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Demands, Potentials, and Economic Aspects of Thermal Spraying with Suspensions: A Critical Review

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Research and development work for about one decade have demonstrated many unique thermal spray coating properties, particularly for oxide ceramic coatings by using suspensions of fine powders as feedstock in APS and HVOF processes. Some particular advantages are direct feeding of fine nano- and submicron-scale particles avoiding special feedstock powder preparation, ability to produce coating thicknesses ranging from 10 to 50 μm, homogeneous microstructure with less anisotropy and lower surface roughness compared to conventional coatings, possibility of retention of the initial crystalline phases, and others. This paper discusses the main aspects of thermal spraying with suspensions which have been taken into account in order to produce these coatings on an economical way. The economic efficiency of the process depends on the availability of suitable additional system components (suspension feeder, injectors), on the development and handling of stable suspensions, as well as on the high process stability for acceptance at industrial scale. Special focus is made on the development and processability of highly concentrated water-based suspensions. While costs and operational safety clearly speak for use of water as a liquid media for preparing suspensions on an industrial scale, its use is often critically discussed due to the required higher heat input during spraying compared to alcoholic suspensions.

Keywords concentrated suspension, economic aspects, hardware development, process stability, suspension thermal spraying

1. Introduction

For about one decade, modified thermal spraying processes using suspensions of fine submicron- and nanosized-powders as feedstock materials have continuously gained increasing interest in the scientific world. Extensive development efforts reflected by an important number of papers and reviews made over the last years have uncovered the potential of thermal spraying with suspensions, e.g., Ref 1-6. Compared with conventional thermal spray methods, the suspension spraying technique presents some advantages: direct feeding of fine nano- and submicron-scale particles; tailored coating architecture that can be adapted to the given application; less anisotropy and lower surface roughness of the coating; retention of the initial crystalline phases (i.e., α-Al_2O_3, anatase modification of TiO_2, hydroxyapatite) resulting in improved or new coating properties. Moreover, the technique allows thick and thin, finely (nano)-structured coatings to be prepared.

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Suspensions are used as feedstock for both atmospheric plasma spraying (APS) and for high velocity oxy-fuel (HVOF) spraying. The processes can be abbreviated analogously to powder and wire flame spray processes as "S-APS" and "S-HVOF" to identify them as processes using suspensions as feedstocks. Abbreviations as "SPS" (suspension plasma spraying) and "HVSFS" (high velocity suspension flame spraying) are also used in the literature. The use of suspensions allows a direct processing of nanopowders. However, an important advantage is the direct use of finely dispersed oxide powders commonly applied in the production of sintered technical ceramics. For this reason, thermal spraying with suspensions is primarily seen as a technology for the preparation of ceramic oxide coatings. Except oxides (Al_2O_3, TiO_2, Cr_2O_3, YSZ), biomaterials (hydroxyapatite, bioglasses) and perovskites were studied to produce suspensions for spraying (i.e., Ref 4, 7-18). In the case of metals, only the chemically prepared metallic powders are good candidates for suspensions. However, the preparation of coatings from composites, such as WC-Co (Ref 19-21), or oxide-coated SiC (Ref 22) is much more difficult as from plain oxides. Using aqueous suspensions of different WC-Co powders, coatings with a hardness of up to 1000 HV0.3 and a good sliding wear resistance were obtained (Ref 20, 21).

Before the technology can be transferred to industry, industrial-grade hardware, i.e., suspension feeders and injectors, as well as modified or specially designed spray guns must be available. All issues related to use of suspensions as feedstock, including preparation or commercial availability, transport, handling, storage, and operational safety must be clarified, too (Ref 5). The choice of the powders for the suspensions has to be made carefully, because the specific material properties play a more significant role than in conventional spraying.

In this paper, the suspension characteristics and the options for suspension supply are discussed, and specific hardware components are presented. Economic aspects (suspension concentration and feed rates, deposition efficiencies) together with the appropriate hardware components and long-time process stability are the basis for cost-effective coating manufacturing by suspension spraying to meet the industrial expectations.

2. Suspensions for Thermal Spraying: Demands and Processability

High process stability and reliability are indispensable for use of suspension spraying at industrial scale, with suspension properties playing a main role. Thus, the suspension development should be tailored, which includes selection and dispersion of the raw material in the liquid to enable all requirements to be met:

- Requirements of the spray process: homogeneity, low viscosity (good flowability), high content of solids, high stability of the suspension (neither sedimentation nor modification of the suspension composition), compatibility with the hardware components (avoidance of corrosion, abrasion, or clogging), long-term process stability (constant suspension flow rate).
- Requirements to achieve tailor-made coating properties specific for each application: material, phase composition, crystallinity, tolerance concerning the impurities, primary particle sizes, dispersant choice and content.
- Expectations of the industry are availability, low price, reproducibility of batches, safety of transport and handling, low environmental impact, long-term storage, high deposition efficiencies, and coating qualities.

In the development of the suspensions, both water and various alcohols are used as liquids. As with all other feedstocks, the coating is generated solely from the solid; the liquid of the suspension acts as a transport media that evaporates during deposition process (Ref 5). In order to meet the requirements mentioned above, particles must exist in separated form, i.e., in a colloidal stable suspension. A summary of the key parameters which is needed to be considered for suspension development is given in Fig. 1. The combination of raw material properties (shown with blue background in the figure, left side) and suspension properties (shown with orange background in the figure, right side), which can be optimized through the use of suitable additives, determines the applicability of a suspension for thermal spraying.

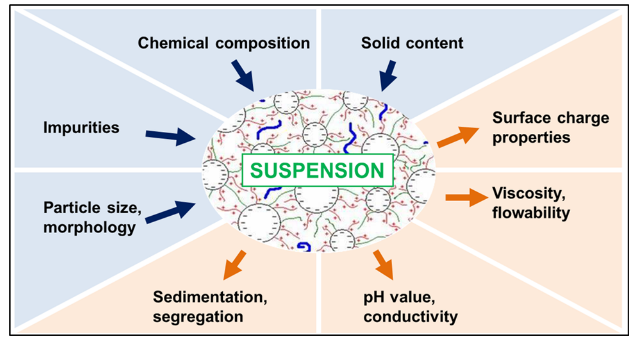

Fig. 1 Suspension parameters—initial parameters defined by the solids (blue) and resulting suspension parameters (orange) (Color figure online)

Physical parameters such as primary particle size, agglomeration state, and morphology of the powder particles determine the potential of the raw material because they are directly connected with the coating structure. If the particles can be adequately separated, a homogeneous coating with low surface roughness can be prepared, whereas large, irregularly shaped, and sized agglomerates result mostly in porous coating structures. Apart from the chemical composition, the crystal structure and the amount of impurities affect the applicability of the raw material. Low amounts of impurities (in the range of ppm) may not only change the suspension behavior dramatically, but they also accelerate the phase transformations of the material during spraying, as observed for Al_2O_3 (Ref 23).

Key parameters determining the properties of the water-based suspensions include additives and pH value, as well as the specific energy input for dispersion, besides the solids content. Addition of a dispersant, which is intended to interact with particle surfaces, has a stabilizing effect on the suspension. Because these organic polymer additives are charged, they have an electrostatic stabilization effect; because they expand, they also have a steric stabilization effect. Hence, only very small amounts (less than 1 wt.% in relation to solids content) are needed. The dispersants must decompose without forming harmful species and without any solid residues during spraying. Both the suspension composition and the energy input for dispersion of the powder into the water are decisive for the resulting suspension properties. The effectiveness of the additives and dispersion is quantified by means of parameters such as surface charge (colloidal stability), viscosity, and sedimentation properties (Ref 5).

The choice of the appropriate powder for the suspension has to be made in relation to its costs and to the application of the coating. The purity of the powder should not be neglected because the presence of the impurities (i.e., alkaline ions) can influence the coating properties as it was observed for example in the case of alumina. Figure 2 illustrates the color change of the HVOF flame during spraying of a suspension from an Al_2O_3 powder (purity $> 99.7\%$) containing alkaline ions as impurities (about 0.1 wt.%, Fig. 2a) and from a highly pure powder $>99.99\%$; Fig. 2b). The presence of the sodium impurities in the raw powder results in a yellow

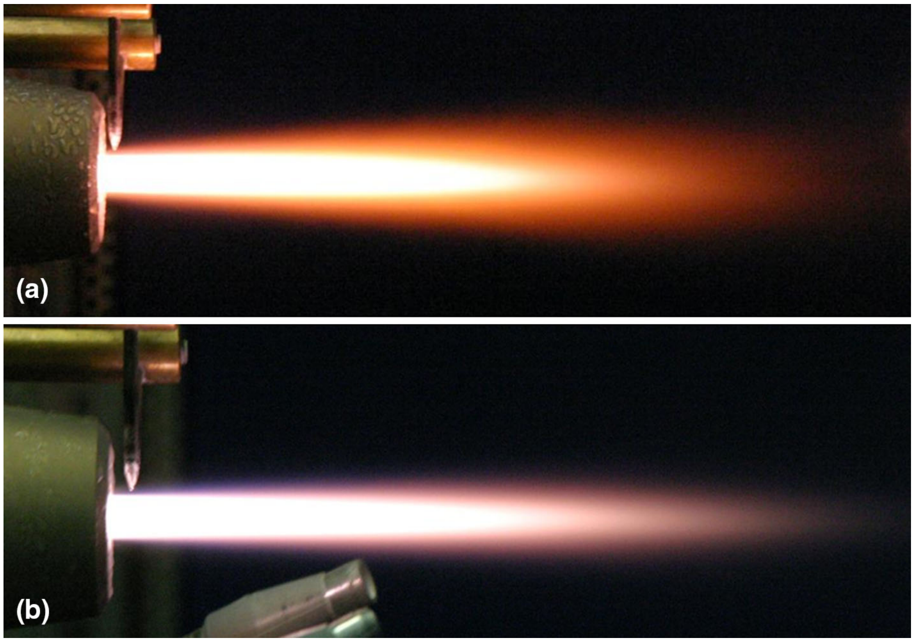

Fig. 2 Color of the HVOF flame during spraying of suspensions starting from an Al_2O_3 powder with alkali impurities (a) and a very high pure Al_2O_3 powder (b)

flame compared to the bright flame observed during spraying of the very pure alumina powder suspension. A significant retention of the α-Al_2O_3 was observed in the coatings coming from suspensions of very high pure powders. However, further investigations are necessary to elucidate the role of powder purity on the crystallinity of the suspension sprayed coatings (Ref 23).

The efficiency of the spray process can be improved through an increase in the solids content of the suspension (up to 50% by weight or more) because the amount of liquid to be evaporated is thus limited and the spray time is reduced. Especially powders with grain sizes over 1 µm allow such high concentrations to be reached.

There are different ways to obtain sprayable suspensions: (1) ready-to-spray suspensions (commercially available or tailored suspensions according to the client demands) from the producers, comparable to the delivery of grinding slurries; (2) development of a recipe in a laboratory, followed by on-site preparation of the suspensions according to this recipe in the spray shop. The latter approach requires the availability of equipment for suspension preparation and characterization.

2.1 Commercial Suspensions

For various materials, water-based Al_2O_3, TiO_2, YSZ suspensions with solid contents up to 50 wt.% and alcohol-based suspensions of YSZ with solid contents up to 25 wt.% are commercially available from different producers. The delivered suspensions are often based on well-dispersed nanomaterials and contain dispersant aids coming from the manufacturing process or are added to ensure a high stability (up to 6 months or more) and an easy redispersibility. The advantages of ready-to-use suspensions are the easy handling and mostly only stirring equipment to homogenize the suspension is necessary. There is no contact of the user with the fine (nano)-powder materials (healthy and safety aspects) at this stage. Nonetheless, there are some disadvantages such as limited flexibility regarding for example the crystallinity of the raw material and particle sizes, unknown ingredients (organic stabilizers) in the composition of the suspension (‘‘black box’’), limited information regarding the specific surface area of the raw material, particle size distribution in the suspension, rheological properties (viscosity), content of dispersant aid, drying rate. In most cases, some characterizations of the delivered suspensions, i.e., particle size distribution, viscosity, pH measurements are recommended before spraying.

2.2 On-site Prepared Suspensions Based on a Recipe

When on-site preparation of suspensions is preferred, a large variety of raw materials can be used for tailored suspensions for a specific application, but selection of the appropriate raw material and its characterization are required. Special knowledge of the suspension preparation procedure, which is specific for each raw material, as well as adequate equipment for dispersion and characterization of the suspension are needed. All necessary equipment is commercially available from various companies. Safety precautions for the user should be considered when fine powders are handled (i.e., working under exhaust, usage of masks, gloves).

A transfer scenario of the on-site developed suspensions from laboratory to the industrial user can be envisaged. The laboratories develop the recipes for the suspensions by order and transfer the instruction of preparation to the spray shops. After delivery of the components for the suspension (raw material, liquid media, and dispersant agent), the suspension is prepared following the recipe describing the steps of adding, mixing, and stirring of the components before use, including the precautions and safety data, which should be considered.

Figure 3 shows the properties of different commercially available Al_2O_3 suspensions (P1-P4) in comparison with an experimental Al_2O_3 suspension (E1). The viscosity measurements (Fig. 3a) showed that the commercial suspensions disposed of increased viscosity values over 50 mPa s, with an extreme value for suspension P2 (around 10,000 mPa s). With increase of the shear rate, decrease of the viscosity until of about 20 mPa s occurred. Nonetheless, these values are significantly higher when compared to the viscosity of the experimental suspension. Because of their non-Newtonian behavior for all suspensions, a continuous stirring during deposition process is recommended.

For the stability measurements during feeding, the suspensions were fed from a pressurized suspension feeder at 4 bars pressure and sent to the mechanical injector disposing of 0.3 mm inner diameter. From Fig. 3(b) and (c), it can be seen that the suspensions P1, P3, and E1 were very stable. The flow rates (feed rates) of suspensions P1 and P3 were of 40 mL/min (23 g/min) and 45 mL/min (14 g/min), respectively, slightly lower than the flow rate (feed rate) of the suspension E1 of 60 mL/min (27 g/min). The suspensions P2 and P4 were less stable and their flow rates (feed rates) decreased very fast with time which results in limited process stability. Table 1 summarizes the different aspects regarding the use of commercially available ready-to-spray suspensions and suspensions prepared on-site based on recipe.

3. Hardware Components for Suspension Spraying

The specific hardware components for suspension spraying are the suspension vessels, feed units, and injectors. The feeding systems are based on peristaltic pumps and pneumatic vessels. The latter offer advantages in terms of constant suspension feed rates, stability, monitoring of the feeding process, and wear of the feed system. Technological development of spraying with suspensions has thus far been concentrated in research institutions using laboratory-scale set-up integrated into the current spray booths. Intense efforts have been made in industry recently to develop suspension feeder hardware components, especially suspension feeders, as evidenced by the patent literature (i.e., Ref 24, 25). However, information on industrial activities in conference proceedings and journal articles is relatively scarce up to now (e.g., Ref 26). Important industrial developments originated in North America by Northwest Mettech Corp. (Nanofeed™), Progressive Surface Technologies (LiquidfeederHE™), or Oerlikon Metco. In Europe, GTV provides an industrial suspension feeder (SSF). Fraunhofer IWS developed an industrial scale three-vessels suspension feeder (Fig. 4a) allowing the continuous spraying without process interruption for suspension refilling as well as the spraying

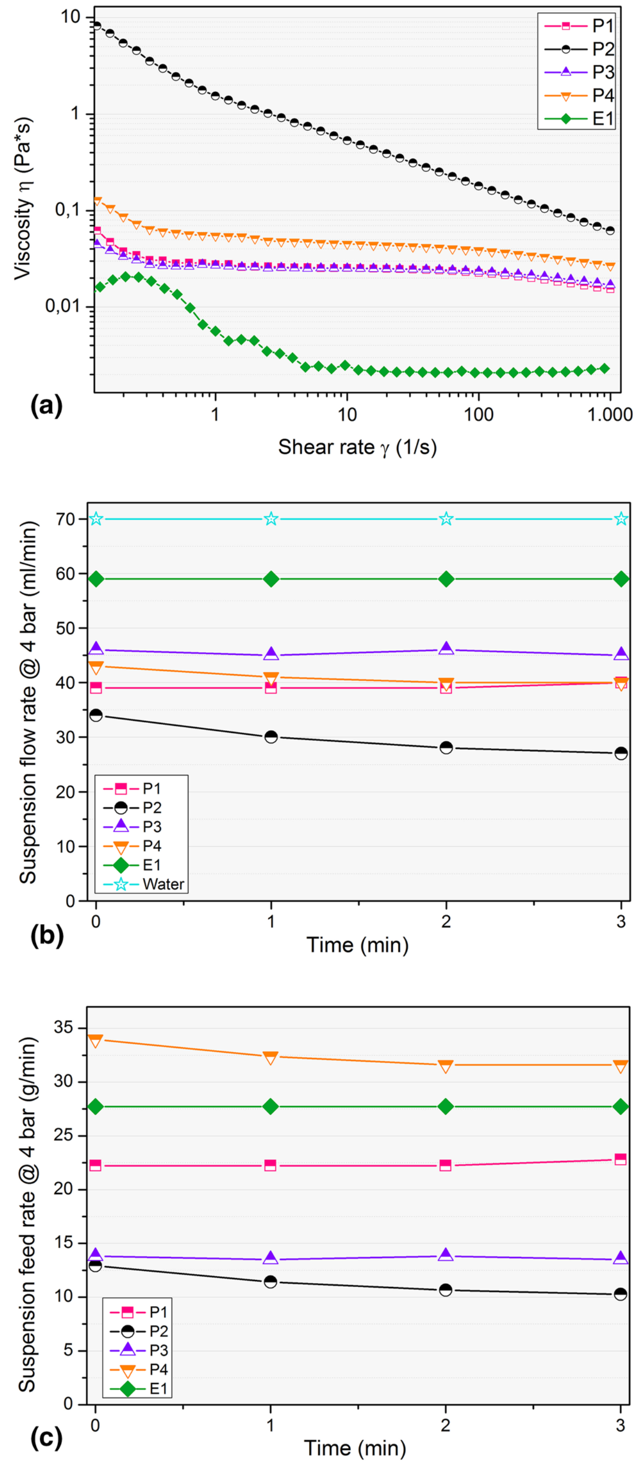

Fig. 3 Comparison of different properties of commercially available Al_2O_3 suspensions (P1-P5) and an experimental suspension (E1): (a) viscosity; (b) stability of the suspension flow rate; (c) stability of the suspension feed rate

Table 1 Criterions regarding on-site suspension preparation or use of commercially available suspensions

Criterion	Commercial	On-site preparation
Tailor-made availability for application; flexibility	−	+
Necessity of suspension preparation knowledge	(Yes)	Yes
Availability of hardware for handling	+	+
Process stability while spraying	(−)	+/−
Safe handling	+	+/−
Storage of the suspension feedstock available	+/−	+
Process monitoring available	Yes	Yes

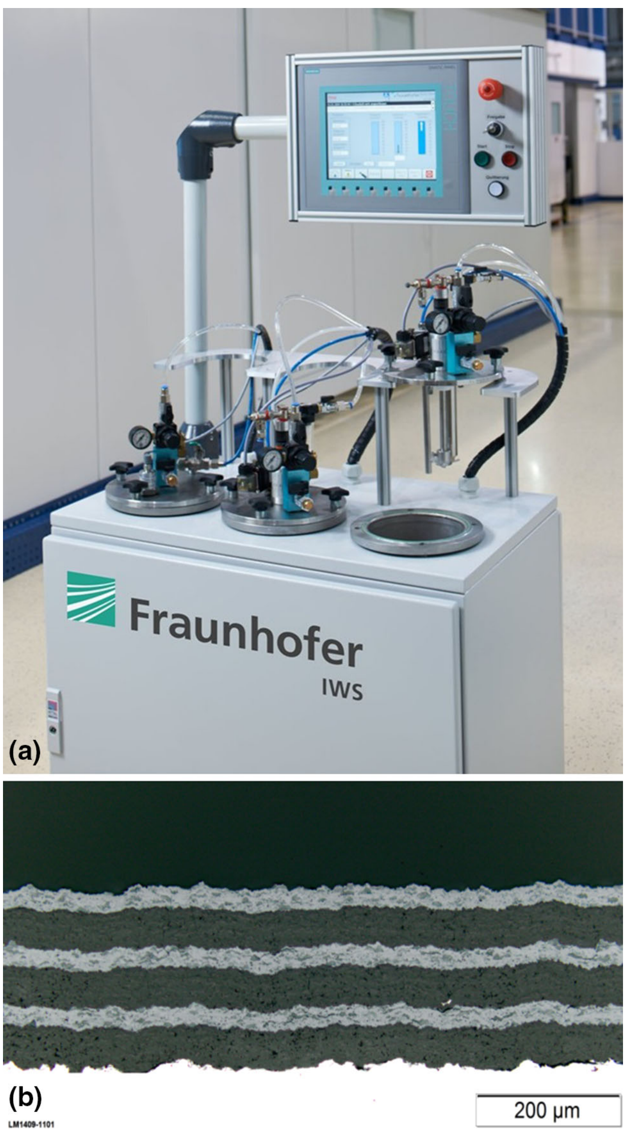

Fig. 4 (a) Three-vessels suspension feeder (courtesy of Fraunhofer IWS). (b) Multi-layered Al_2O_3-TiO_2 coating system

of two suspensions to produce composite coatings or multi-layered coatings in only one step (Fig. 4b).

Information on use of the following plasma spray systems for suspensions can be found in the literature (Ref 3, 6):

– Plasma spray guns of conventional design with a stick-type cathode: F4 (Oerlikon Metco), SG100 (Praxair Surface Technologies), F6 (GTV mbH), 100-HE (Progressive Technologies).
– Triplex three-cathode plasma (Oerlikon Metco).
– Axial III (Northwest Mettech Corp).

The development of HVOF suspension spraying (S-HVOF or HSVFS) started with a patent application of Caterpillar Inc. (Ref 27), which was however not granted in any country. Currently, the use of the Diamond Jet Hybrid 2700 (Oerlikon Metco) and TopGun (GTV) is described in the literature (Ref 3, 4). A new TopGun-S torch was recently developed by IFKB of the University of Stuttgart in cooperation with GTV (Ref 28-30).
The suspensions can be injected in one of the two ways: (1) through atomization with an inert gas prior to introduction into the plasma jet or (2) via mechanical injection through a nozzle as a fine stream directly into the plasma jet or HVOF-flame. The suspension injectors are fixed externally on the plasma spray guns enabling radial injection. In the case of the Axial III plasma gun, the injector is positioned internally allowing the axial injection of the suspension. Influence of the injectors based on atomization and those based on mechanical injection on the spray process was discussed largely by Fauchais et al. (Ref 6). With corresponding design of the spray gun in the S-HVOF spraying, the injection of the suspension is performed directly into the combustion chamber of the gun (Ref 3, 29, 30), but the radial injection with an external injector is also possible (Ref 3).

4. Microstructures and Properties of Suspension Sprayed Coatings

Due to the possibility of feeding of fine nano- and submicron-scale particles, tailored coating architecture that can be adapted to the given applications and coating thicknesses from several µm up to several mm is produced by suspension spraying. Examples of coating microstructures produced from aqueous suspensions are shown in micrographs of Fig. 5 as illustrative purposes. Generally, S-HVOF spraying allows the production of denser coatings than S-APS process. Besides the dense or porous microstructures of the suspension sprayed coatings, the specific columnar microstructures (mostly with S-APS

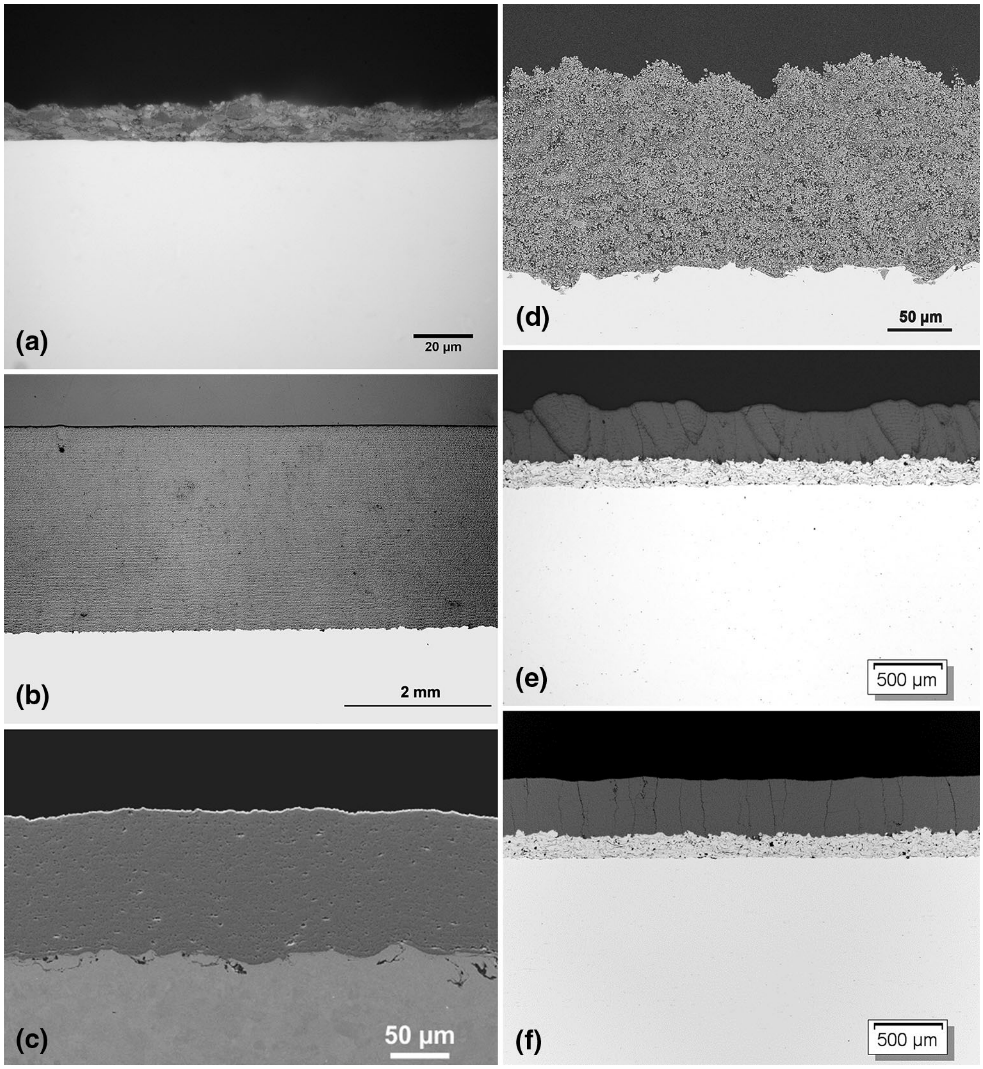

Fig. 5 Coating microstructures produced from aqueous suspensions: (a) thin (20 µm) TiO_2 S-HVOF coating; (b) thick (2.75 mm) Al_2O_3 S-HVOF coating (Ref 5); (c) dense Cr_2O_3 S-HVOF coating (Ref 33); (d) porous Al_2O_3 S-APS coating; (e) YSZ S-APS coatings with columnar-like structure (Ref 11); (f) YSZ S-HVOF coating with vertical cracks

process) and dense structures with vertically cracks are notable.

Due to the use of fine particles, the suspension sprayed coatings are built by impingement of flattened particles of the substrate in form of fine micron- or submicron-sized lamellae which are smaller than those produced by conventional spraying (Fig. 6). When compared to HVOF spraying, S-HVOF process allows smooth surfaces coatings with roughness values of R_a of about $<$1-3 µm and of R_z from 5 to 25 µm to be produced. Moreover, thanks to their lower surface roughness, thinner suspension sprayed coatings with refined microstructure can be produced. Because of the smaller particle sizes in the suspension compared to the spray powders, an appropriate substrate preparation (no or less intensive grit-blasting, adjustment of the grit size and blasting pressure) is required. This is of particular importance for thin (10-20 µm) coatings.

Influence of the spray parameters on the properties of suspension sprayed coatings is intensively described in the literature. For example, Killinger et al. (Ref 4) compiled the main characteristics of the coatings dedicated to the development of the SOFC components (i.e., suspension plasma-sprayed YSZ electrolyte, NiO/YSZ anode, and La_2NiO_4 cathode) and wear-resistant coatings based on Al_2O_3, Al_2O_3-ZrO_2, and Al_2O_3-TiO_2.

Due to their dense microstructures, the properties of S-HVOF coatings are superior to those reached by conventional coatings. Remarkable are the high hardness values up to 1800-2000 HV0.1 of S-HVOF Cr_2O_3 coatings obtained from alcoholic suspensions as published by Killinger et al. (Ref 30). Al_2O_3 S-HVOF coatings obtained from aqueous suspensions of very high pure powder retained their electrical insulating properties even in high

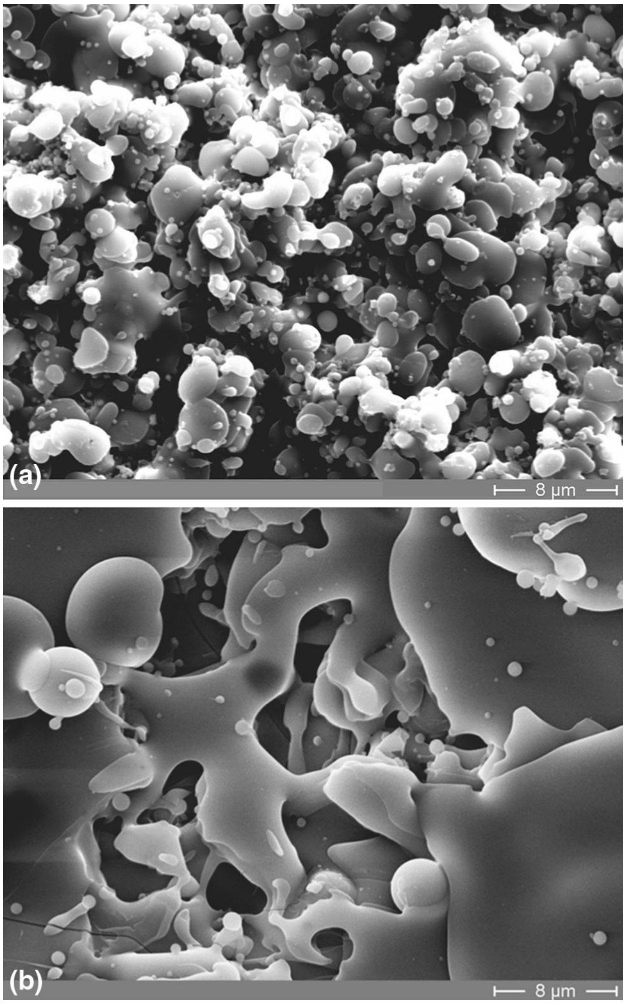

Fig. 6 Top-surface topographies of Al_2O_3 coatings obtained by (a) S-HVOF; (b) HVOF

humidity environments. Values of electrical resistivity between 10^9 and 10^{11} Ω m after 48 h conditioning at 97% relative air humidity were measured by Toma et al. (Ref 12). TiO_2 suspension sprayed coatings are more photocatalytic active in comparison to the conventional coatings. The retention of the anatase was found to be necessary but no direct correlation could be ascertained. Coatings produced from an appropriate rutile suspension were found to present a photocatalytic activity comparable with that of coatings obtained from the anatase suspension (Ref 31). Nanostructured WC-Co coatings with low porosity and hardness between 850 and 950 HV0.3 have been deposited by S-HVOF using aqueous suspensions (Ref 20, 21) and were higher than those obtained by S-HVOF of alcoholic suspensions (Ref 19). Although phase compositions occurring in the S-HVOF WC-Co coatings led to the nanostructured and amorphous phases, sliding wear evaluations indicated that the water-based WC-Co suspension sprayed coatings resulted in a relatively lower averaged volume loss in comparison to the conventional HVOF coatings. Similar trend was observed for the friction coefficient values, too (Ref 20). Thanks to their lower thermal conductivity values, between 0.5 and 1.2 W/m K for SPS and 0.9-2.1 W/m K for S-HVOF (i.e., Ref 10, 11) the YSZ suspension sprayed coatings are considered an interesting alternative for the development of new TBC coatings.

5. Economic Efficiency of Suspension Spraying

Costs and operational safety clearly speak for use of water as a liquid for preparing suspensions for thermal spraying on an industrial scale. The unfavorable energy balance of aqueous suspensions in comparison to the alcohol suspensions due to the heat input required for evaporation is often critically discussed (the vaporization of the water requires 2.63 MJ/kg compared to 1.01 MJ/kg for ethanol, Ref 1). However, conventional oxide feedstock powders are also prepared from finely dispersed powders by fusing and crushing or agglomeration and sintering with high additional energy consumption. Compared to the state-of-the-art, using water-based suspension the energy consumption along the entire technology chain is even lower.

Recent developments have demonstrated the possibility of significantly increased concentrations of aqueous suspensions with good processing characteristics. This has helped to verify the economic efficiency of the process in terms of deposition efficiency (layer thickness per torch pass) and feed rate in relation to the solids content. To illustrate that, Fig. 7 shows optical micrographs of two S-HVOF coatings sprayed using Al_2O_3 powders of varying concentration with the feed rate and other spray parameters kept constant. With the aim of producing dense coatings with a thickness in the range 200-300 μm, the concentration was increased from 35 to 50 wt.%. This led almost to a doubling of the coating thickness per pass and hence to a significant increase in efficiency. The coating hardness (about 850 HV0.3) also corresponded to the hardness of conventional alumina coatings and did not change with increase of the concentration from 35 to 50 wt.%. Typical advantages of S-HVOF sprayed coatings such as the high α-Al_2O_3 content were preserved (Ref 32). The feed rates between 15 to 35 g/min are comparable to those of conventional spray powders. The deposition efficiency for these coatings was estimated at about 65-70%.

For the spraying of ceramics with very high melting temperature such as the YSZ, Y_2O_3, or Cr_2O_3, alcohol-based suspensions are mostly applied (Ref 9, 10, 30), but the use of appropriate aqueous suspensions permits to produce thick mechanically stable coatings, too (Ref 11, 33, 34). The deposition efficiencies (around 20%) and coating thicknesses deposited per pass (2-5 μm/pass) are lower than in the case of alumina. Similar values of deposition efficiency for alcohol-based suspensions were published by Killinger et al. (Ref 30).

However, in contrast to conventional powders, high melting point ceramics (i.e., Cr_2O_3, YSZ) can be

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processed easier by S-HVOF (Fig. 5c, e, and f). Microhardness values from 1250 HV0.3 up to 1560 HV0.3 were measured for different aqueous S-HVOF sprayed Cr_2O_3 coatings, which are significantly higher than those of the conventional APS sprayed coatings, and are comparable to those produced from alcohol-based suspensions (Ref 4, 35).

Thanks to their lower surface roughness, thinner coatings than those produced conventionally can be sprayed.

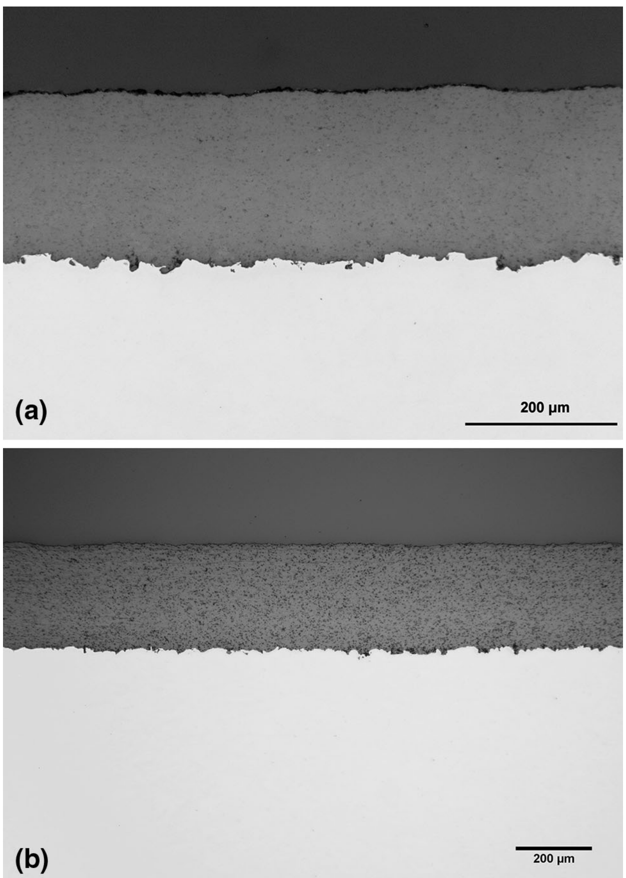

Fig. 7 Optical micrographs of S-HVOF Al_2O_3 coatings sprayed using suspensions with: (a) 35 wt.% solid content and (b) 50 wt.% solid content (Ref 5)

For various applications, production of effective functional coatings with lower thickness has an interesting economic impact in terms of reduction of costs and time production.

6. Examples of Coating Applications and Patents

In the last decade, suspension spraying was largely studied to develop coatings for many potential applications which are subjects of numerous reviewed papers and contributions to conference proceedings. Thanks to their interesting features, suspension sprayed coatings are under development for thermal barrier coatings with columnar microstructure, solid-oxide fuel cells components, photocatalytic and self-cleaning surfaces, medical applications and biocompatible coatings, insulating and wear-resistant coatings, high plasma erosion resistance applications. Although there is an abundance of scientific papers, very limited information about industrial implementation of suspension spraying is available. Some examples of patents and patent applications are reported here: low-thermal conductivity thermal barrier coatings based on suspension plasma sprayed with improved erosion properties (Ref 36), coatings for electrical insulating properties (Ref 32), dense Y_2O_3 coatings using S-HVOF process to coat electrostatic chucks for the semiconductor industries (Ref 34), high porous suspension sprayed plasma coatings for development of thermo-shock-resistant sensors for automobile industry (Ref 37), dense coatings for solid-oxide fuel cells (Ref 38, 39), and coatings on blades for paper industry (Ref 40).

7. Conclusions and Outlook

Suspension thermal spraying is a new technology in the group of thermal spray processes. It makes use of suspensions instead of powders and is mainly applied to APS and HVOF processes. Besides, finely dispersed materials with particle sizes ranging from nanometers to a few micrometers can be processed directly without the need for preparation of feedstock powders. After around a decade of development, the introduction of the suspension

Table 2 Basic characteristics of suspension spray processes

Characteristics	Value
Materials	Oxides and non-oxides
Particle size	From nm up to 5 µm
Solvent	Water, alcohol (i.e., ethanol, isopropanol), alcohol-water mixtures
Solid content	Typically 15-30 wt.%; up to 50-70 wt.% possible (depending on material)
Feeding system	Pressurized vessels; pump systems
Suspension feed rate	20-120 mL/min (10-60 g/min)
Coating thickness	Typically 10-150 µm;mm-thickness also possible
Layer thickness per pass	Typically 2-15 µm
Deposition rate	30-70% for low melting ceramics (i.e., Al_2O_3, TiO_2); 10-30% for high melting ceramics (i.e., Cr_2O_3, YSZ)
Coating roughness	R_a: <1-3 µm; R_z: 10–30 µm

spray technology into industrial practice is increasing. This development is evidenced by the appearance of a general technical bulletin about this technology (Ref 41). Parameters such as deposition efficiencies and layer thickness deposited per pass lie in a range enabling cost-effective coating preparation. The main features of the spraying with suspensions are summarized in Table 2.

Suspension spraying is a competitive technology, but some technological challenges still need solutions. More efforts have to be undertaken for the implementation of the suspension spraying from laboratory to industry, which should allow production of suspension sprayed coatings in serial production. Apart from development of suitable suspensions, adaptation of the system equipment for feeding and injection of the suspension is necessary. The commercial availability of suspension feeders, new designed spray guns, development of new spray booths, as well as the availability of the suspensions will definitely drive the development.

The materials, which are processed by suspension thermal spraying, will be surely extended in the future. However, it can be expected that this will be focused on plain materials, in particular oxide powders. Recently, it has been shown that also WC-Co coatings with relatively high hardness and good wear resistance can be produced (Ref 20, 21). However, the question of optimized feedstock powders and process conditions is much more critical than for oxides. Investigation of coating microstructures and properties in dependence on the powder and suspension properties, development of spray processes and parameters will be continued in order to develop tailored and innovative coating solutions. Many works especially in the application domains are not disseminated because of non-disclosure restrictions or their publication is delayed.

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