SOLID PARTICLE EROSION BEHAVIOUR OF PLASMA SPRAYED COATINGS ON A FE-BASED SUPERALLOY
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ABSTRACT
In the present investigation plasma sprayed metallic coatings of NiCrAlY and Ni-20Cr were deposited on a Fe-based Superalloy (32Ni-21Cr-1.5Mn-1Si-0.3Ti-0.3Al-0.1C and Balance Fe) by shrouded plasma spray process. NiCrAlY was used as bond coat in both the cases. Erosion studies were conducted on uncoated as well as plasma spray coated superalloy specimens using an air-jet erosion test rig at a velocity of 40m/s and impingement angles of 30° and 90°. Silica sand particles of size ranging between 150 and 212 μm were used as erodent. The coatings have been characterised for porosity, microhardness and microstructure. Erosion behaviours of the superalloy and plasma spray coatings are discussed. Of the two plasma sprayed coatings, the NiCrAlY coating gave the lowest erosion rate regardless of the impact angle.

INTRODUCTION
Erosion and high temperature oxidation by the impact of fly ash and unburned carbon particles are the main problems in heat exchanger tubes and other structural materials in coal-fired boilers (Hidalgo et al., 2001). Gas and steam turbines operate in the environments where the ingestion of solid particles is inevitable and results in erosion of the material. In such environments protective coatings on the surface of superalloys are frequently used (Tabakoff, 1999).

It has been reported that the thermal spray is a technique that produces a wide range of coatings for diverse applications. Plasma spraying is the most flexible and versatile thermal spray process with respect to the sprayed materials (Knotek, 2001). This work attempts to investigate the erosion behaviour of plasma sprayed Ni-22Cr-10Al-Y and Ni-20Cr coatings on superalloy substrate superfer 800H.

EXPERIMENTAL PROCEDURE
The details of the coating formulation, characterization method, erosion testing as carried out using a room temperature erosion test rig, and the erosion test conditions used in the present study are reported elsewhere (Mishra et al., 2005).

RESULTS AND DISCUSSION
Characterisation of the as-sprayed coatings
The optical microstructures along the cross-section of the plasma sprayed coatings are shown in Figure 1. Microstructures revealed are typical for a plasma spray process consisting of splats, which are of irregular-shaped with distinguished boundaries. The as-coated structure is lamellar with some oxide inclusions and open pores. The average porosity of the NiCrAlY coating was found to be in the range of 2-5% whereas that of the Ni-20Cr coatings was found to be higher and is in the range 3-5%. The microhardness profiles of different plasma sprayed coatings are shown in Figure 2. Of the two coatings, the maximum value of the average microhardness was achieved by the Ni-20Cr coating which was of the order of 724 HV, whereas a minimum of 385 HV by NiCrAlY coating.

Erosion rate as a function of impingement angle
Figure 3 shows the effect of impingement angle (30° and 90°) on erosion rate at an impact velocity of 40m/s for uncoated and coated superalloy. Both the coatings have shown a considerably higher erosion rate than the superalloy. Erosion rate graphs of the NiCrAlY coating and superfer 800H substrate show that they are marginally dependent upon impact angle. Whereas in the case of the Ni-20Cr coating the effect of impact angle is appreciable.

The erosion rate of Ni-20Cr coating is higher than that of NiCrAlY coating, this might have also been contributed by the higher porosity content of this coating. This is in agreement with the findings of Levy (1988), in which he has reported that the greater the porosity of the coating, the greater is the material removal rate. It can be perceived from Figure 2 and 3 that increasing erosion rates correspond to decreasing hardness. Similar findings for hardness and porosity of the ceramic thermal barrier coatings have been reported by Davis et al., (1986).

Surface morphology of eroded material
The SEM observations made on the eroded surfaces (Figure 4) reveal severe plastic deformation at the surfaces. The morphology of the eroded surface of superfer 800H at a 30° impact angle (Figure 4a) indicates that the failure is due to sand erosion where ploughing and lip fracture play a dominant role. Formation of lips with plastic deformation can be clearly seen from the eroded surface of superfer 800H at a 90° impact angle (Figure 4b). Also broken piece of sand particle embedded in the material is revealed in Figure 4b. From the SEM micrographs (Figure 4c,d,e and f) of eroded NiCrAlY and Ni-20Cr coatings at 30° and 90° impact angles, it can be seen that the material removal by erosion take place by plastic deformation and lip fracture. The erosion occurred by the platele mechanism with plastic deformation and lips fracture in all the uncoated and coated materials, similar to that described by Hutchings and Levy (1989).
CONCLUSIONS

Of the two plasma sprayed coatings, the NiCrAlY coating gave the lowest erosion rate regardless of the impact angle, and the Ni-20Cr coating gave the highest erosion rate which might have also been contributed by the higher porosity content. It can be inferred that the porosity contents have direct effect on increasing the erosion rate of the plasma sprayed coatings whereas the hardness may not be directly contributing to the improvement of the erosion resistance.

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REFERENCES


Figure 1. Cross-sectional microstructure of NiCrAlY and Ni-20Cr coating on superfer 800H substrate.

Figure 2. Microhardness profiles of as-sprayed NiCrAlY and Ni-20Cr coatings with bond coat of NiCrAlY on Superfer 800H substrate along the cross-section.

Figure 3. Erosion rate (g/g) against cumulative mass of erodent of Superfer 800H and plasma sprayed coatings.

Figure 4. Scanning electron micrographs of eroded superfer 800H and plasma sprayed coatings. (a) and (b)superfer 800H; (c) and (d) NiCrAlY coating; (e) and (f)Ni-20Cr coating at 30° and 90° impact angles respectively.