletin contains information about the current use of suspensions as spray materials in thermal spraying.

Particularly important specific advantages include the production of near-contour coatings in the range of 10-50 µm, as well as low surface roughness values. For some materials, such as Al_2O_3 and TiO_2, it has been possible to demonstrate coating properties that are not possible with conventional processes. Coating thicknesses, morphologies and properties can be varied over a very wide range. With thermal insulation coatings, coating roughness depends on the formation of the columnar structures.

A particular advantage lies in the direct use of finely dispersed oxide ceramic powders, as these are available for the production of sintered technical ceramics with widely varying properties (grain size, purity, etc.).

The technical bulletin provides suggestions and recommendations for selecting coating materials, the characteristics of corresponding suspensions, coating production, particularly with atmospheric plasma spraying (APS) and high-velocity oxy-fuel flame spraying (HVOF), and the characterisation of coatings. Examples are given of coatings produced with suspensions as filler material.

The use of suspensions as a liquid spray material is distinguished from the use of solutions, which is likewise the subject of current research. Whereas in suspensions, finely dispersed particles are contained in the solvent, in the case of solutions the spray material dissociates into ions. The use of nitrates and alkoxides is examined by way of example.

3. Suspensions

Suspensions are currently available from manufacturers as spray materials only by special request. For the supply of suspensions, basically two different approaches are possible in the future: Either suspensions are sold in a spray-ready format (similar to abrasive suspensions), or the suspension is produced during the actual spraying operation according to a specified recipe. The latter method requires additional but commercially available equipment for the production of suspension in the spraying operation.

As with all other spray materials, the coating comes exclusively from the solid - the liquid is only an auxiliary material. Water and various alcohols are used as fluid in development work. For use in industrial practice, water is clearly preferable in terms of costs and occupational safety.

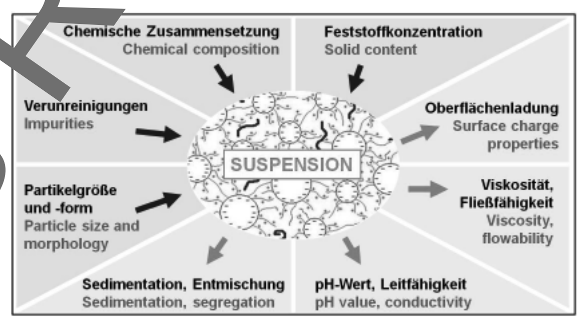

Figure 1: Parameters for suspensions – input parameters defined for solids (blue) and resulting parameters (red) of the suspension [L.-M. Berger, F.-L. Toma, A. Potthoff, Therm. Spray Bull., 2013, 6 (2), 98-101].

Figure 1 shows key parameters that determine the suspension properties. All the suspension properties resulting from the raw material properties (in the picture with blue background) which can be optimised by including additives (in the picture with red background) determine the suitability of a suspension for thermal spraying. Good coating qualities can only be guaranteed through the use of homogeneous suspensions with very good fluidity, because these allow a spraying process with high long-term stability. That is to say, the suspension must not segregate during the spraying process, but must be feedable with constant properties. To achieve this, the particles must be isolated, i.e. in a colloidally stable suspension.

Another requirement of the suspension is that it must have no corrosive effect on the equipment.

DVS, Technical Comittee, Working Group „Thermal spraying and thermally sprayed coatings“

Orders to: DVS Media GmbH, P. O. Box 10 19 65, 40010 Düsseldorf, Germany, Phone: + 49 (0) 211/1591- 0, Telefax: + 49 (0) 211/1591- 150

The efficiency of the spraying process is positively influenced when the solid content of the suspension is as high as possible (up to 70 % by mass, as the volume of water to be evaporated is reduced and spraying times are shortened. In particular the use of powders with grain sizes > 1 µm allows such high concentrations.

4. System technology

Figure 2 schematically illustrates a system for thermal spraying with suspensions. Specific components include a suspension feed and injection unit and a modified spray torch.

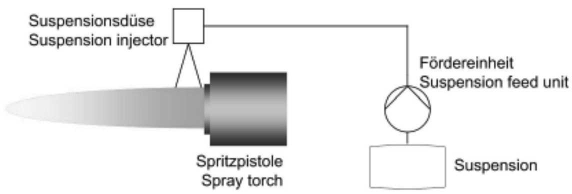

Figure 2: Schematic illustration of an installation for spraying with suspensions [L.-M. Berger, F.-L. Toma, S. Langner, T. Naumann, Therm. Spray Bull., 2010, 3 (1), 24-29].

In recent years, various activities have been carried out in industry relating to the development of suspension feed units, some of which are now commercially available. As well as feeding under pressure, peristaltic pumps are also used as the feeding method.

In the case of injection, a distinction is made between external and internal injection. Internal injection requires a higher modification cost. In the case of APS, in view of the design, external radial injection is almost the only possibility. Due to the small particle size, injection requires particular care in the selection of injection conditions. Only special plasma torch designs allow axial injection. Axial injection directly into the combustion chamber is easier when using HVOF.

Figure 3 shows different injection methods for suspensions with APS-S and HVOF-S.

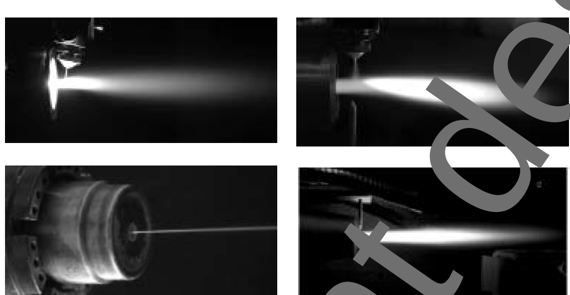

Figure 3: Injection methods for suspensions with APS-S and HVOF-S [images Fraunhofer IWS].
External radial injection as a continuous suspension jet in APS- S (a) and in HVOF-S (b) and axial internal injection into the combustion chamber with HVOF-S: (c) escaping suspension jet without flame), (d) Spraying process

5. Substrates and substrate surface preparation

Through thermal spraying with suspensions, the same range of substrate materials can be coated as with spraying processes that use conventional spraying materials. The main rules for the substrate preparation are described in DVS technical bulletin 2301, point 7. Due to the much smaller size of particles in suspensions compared with conventional coating powders, particularly when using blasting processes, it is necessary to adapt the spraying conditions (grain size of abrasive, jet pressure) to the lower surface roughness required. Especially with thin coatings, excessive surface roughness of the substrate makes it impossible to achieve very smooth coating surfaces, or abrasive residues lead to faults in the coating microstructure.

6. Coating microstructures

The advantages of thermal spraying with suspensions include the fact that completely different coating micro-structures of a material – from porous to dense with large differences in coating thicknesses – can be produced. Figure 4 shows some selected coating microstructures. The coatings in the light microscopic images in Figures 4a and 4b show HVOF-S sprayed Al2O3 coatings. The image in Figure 4a shows a dense coating with a thickness of around 200 µm and a blasted substrate, and image 4b a coating with a density in the range of 10-15 µm on an unblasted substrate. Figure 4c shows an HVOF-S sprayed titanium oxide coating. Figure 4d shows a thermal insulation coating made from La-Al-Mg-Ta-Perovskite with columnar structure that was produced with APS-S.

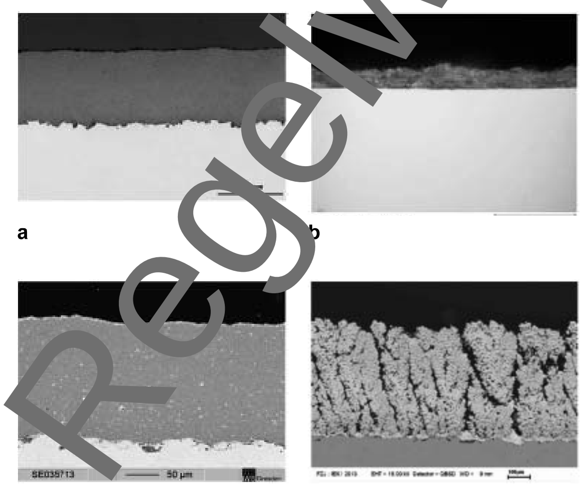

Figure 4:
(a) Al_2O_3 coating [L.-M. Berger, F.-L. Toma, A. Potthoff, Therm. Spray Bull., 2013, 6 (2), 98-101],
(b) Thin Al_2O_3 coating [L.-M. Berger, F.-L. Toma, A. Potthoff, Therm. Spray Bull., 2013, 6 (2), 98-101],
(c) Dense TiO_2 coating [L.-M. Berger, F.-L. Toma, S. Langner, T. Naumann, Therm. Spray Bull., 2010, 3 (1), 24-29],
(d) Thermal insulation coating made from La-Al-Mg-Ta-Perovskite with columnar structure [Forschungszentrum Jülich GmbH, Institute for Energy and Climate Research].

7. Testing the coatings

The methods of testing the coatings described in DVS technical bulletin 2301, point 11 can also be used here.

8. Applications

ZrO_2-based thermal insulation coatings are the most intensively studied up to now. In view of the special coating structures required here, APS-S offers particular advantages.

Developments for biomedical coatings are also extensively described in the literature. In particular, hydroxyapatite and glass-ceramics are used as coating materials.

Another special focus area is the development of photocatalytically active TiO_2 coatings, which have only become possible through the use of suspensions.

Suspension-coated Al_2O_3 coatings exhibit more stable insulation properties over the long term where used in conditions of high humidity.

More detailed information can be found in the summarising publications mentioned in the references, as well as other publications listed in the bibliography.