Study of the splat microstructure and the splat-substrate interface for a NiCr coating HVOF sprayed on to a steel substrate

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The High Velocity Oxygen Fuel (HVOF) spraying process allows the preparation of thin coatings by the melting and spraying of a fine powder onto a substrate using an oxygen flame [1]. However, splat formation and the bonding processes at the substrate are not fully understood. Particles can impact the substrate in a fully molten, partially melted or even unmelted state [2]. In this study a NiCr (80Ni-20Cr) powder was HVOF sprayed onto a mirror polished stainless steel 304 substrate.

This study focuses on fully melted splats. These were studied using a scanning electron microscope (SEM) (Hitachi S-3400X, Mito, Japan), a focused ion beam (FIB) microscope (FEI XP200, Hillsboro, USA), a dual beam high resolution focused ion beam instrument (FEI XT Nova Nanolab 200, Hillsboro, USA) used to prepare the TEM specimens, and a transmission electron microscope (TEM) (Philips CM200, Eindhoven, The Netherlands).

Figure 1 shows SEM images of typical fully melted splats. These are disc-shaped with an irregular rim; the splats display a shallow central crater from the impact of the particle. Pores can sometimes be found at their centre. Diameters are usually between 20 and 110µm, with an average of ~58µm.

Figure 2 displays FIB cross-sections performed on a disc-shaped splat. On top of these sections is a strip of Pt deposited *in situ* in the FIB. It can be observed that the grain structure is columnar, with very fine grains in the centre of the splat (c.1) and larger grains towards the periphery (b.2). The contact between splat and substrate is mostly good (b.3), with a distinct and straight interface (the curvature of the crater can be seen quite clearly (b.4)). However, under the rim splat delamination can be found (a.5), and a layer of FeO (identified later by TEM) is present at the bottom surface of the splat (a.6). In the centre of the splat some porosity can be found (c.7). On the walls of the pores FeO can also be found. For some other splats NiO was also found to be present in these central pores.

Figure 3 presents a TEM cross-section of a fully melted splat: the splat-substrate interface is indistinct on the bright field image (1) which is evident from the lack of contrast at this boundary. However, the interface appears clearly on the elemental maps (2). EDS maps also reveal that a thin distinct layer of Cr_2O_3 is present on the outer surface of the splat (3), from oxidation of the splat after flattening. Elemental linescans performed across the interface shows that diffusion has occurred across this feature over a depth of about 180µm. Diffraction provided confirmation of the identification of the various phases.

Among the other FIB and TEM cross-sections that was performed, it was found that diffusion across the interface was commonly observed, although the degree of diffusion at the centre and the periphery of the splats was reduced, where the contact between splat and substrate is poorer.

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The results suggest that the HVOF process leads to the production of high quality coatings, compared to other techniques [1, 2], as the splats formed have regular shapes, a limited amounts of oxide and porosity and limited splashing. Moreover, the occurrence of diffusion is a sign of good bonding and adhesion between the coating and the substrate. Further study is currently underway to study the effects of the surface chemistry on the splat formation.

1. M. Dorfman, Adv Mat. & Proc. (2002) p47
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Figure 1. SEM images of typical fully melted splats

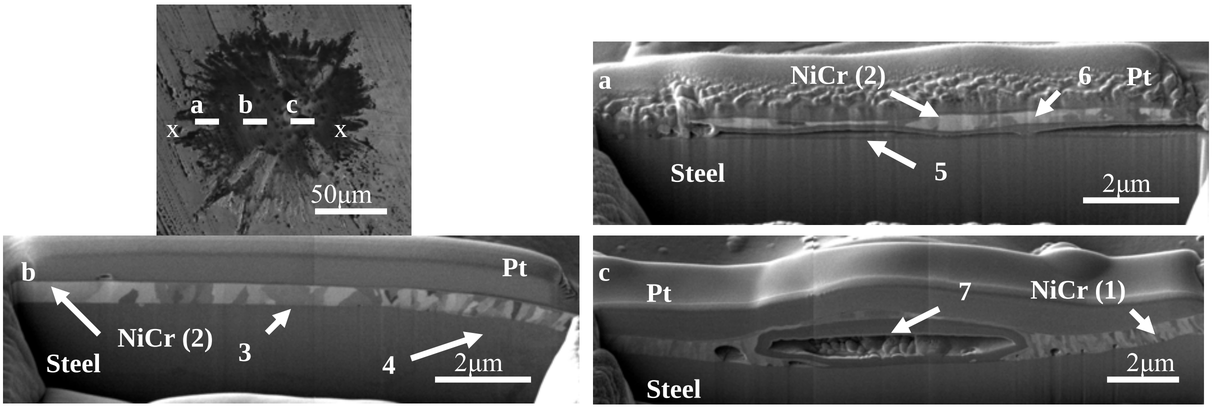

Figure 2. FIB cross-sections of a regular splat: (a) across the rim; (b) across the side of the impact crater; (c) across the centre of the splat.

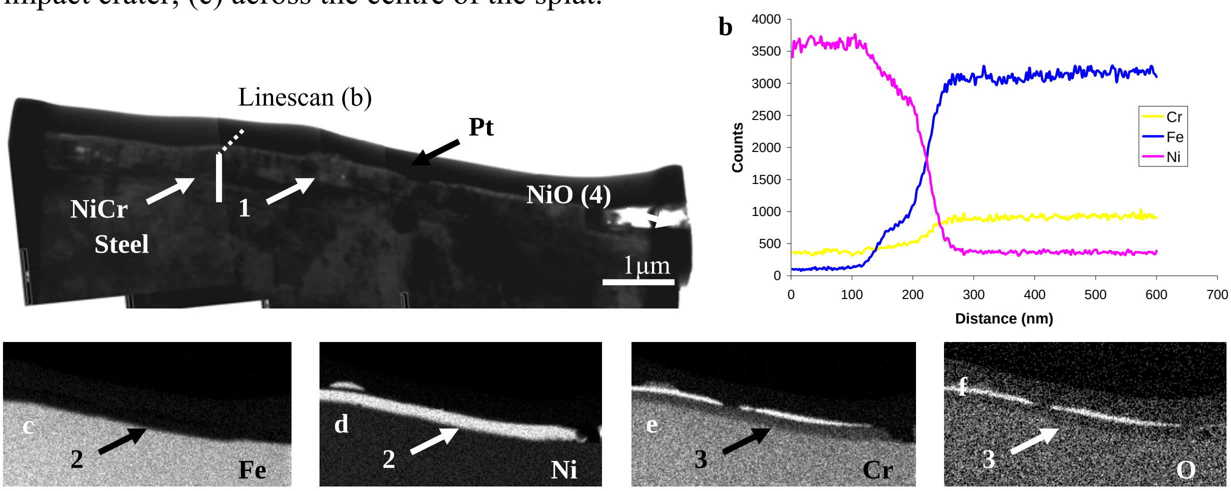

Figure 3. TEM cross-section of a regular splat: (a) Bright field image; (b) Linescan performed across the interface; (c-f) EDS maps of Fe, Ni, Cr and O.

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