Fly Ash Utilisation for Value Added Products
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Fly ash as a coating material for plasma spray coatings

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ABSTRACT

The present piece of work has been undertaken to use fly-ash in developing plasma spray coatings on metal substrates. Fly-ash and fly-ash with 5% alumminum metal powder were (premixed thoroughly) plasma sprayed on stainless steel and aluminum substrates at various operating power levels of plasma torch. The coating thus produced, was characterized by thickness measurement, X-ray diffraction analysis, microscopic studies and measurement of coating-substrate adherence strength. X-ray analysis reveals the presence of alumina, silica and mullite phases. The adherence strength seems to increase with aluminum addition to fly-ash.

Key words : *Flyash utilisation, Coating material, Plasma spray*

1.0 INTRODUCTION

Thick ceramic coatings (greater than 50 microns) are used for a remarkable number of applications[1] viz. wear/erosion and corrosion resistance, thermal barrier etc. Plasma sprayed refractory coatings are used for handling liquid metals and increasingly for electrically insulated metal substrates in automotive industries. The unique feature of plasma sprayed coatings is that it combines the process of melting, quenching and consolidation into a single operation, potentially retaining the rapid quench structure. Although plasma spraying offers a high quench rate, the deposit annealing occurs due to both the hot plasma flame and adiabatic recalescence during particle solidification[2], enables in formation of complex/multiphase products of the feed powders. The suitability of a sprayed coating depends on (i) the adherence strength at coating-substrate interface and (ii) stability at operating conditions. Since long silica and alumino-silicate bricks are preferred as refractory materials in many industrial applications due to their high wear resistance and high load bearing capacity at high temperatures. During the last decade a large no. of investigations have been carried out on processing plasma spray ceramic coatings[1-4], but not much efforts have been made to use low grade raw materials for plasma spray purpose. With a view to such, the present piece of work has been undertaken to produce plasma spray ceramic coatings on metal substrates using fly ash of Rourkela power plant..

2.0 MATERIALS AND METHODS

Fly ash and commercial grade aluminum powder (98% pure) are taken and screened through -140 +200 mesh sieve size. The substrates (Stainless steel and Aluminum plates, 3 mm thick) surface was prepared by sand blasting to produce a surface roughness of ~ 4.00 Ra. Plasma spraying was done with a non-transferred arc plasma torch (at thermal plasma sec. LPTD, BARC, Bombay) operated at various power levels ranging from 10 to 20 Kw DC. The powder was fed at a rate of 11.5 gms/min using Ar as carrier gas at a flow rate of 10 LPM.Ar and ($Ar+N_2$) were used as plasma forming gases. Substrate to torch distance was fixed at 100 mm, and with torch traverse rate of ~300 mm/min. the coatings were deposited layer wise. Depending on operating conditions, the layer thickness varied between 15-30 microns. The coated samples were subjected to various analysis. Thickness of the coatings was measured by travelling microscope averaging over a distance of 10mm on polished cross sections of the specimens. X-ray diffractograms were taken on selective specimens for phase analysis/identification. Surface and interface morphologies were studied through SEM. Coating pull out test[5] was carried out with tensometer on all specimens to evaluate the coating-substrate adhesion strength, the details of the test procedure being mentioned else where[6].

3.0 RESULTS AND DISCUSSION

The chemical analysis of the fly ash is given in table-1. To this, Aluminum at a rate of 5% was mixed thoroughly.

Table - 1 : Chemical analysis of fly ash used for coating

SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	MgO	P_2O_5	K_2O	Na_2O	SO_3
58.00	29.33	5.60	1.05	1.70	1.25	0.25	0.84	0.61	0.41

It is observed that the coating thickness is independent of the subtrate used. The variation of coating thickness with torch input power is shown in Fig. 1. Maximum thicknessess of ~ 310 and ~450 microns are obtained at 20Kw power level with fly ash and fly ash + 5% Al powder compositions respectively. It is evident that with increase in torch input power the coating thickness has increased. Such trend is generally observed in plasma sprayed coatings[7].

The interface bonding strength of the coatings is evaluated by coating pull out method. In all cases, fracture occurred at the coating-substrate interface. Figure 2(a&b) shows the variation of coating adherence strength with torch input power. The increase of adherence strength with increase in ooperating power is evident from the figure. In case of stainless steel substrate, (fig. 2a). a maximum strength of 30.65 MNm^{-2} is obtained for fly ash coatings and the maximum of 35. 0MNm^{-2} is found for fly ash + Al coatings at 20Kw power level. In case of Al substrate, (fig. 2b), the maximum strength of 31.75 MNm^{-2} and 35.20 MNm^{-2} are recorded for the raw materials fly ash and fly ash+Al mixtures respectively. In general, it can be said that the coating adherence strength has increased with aluminum powder addition to fly ash than that of fly ash coatings. This may be due to the fact that, during plasma spraying, the molten species i.e. Al powders have helped in interparticulate bonding and bonding of the coating at the interface as well. In previous investigations[8], thermal barrier coatings have been made with pre-mixed metal powders and the increase of interface adherence strength was observed. So, in this study the increase of adherence strength with aluminum addition is not out of way. From the figures it is also noted that, the adherence strength is higher in case of Al substrate than that of stainless steel. This may be due to the higher thermal conductivity of Al than that of stainless steel so that the sprayed particles/powders transfer heat at a faster rate and hence provide better adherence at the interface resulting in strong interface bonding.

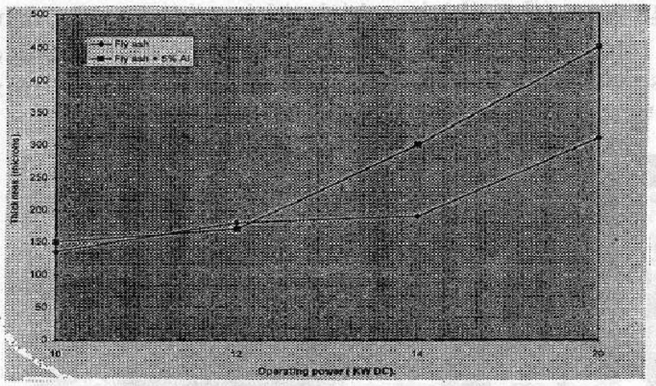

Fig. 1 : Variation of coating thickness with operating power of the plasma torch

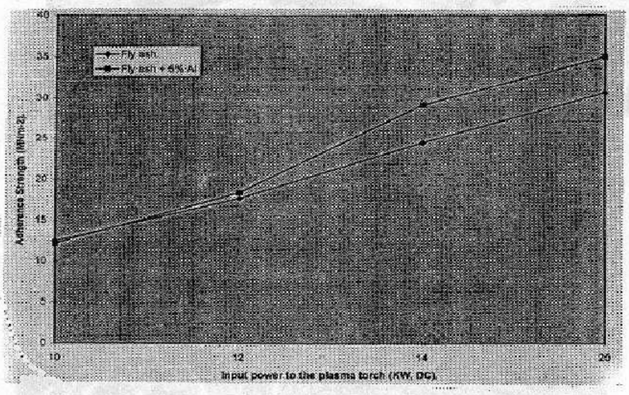

Fig. 2a : Interface adherence strength on the coatings on stainless steel substrates.

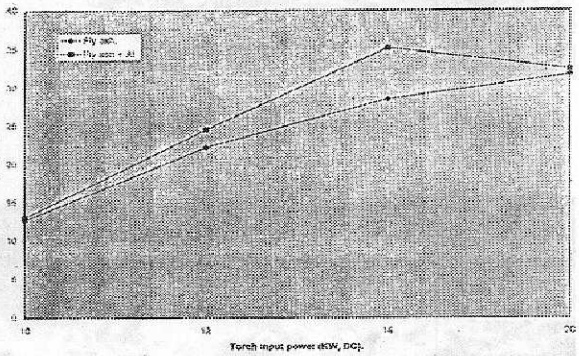

Fig. 2b : Interface adherence strength on aluminium substrate

X-ray diffractograms taken on selected specimens show the presence of SiO_2, Al_2O_3, and ($2SiO_2\,3Al_2O_3$) mullite phase mainly. The detailed x-ray investigation has revealed the presence of similar phases and it was also observed that the mullite phase was varied with torch input power[6]. Hence the variation of amount of different phases might have affected the interface bonding also.

The surface morphology of the coating of the samples in which maximum adherence strength was observed, (for Al substrates) are shown in figure-3a and 3b for fly ash and fly ash+aluminium coatings respectively. In case of fly ash coating, (fig. 3a), fully molten and partially molten particles are seen. These particles are observed near the cavity areas. Probably due to the presence of these particles, the packing homogenity is reduced and cavities are formed in such areas. In case of fly ash+Al coating, (fig. 3b), although some porosity is present, but the amount is less than the of the previous case. Some globular particles are seen which are formed from fully molten state, which might have provided dense packing of sprayed powders and results in less porosity. The interparticulate and inter-phase bonding appears to be better than that of fig. 3a. The coating substrate interface of the above samples are shown in figure 4a and 4b for fly ash and fly ash + Al coatings respectively. Comparing these two figures, it is seen that the coating is more uniform and homogenous (fig. 4b) in which Al is added to fly ash. This coating also shows less amount of porosity/cavities. For these reasons the interface adherence strength has increased in case of the specimen sprayed with fly ash+Al mix powder.

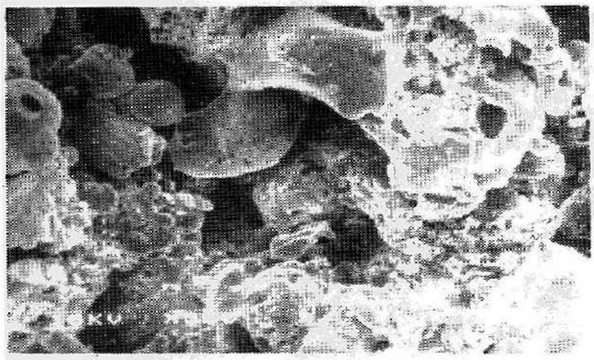

Fig. 3a : The surface morphology of the flyash coating

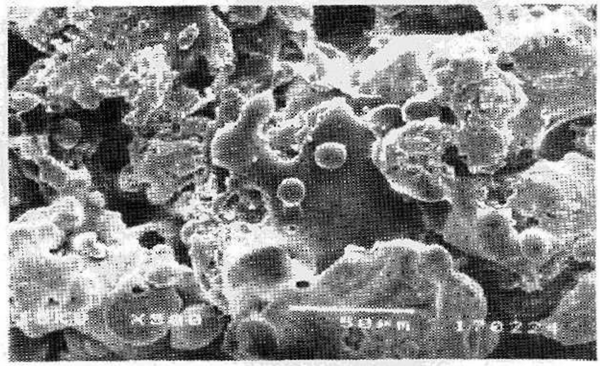

Fig. 3b : The surface morphology of the flyash +Al coating

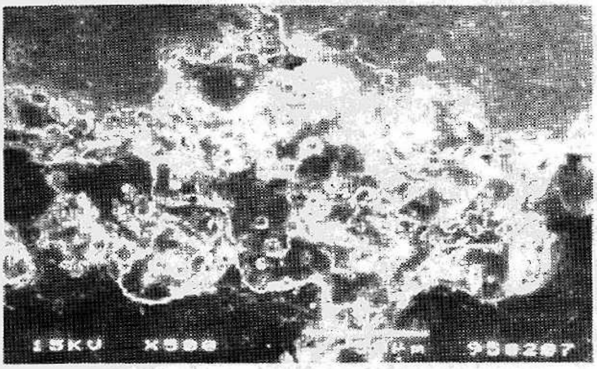

Fig. 4a : The interface structure of the flyash coating

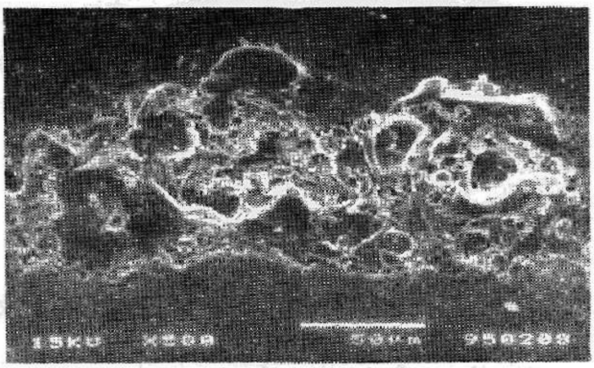

Fig. 4b : The interface structure of the flyash +Al coating.

4.0 CONCLUSION

Fly ash and fly ash with aluminum powder additions can be used for plasma spray ceramic coatings on metal substrates. A maximum adherence strength of 35.00 MNm^{-2} is achieved in such coatings. The adherence strength is higher in case of the substrate having higher thermal conductivity. Addition of aluminum powder provides homogenous and uniform coatings.

5.0 ACKNOWLEDGEMENT

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6.0 REFERENCES

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