SANS Study of Microstructure and Microporosity in Thermally Sprayed Metallic Deposits

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Thermally sprayed deposits exhibit a special type of microstructure related to the manufacturing method. Anisotropic Porod scattering was used to characterize thermally sprayed deposits made of metals and metal composites (Ni, NiCr, and NiAl). Strong microstructural variations were found in deposits produced by different techniques, with a Porod constant varying by up to a factor of 5. Analyzing the coatings ‘edge-on’, some of the samples, depending on the manufacturing method and the material, showed only small anisotropy whereas others showed an anisotropy as pronounced as known from ceramic coatings.

An improved understanding of the relationship between microstructure and the (macroscopic) properties of thermal spray deposits can help to shift from purely empirical to science-based developments. The research on this subject done so far was based in most cases on deposits manufactured by only one of the thermal spray techniques. The results therefore are often specific for the spray technique applied and cannot readily be generalized. The present study aims to overcome this drawback by involving samples manufactured by a number of different thermal spray techniques: flame spraying, HVOF, and plasma spraying (APS, VPS, WSP), in order to generate a wide range of different microstructures. Various Ni-based alloys are included in this program, starting from a simple chemistry (Ni) and ending with complex NiCrAlY alloys. The here presented results were obtained with NiCr (80% Ni, 20% Cr) feedstock.

In the present project various techniques are applied to characterize the microstructure, including optical and electron microscopy, and the scattering techniques XRD and small-angle neutron scattering (SANS). The present report concentrates mainly on the SANS-measurements which were carried out at the SINQ-SANS facility at PSI. The coatings used for these measurements were about 1.5 mm thick. Cross sections of the coatings on their (steel)-substrate were prepared, mostly 2 mm in thickness, mounted in pairs face-to-face on the sample holder and measured with the neutron beam entering the samples edge-on. To prevent influences from multiple magnetic refraction, the samples were placed in a (saturating) magnetic field at the sample position. The measurements were usually made with neutrons of 5 Å in wavelength, and at sample-to-detector distances of 2m, 4.5m and 20m.

Fig 1 shows two typical scattering curves to illustrate that the \( Q^{-4} \) (Porod) behavior is observed over a wide range in \( Q \), and also, comparing the absolute intensities, that the differences observed from samples of the same material, but sprayed by different techniques, can be quite significant. The related Porod-constants were found to differ by up to a factor of 5. From the Porod constants, the voids specific surface area can be determined, which in a quite characteristic way could be related to the fabrication technique and to the macroscopic properties like wear and corrosion resistance [1].

Also, anisotropy in the scattering was found quite pronounced in many of the samples, whereas in others the scattering was found fairly isotropic. Fig. 2 gives two examples by means of the Porod constant as a function of the rotation angle relative to the sample orientation. The sample shown on the left is only slightly anisotropic, the one on the right shows pronounced anisotropy with the indication of a neck at 90° and 270° (the sample orientation in both cases was vertical). This type of anisotropy can be interpreted in terms of a well organized porosity system with extended voids in-plane and small voids or cracks in the direction from the substrate to the surface.

Further research in this project is oriented towards the increasing quantity and quality of data for this material as well as towards gaining similar data on more complex Ni-based materials.