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Microstructure and Characterization of Detonation Gun Sprayed Al_2O_3 Coating

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***Abstract* - Thermal spraying is economic and extensively used method to develop coatings on various materials to achieve desired surface properties. Coatings are widely used in different applications of material, like in automotive system, power generation equipments, orthopedics and dental use etc. Detonation gun spraying is one of the thermal spraying technique known to produce dense microstructured, hard and wear resistant coating. In this work Al_2O_3 Coating was deposited on substrate of Grade-A1 boiler tube steel by detonation gun spraying technique. The characterization of coating was done by Scanning Electron Microscopy (SEM), X-Ray diffraction (XRD), and X-Ray Mapping.**
***Keywords:* Alumina Coatings, Boiler tube steel, Detonation Gun, Thermal spraying.**

I. INTRODUCTION

Thermal spraying offers an effective and economic way to make the coating without affecting any other properties of the component. Thermal spray coatings are produced by rapidly heating the feedstock material in a hot gaseous medium and simultaneously projecting it at a high velocity onto a prepared surface where it builds up to produce the desired coating [1]. Thermal spraying is a common family of hardfacing techniques, which, compared to other processes (like welding techniques), are characterized by flexibility in coating material choice, low substrate thermal input and virtually no substrate dissolution. Various thermal spray processes, such as detonation-gun, plasma and high velocity oxy-fuel (HVOF) spraying methods are mostly used to apply coating to impart a wear resistance against abrasion and erosion in corrosive environment at high temperature up to 900 °C [1]. Detonation gun spray process is a thermal spray coating process, which gives an extremely good adhesive strength, low porosity and coating surface with compressive residual stresses [2]. Ceramic coating is a very promising approach to tailor the surface properties of metal component due to their high hardness, excellent wear, corrosion, chemical and thermal resistance [3]. Alumina is a ceramic material which retain up to 90% of their strength even at 1100 °C [4].

In this work Al_2O_3 coating was developed on GrA1 boiler tube steel by detonation gun spraying technique. The coating was characterized for its microstructure, elemental distribution, interface development with substrate and coating thickness.

II. MATERIAL AND METHODS

A. Substrate Material

Boiler steel "ASTM-SA210-Grade A1", have been selected as the substrate material for the present study. The nominal chemical Composition of boiler steel used is shown in Table 1. This boiler steel is used as boiler tube materials in some of the power plants in Northern India.

TABLE I NOMINAL CHEMICAL COMPOSITION OF GR A1 BOILER TUBE STEEL

Alloy	C	Mn	Si	S	P	Cr	Mo	Fe
Gr A1	0.27	0.93	0.1	0.058	0.048	-	-	Bal.

The specimen of the steel sample was cut with dimensions of approximately 20.mm x 15 mm x 5 mm. The specimen was polished by using SiC emery paper of 180, 220, 400, 600 grit sizes.

B. Coating Development

Commercially available, Al_2O_3 in the powder form was used as the coating material in the study. Specimen was grit blasted with alumina powder (Al_2O_3) before coating. Coating was formulated using D-Gun spraying Apparatus. Oxy-acetylene gas was used as fuel gas. Nitrogen gas was used as carrier gas.

C. Characterization of Coating

Surface morphology of the deposited coating was studied using Scanning Electron Microscope (SEM) with EDAX Genesis software attachment. The EDAX genesis software indicates the elemental composition (wt. %) present at point/area of interest. To identify the various phases formed on the surface, the XRD analysis of the coated specimen was carried out with X-ray diffractometer. The specimen was scanned with a scanning speed of 2°/min in 2θ range of 20° to 120° and the intensities were recorded. EDAX analysis was carried out at different points of interest along the cross-section of coated specimen. X-ray mapping of different elements present across the coated samples was revealed using SEM. Specimen was cut with a diamond cutter across its cross-section and subsequently mounted in epoxy resin. The mounted specimen weas polished manually using emery papers of 220, 400, 600 grit sizes and subsequently on 1/0, 2/0, 3/0 and 4/0 grades. Finally, the specimen was mirror polished on a cloth polishing wheel machine with 0.05 µm alumina powder suspension. The specimen was washed thoroughly with flowing water, and dried in air to remove any moisture. The analysis was carried out by SEM**.**

III.RESULTS

The Surface morphology and EDAX analysis of Al_2O_3 coating on substrate "ASTM-SA210-Grade A1" steel is shown in Fig. 1.

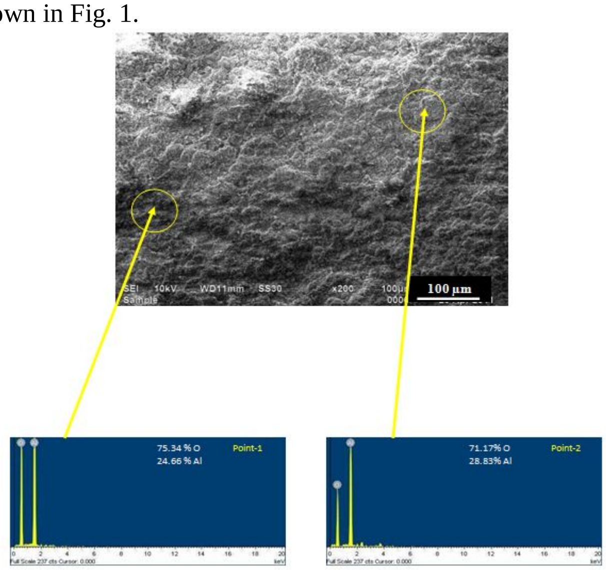

Fig. 1 SEM / EDAX analysis of Al_2O_3 coated "ASTM-SA210-Grade A1" boiler steel showing elemental composition (wt.%) at different points, (X200).

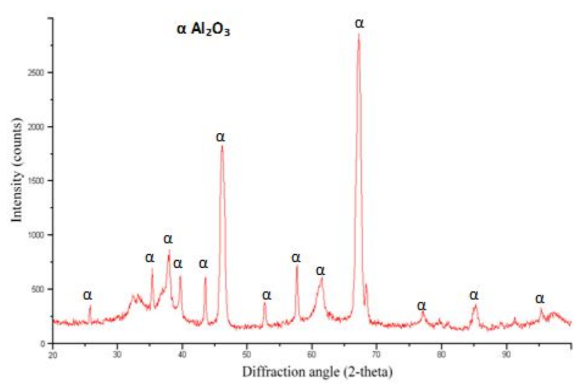

Fig. 2 XRD for Al_2O_3 coated "ASTM-SA210-Grade A1" boiler steel

The microstructure indicates uniform and dense coating. The coatings contains some unmelted and semimelted particles. EDAX analysis confirms the presence of Al and O as the main elements in Al_2O_3 coating.

The XRD pattern of the as sprayed Al_2O_3 coating is shown in Fig. 2. XRD of as sprayed Al_2O_3 coating indicates the presence of Al_2O_3 as main phase. The cross sectional back scattered electron images of the coated "ASTM-SA210-Grade A1"boiler steel is shown in Fig. 3. From the micrograph it is observed that the coating has formed a continuous and homogeneous bond with the substrate. The measured coating thickness for coated specimens is 325µm.

Back Scattered Electron Image (BSEI) micrograph and elemental variation across the crosssection for coated "ASTM-SA210-Grade A1" boiler steel is shown in Fig. 4. EDAX analysis reveals the presence of Aluminium and oxygen throughout coating. The EDAX analysis shows the presence of Fe, C and Mn as main elements in substrate. BSEI (Back Scattered Electron Image) and X-ray Mapping of different elements in the Al_2O_3 coated "ASTM-SA210-Grade A1"boiler steel is shown in Fig.5. The figure illustrates that Al and oxygen are distributed uniformly throughout the coating.

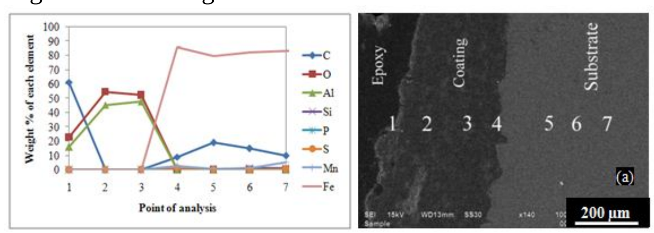

Fig.3 Cross-sectional morphology and variation of elemental composition across the cross- section of Al_2O_3coated "ASTM- SA210-Grade A1" boiler steel

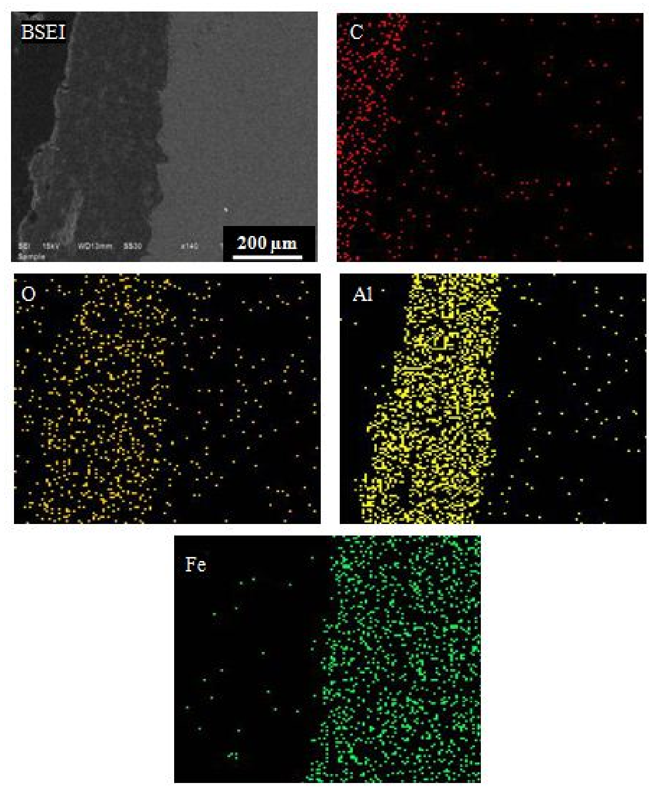

Fig. 4 BSEI and X-ray mapping of the cross-section of Al_2O_3 coated "ASTM-SA210-Grade A1" boiler steel

IV. DISSCUSION

Coatings produced by D-gun spraying techniques are with very high bond strength and generally porosity lower than 2% with thickness ranging from 50 to 500 μm as reported by Souza and Neville, (2007). Al_2O_3 coating has been formulated successfully by D-gun spraying technique on "ASTM-SA210-Grade A1" boiler tube steel. The coating thickness has been measured along the cross-section of sample and found to be in the range of 260- 330 μm as taken by Sidhu et al., (2006b) for study of performance of coatings on boiler tube steel in actual industrial environment. Coating microstructure presented in Fig. 1 indicates dense coating of Al_2O_3 on Grade A1 steel. Observing the BSEI of cross-section, the coating substrate interface has no gaps, which indicates good adhesion between coating and substrate.

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