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Investigation on microstructural and mechanical properties of HVOF sprayed Inconel-718 coatings on grey cast iron

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ABSTRACT

In the present work Inconel-718 powder was deposited on grey cast with High velocity oxy-fuel (HVOF) thermal spray coating technique. The thickness of coating was kept 220µm with powder having average particle size of 45µm. The deposited coating was characterized with Scanning Electron Microscope (SEM) equipped with Energy Dispersive Spectroscopy (EDS) and Optical Microscope (OM). Microstructure analysis reveals the splat by splat formation of coating with good mechanical keying to the substrate. Further the microhardness was investigated and it was found that the microhardness of Inconel-718 coatings is (567Hv) significantly 2.5 times higher than base material microhardness (229Hv).
Keywords: Inconel-718, Grey cast iron, High Velocity Oxy-fuel.

I. INTRODUCTION

Thermal spraying coatings (TSC) methods have contributed a major role in the protection of working surfaces in various engineering applications. This technique is very useful for repairing the components and at the same time it is economical process.

Engineering components has to withstand against aggressive environments for long service periods and TSC process is effective technique as it can deposit any engineering material .Researchers have utilized the HVOF process in many engineering applications according to the desired properties[1-4].In this technique the powder particles are accelerated towards the substrate with high velocity and these particles then impacted on the substrate and forms splat by splat coating with good mechanical bonding. The both velocity and temperature imparts dense structure of the coating [5].Nickel based coatings has gained interest of researchers due excellent properties to resist failures of wear and corrosion[6-10].Inconel- 718 is a nickel based alloy which contains significantly amounts of nickel, chromium and iron with marginal amounts of niobium , molybdenum ,aluminium and titanium. This alloy is used in many applications of high temperature applications like jet engines, turbine blades [11-12]. The work has been done for slurry erosion behaviour with air plasma spray coating process using Inconel-718 as coating powder and resulted in good properties against erosive wear [13].The authors have reported the failure of working surfaces of glass manufacturing tools which works in high temperatures and these tools include moulds, neck rings and bottom plates. These components are made of grey cast iron FG-200 [14-15].
The main objective of the present work is to deposit the Inconel-718 coating on the grey cast iron and the analysis of the coating with regard to mechanical performance in terms of microhardness and microstructural characterization of the as sprayed coatings using Scanning Electron Microscope (SEM) equipped with Energy Dispersive Spectroscopy (EDS) and Optical Microscope(OM).

II. METHODS AND MATERIAL

Substrate material and coating powder

In this study, Grey cast iron FG-200 grade was selected as a substrate material. The elemental composition of the grey cast iron substrate material and Inconel-718 powder is reported in Table 1. The main reason for the selection of base material is its use in engineering applications especially like machine tools such as glass manufacturing components include dies, bottom plates and neck rings.Inconel-718 was selected as a coating powder

owing to its excellent strength at high temperature and it provides wear and corrosion resistance in addition with higher impact strength which is also required in case of moulds as the red hot raw material enters into the mould with high impact. The powder was procured from Metallizing Equipment Corporation, Jodhpur, India. The SEM micrograph of the Inconel-718 powder is shown in Figure1.which indicate the average particle size of 45 µm with spherical morphology.

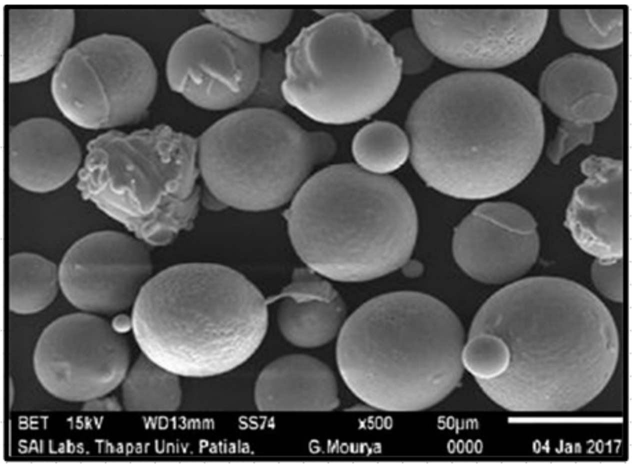

Figure 1. SEM micrograph of Inconel-718 coating powder

The substrate material was obtained after cutting on Wire-cut Electro Discharge Machine (WEDM). The substrate size was taken as $20\times20\times5mm^3$ for SEM analysis and microhardness. Substrate was properly cleaned using acetone to ensure its surface free from any dust particles present on the surface before coating process. The specimen required for hardness testing was properly polished to get the hardness measurements.

Table 1. Elemental composition of grey cast iron and Inconel-718 powder

Elements wt%	Ni	Cr	Fe	C	Mo	Others
Inconel-718	50	21	19	0.08	2.8	Bal.
Grey cast iron	--	--	95	3.1	--	Bal.

X-Ray Diffraction (XRD) of coating powder is shown in Figure 2. and indicates the presence of nickel and chromium as a major element in the coating powder along with cobalt and iron.

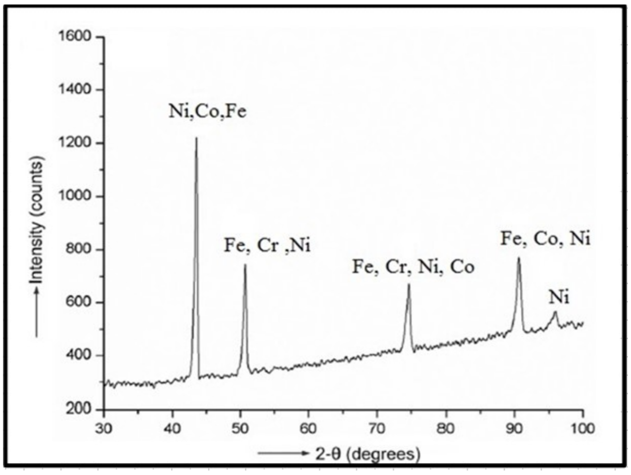

Figure 2. XRD pattern of Inconel-718 powder

Deposition of HVOF coating

High velocity oxy-fuel (HVOF) spraying process with Hipojet-2700 gun was used to deposit the coating on the substrate material at Metallizing Equipment Corporation, Jodhpur, India. Initially the substrates were polished down to the size 1200 emery paper grade followed by mirror finish using alumina powder particle on polishing machine. The polished samples were grit blasted with 16 mesh size virgin brown alumina in a Pressure blasting [Model:MEC-9182] with a blasting pressure of 5.5kg/Sq.cm for abrasive grit blasting. Surface roughness of 6Ra µm was maintained to ensure the proper mechanical anchorage of coating powder to the substrate. The optimized values of process parameters used for the deposition of Inconel-718 coating are listed in Table 2.and were considered to attain dense and uniform coating the coating of 220 µm thickness was deposited. A typical coated sample is shown in Figure 3.

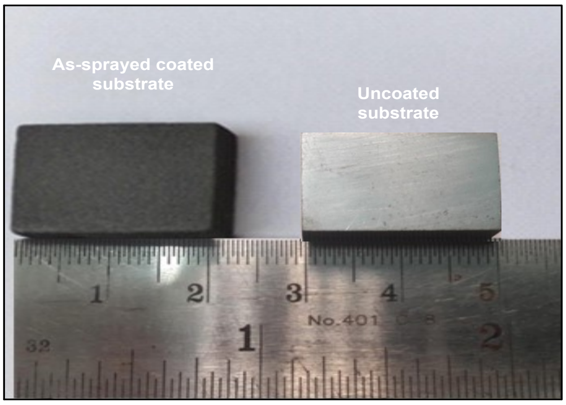

Figure 3. Inconel-718 coated substrate with HVOF spraying.

Table 2. Process parameters for HVOF coating

Process parameters	Inconel-718 coating
Oxygen flow rate (splh)	270
Oxygen pressure(bar)	10
Powder feed rate (g/min)	60
Fuel gas (LPG) flow rate (splh)	55
Fuel gas (LPG) pressure (bar)	8
Stand -off distance (mm)	200

Elemental composition of NiCrAlY powder is reported in Table 3. The bond coat powder has a product code PAC-9620M and it was supplied by M/s.Powder Alloy Corporation, Ohio,USA.

III. RESULTS AND DISCUSSION

Microstructural analysis

The analysis of microstructure was carried out using Optical Microscope (OM) and SEM for the coatings

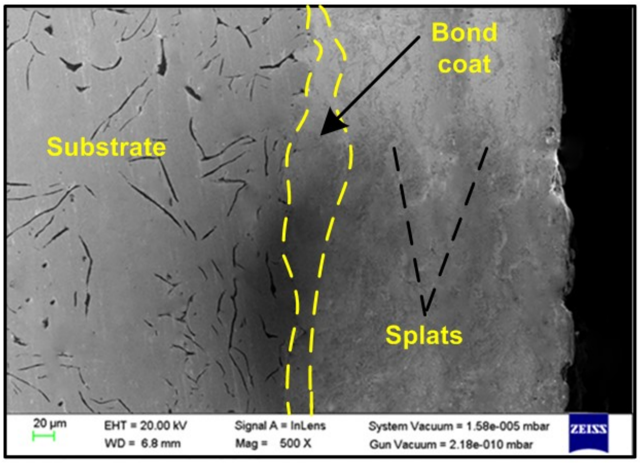

Figure 4. SEM micrograph of as sprayed Inconel-718 coating

uniformity and thickness of bond coat and Inconel-718 coating. Figure 5. Shows the optical micrograph of cross sectional view of developed coatings. They show the thickness of 220 µm and indicate a bond between substrate and coating. It can be clearly seen from the SEM micrograph shown Figure 4. that the powder is well bonded to the substrate material and is free from any crack and semi melted particles. Due to splats molten state coating formed has a lamellar structure and plastically deformed on the surface of the substrate. A uniform and dense coating is observed and the interlayer between the coating and substrate is free from any kind of discontinuities Proper bonding of the powder is due to the high velocity of the HVOF thermal spray coating process and resulted in coating free from any pores and cracks and during the high velocity oxy-fuel coating process the powder particles accelerated towards the work piece with very high velocity of 900 m/sec and it approaches to even more than this velocity value and another factor is high temperature of powder particles due to combustion processing inside the combustion chamber of this apparatus. Both high velocity and high temperature when carries a powder particles towards work piece forms a layer by layer coating which is having good adhesion strength with each other and mechanical bonding with the substrate material.

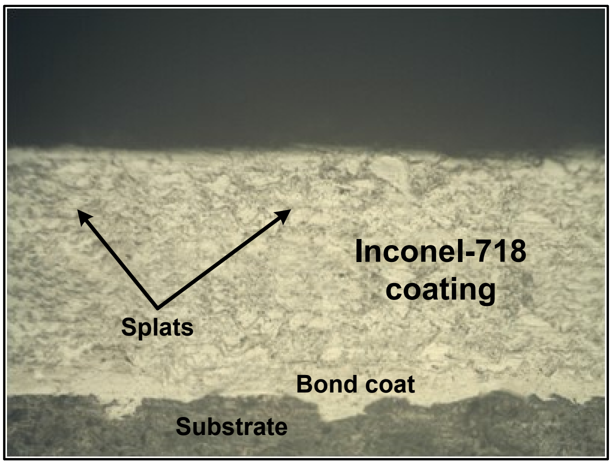

Figure 5. Optical micrograph of Inconel-718 coating

The coating shows the well bonded splat by splat formation and there is bond coat that has been introduced in the coating of 40 µm thickness and NiCrAlY was used as a bond coat material .This bond coat can be seen in the Figure.4 and Figure 5.and reveals proper anchorage between the bond coat and substrate and it also shows the splat formation of Inconel718 coating as a top coat material in the coating and this shows the coating is properly deposited on the substrate .Further the Energy Dispersive Spectroscopy (EDS) analysis was carried out on Scanning Electron Microscope and it is shown in Figure 6(a) and 6(b).The EDS analysis of the coating shows the presence of major elements of Inconel-718 alloy and this include the presence of nickel, chromium and iron corresponds to the feedstock material This shows that there were no changes in the composition of the Inconel-718 powder even after coating process. This confirms that the coating has been properly deposited and therefore elements are uniformly distributed throughout the coating.

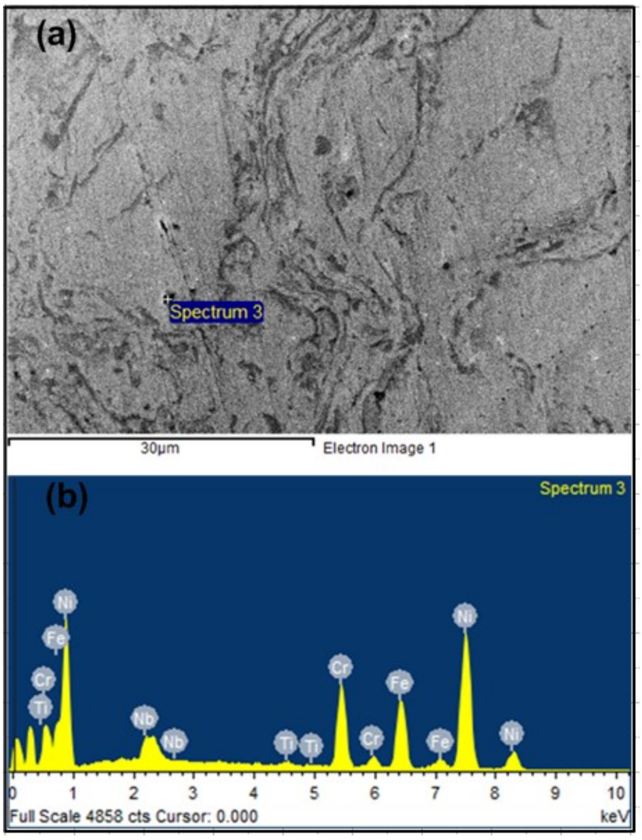

Figure 6. SEM/EDS of Inconel-718 coating

Microhardness analysis

A microhardness test was performed for coated and uncoated substrates. Vickers hardness with load of 50g load for a dwell period of 15 seconds was used and average reading of 5 indentations was recorded. The microhardness was carried out from top of the coatings towards the base metal. A typical hardness profile is shown in Figure.7 .The average hardness of substrate was found to be 229Hv and for the coating it was 557 Hv and has increased approximately 2.5 times that of substrate material. This increased value of hardness is attributed to the presence of nickel, chromium and molybdenum in the coating feedstock material. The microhardness value also increased due to the proper splat contact and it comes out be promising and possible through the high velocity oxy-fuel process due to its high acceleration of powder particles towards the substrate during deposition process. The value from the base material was obtained in the range of 229HV and further moving towards interface this value increases and it may be due to work- hardening of substrate during grit blasting prior to the deposition of the coatings. This process of grit blasting include the striking of alumina particles to the surface of the material and thus produces a rough surface required for the depositon process that resulted in proper mechanical bonding between the coating powder and substrate material. In the coating area next to the interface starting from 125μm to the top of the coating had showed the average hardness of 557 Hv whereas the microhardness of the NiCrAlY bond coat was 345Hv.

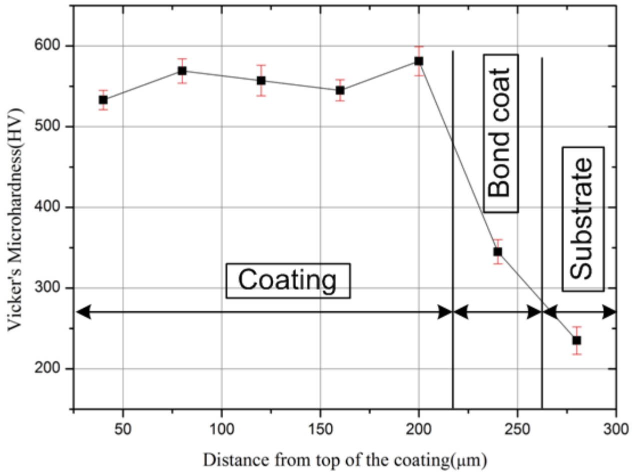

Figure7. Variation of microhardness across the cross section

IV. CONCLUSION

The powder was successfully deposited using High Velocity Oxy-fuel (HVOF) process on the substrate material and showed good mechanical bonding between powder and substrate. Mechanical characterization by micro hardness showed significant increase in high hardness of 577Hv which resulted in due to presence of nickel and chromium as major elements in the coating powder. The microhardness of the Inconel 718 coating (557Hv) was found to be 2.5 times higher than the microhardness of the substrate (229Hv). SEM micrographs showed well bonded interface and free from any semi melted particles, cracks, and also less porosity is seen in the SEM micrograph.

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