Resolidified tips of used cored wires analyzed by µCT

J. Nellesen, F. Beckmann[1], M. Abdulgader[2] and W. Tillmann[2]

RIF e.V. – Institut für Forschung und Transfer, Joseph-von-Fraunhofer-Str. 20, D-44227 Dortmund
[1]Institute of Materials Research, Helmholtz-Zentrum Geesthacht,
Max-Planck-Str. 1, D-21502 Geesthacht, Germany
[2]Institute of Materials Engineering, Faculty of Mechanical Engineering,
Technische Universität Dortmund, Leonhard-Euler-Str. 2, D-44227 Dortmund, Germany

The type of feedstock used in thermal spraying (TS) has a strong impact on the homogeneity of the spraying plume. It is more homogeneous for coating processes where a *powdery* feedstock is deposited (like in High Velocity Oxygen Fuel (HVOF) spraying). On the contrary, if the in-flight particles are atomized out of a melting bath (like in Twin Wire Arc Spraying (TWAS)) the spray jet is less homogeneous. This is due to the fact that these particles are generated by the impingement of fast continuous flowing air upon the melting tips of electrically conductive wires. Therefore, the quality of coatings deposited by the TWAS process is directly dependent on the three successive impact factors: (i) the melting behavior of the feedstock, (ii) the characteristics of the spraying plume/in-flight particles and (iii) the splat formation by the layer-by-layer deposition of the coating. Beside the variation in the used wire types in TWAS, the arc attachment plays a determining role in the observed melting behaviour: In the case of the anode, the diffuse arc attachment heats a large part of the wire tip surface, creating a thin layer of molten metal on the wire tip [1].
In this work, the melting behavior of the feedstock in the TWAS process is studied. For this purpose, cored wires filled with W-rich particles were sprayed. After interrupting the TWAS process, the tips of these cored wires were imaged by 3D µCT in order to analyze how the filling powder interacts with the melted part of the velum.

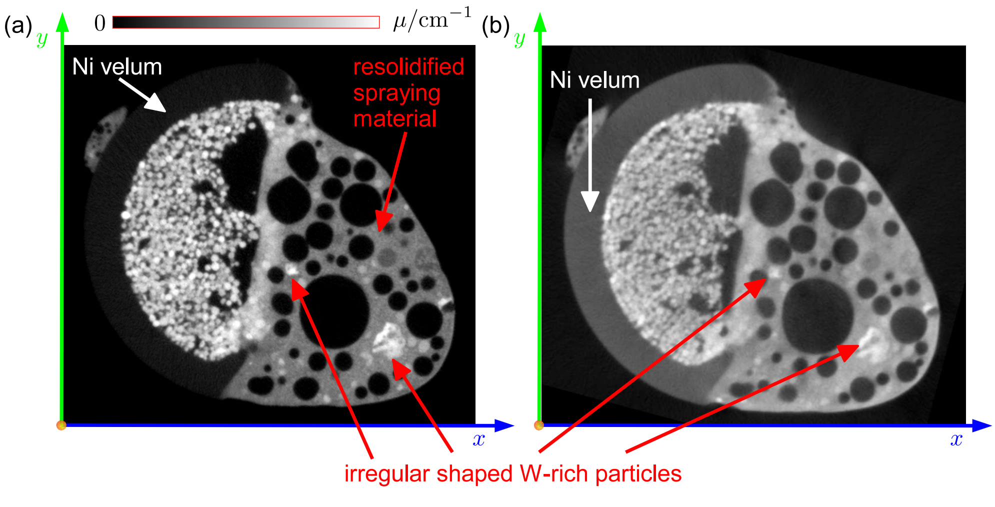

Figure 1: Cross-sections (xy slices) extracted from the 3D tomograms generated with: (a) monochromatic radiation, (b) polychromatic radiation

Different X-ray radiation sources were utilized to tomographically image the tips of cored wires which were connected as anode: On the one hand experiments were carried at the beamline P07 (HEMS) operated by the Helmholtz-Zentrum Geesthacht, at the storage ring PETRA-III, DESY, Hamburg. Monochromatic photons of the energy $E = 120\,\mathrm{keV}$ were selected with a double-crystal monochromator. On the other hand, the same specimens were tomographically imaged with a µCT scanner which is equipped with a micro-focus X-ray tube. Polychromatic photons with a maximum energy $E_{\max} = 220\,\mathrm{keV}$ were emitted divergently from the focal spot of the X-ray tube.

The tip of a used cored wire which consists of a Ni velum filled with spherical WC/Co particles exhibiting diameters in the range of 25-45 µm was investigated. In Fig. 1 cross-sectional views (xy slices) extracted from the reconstructed 3D tomogram are depicted which reveal the same microstructural region: Subfigure (a) represents the cross-section through the 3D tomogram generated with monochromatic radiation whereas the 2D xy slice in subfigure (b) was extracted from a 3D tomogram which was produced by using polychromatic radiation. The images in which the distribution of the linear attenuation coefficient μ_l is coded by grayscale agree very well. The brighter a pixel in the 2D CT slice is, the higher the material in the corresponding 3D voxel (x, y, z) of the tomogram attenuates X-ray photons. On the left in the 2D CT slices circular shaped bright intersection areas are visible which can clearly be identified as the ball-shaped tungsten-rich particles each of which is arbitrarily virtually cut in the 2D CT slice. The subfigures in Fig. 1 suggest that the spraying material was in the molten state during the spraying process since a large contiguous region is visible. This spraying material (velum and filling), which has resolidified after stopping the thermal spraying process, is interspersed with spherical discontinuities, namely smaller high-attenuating WC/Co particles (bright spots in Fig. 1) and larger low-attenuating spherical cavities (dark circular areas in Fig. 1). As expected by the densities ρ and the effective atomic number Z of the wire components, the spherical tungsten-rich particles feature the highest gray value in the tomographic 2D slices. The Ni velum which can clearly be recognized on the left in these slices exhibits the lowest gray value (except for the surrounding air). Moreover, a medium gray value can be recognized in this resolidified spraying material mass. This corresponds to a mean linear attenuation coefficient of the Ni velum and the W-rich particles. Thus, it can be concluded that the components of the cored wire are intermingled in the resolidified spraying material mass.

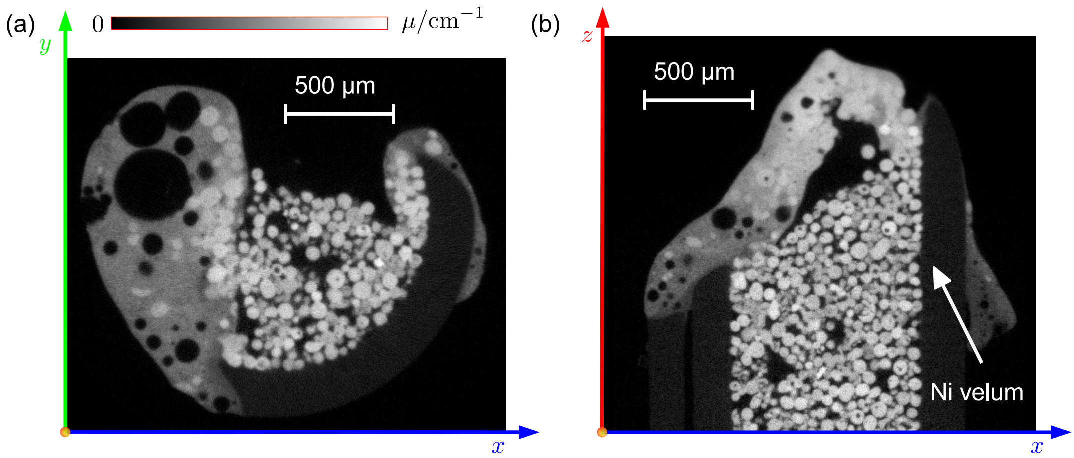

Figure 2: (a) cross-section (xy slice) and (b) longitudinal section (xz slice) extracted from the synchrotron radiation based micro computed tomogram (SRµCT) of a cored wire tip (AS781) containing particles with diameters in the range $\mathrm{K_{ver}} = -90\,\mu\mathrm{m} + 63\,\mu\mathrm{m}$

In Fig. 2 a cross-section ((a) xy slice) and longitudinal section ((b) xz slice) through the SR tomogram of a cored wire (AS781) which is filled with WC/Co powder of the particle diameter range $\mathrm{K_{ver}} = -90\,\mu\mathrm{m} + 63\,\mu\mathrm{m}$ are illustrated. Both subfigures suggest that the resolidified melting bath in the vicinity of the powdery filling (cf. Fig. 2(a)) as well as at the most outer end of the tip (cf. Fig. 2(b)) seems to be enriched by melted W-rich particles since elevated gray values can be found in these regions.

References

[1] W. Tillmann, E. Vogli and M. Abdulgader, J. Therm. Spray Technol. 17, 974–982 (2008).