Characterisation of Redmud Coatings Prepared by Plasma Spraying

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Abstract

Plasma Spraying is a surface modification technique that combines particle melting, rapid solidification and consolidation in a single process. But as high cost of spray grade powders limits the adoption of this technique, exploring newer and cheaper materials suitable for plasma spray coating has drawn a lot of attention. This work reports an attempt to spray coat redmud (the waste generated in alumina producing plants) on different metal substrates. Plasma sprayed coatings of redmud have been developed at different operating power levels of the plasma gun on aluminium and copper substrates. Coating adhesion strength and deposition efficiency were studied at various operating conditions. Characterisation of the coatings was performed using micro hardness measurement and scanning electron microscopy (SEM). It was observed that the operating power appreciably influences the coating adhesion strength and coating thickness. Coatings deposited at very low and very high power levels show poor adhesion. Maximum interface adhesion strength of -8 MPa was recorded at an operating power of 9 kW. This work establishes 'redmud' as a potential coating material, which may be suitable for wear resistant applications. It also suggests a value added utilisation of this industrial waste.

1.0 Introduction

Redmud is the major waste produced during alumina production using the Bayer Process. Depending on the quality of the Bauxite I to 2.5 tonnes of redmud is generated per tonne of alumina produced. The treatment and disposal of this residue is a major operation in an alumina plant. Although a lot of research and developmental activities are going on throughout the world to find out effective utilisation of redmud. almost no attempt has been made to develop plasma sprayed coatings out of it on metallic components which can have various applications. The use of redmud as yet is restricted only as building materials, paints and pigments etc. Some efforts are also made for recovery of metal values.' But none of these uses are aimed at processing this material for a high valued product.

Over the past three decades thermal plasmas have been used for processing various types of materials, some of which would not have been possible by conventional techniques.[2] In thermal plasma it is possible to spray all metallic and non metallic materials such as metal oxides, carbides, nitrides, silicides etc.' Today plasma spray coatings find wide applications not only in R & D but also in the industrial work places ranging from textile industries to medical applications even. In the automotive industries of many industrially advanced countries, plasma sprayed coatings are used to improve the wear resistance, thermal resistance and resistance to cavitation and corrosion of machine components. The Fiat

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car factory introduced plasma-spraying technology in its production of gearshift forks for gearboxes. Previously produced bronze forks were replaced with steel ones coated with a layer of special bronze 0.4 mm in thickness sprayed on NiAl interlayer.

The chemical analysis of the redmud shows that its major constituents are Iron Oxide (Fe_2O_3), Aluminium Oxide (Al,O,). Titanium Oxide (TiO_2)and Silicon Oxide I SiO.) etc. Since all these are metal oxides can melt without sublimation, it was felt that redmud which otherwise is a waste, can possibly be spray coated. Moreover oxides of iron, aluminium and silicon are known to have high hardness, high wear resistance and good corrosion resistance which are obviously desirable of protective coatings for the wear resistance application. Since redmud is available in plenty the cost involvement will also naturally be very marginal.

2.0 Experimental Procedure

The raw material (redmud) collected from NALCO Orissa was sieved to obtain a particle size of about 60 100 um Fxperimenls were carried out using a 4!) kw plasma spray system at the Laser & Plasma Technology Division. BARC. India. This is a typical atmospheric plasma spray system working in the non-transferred arc mode. The major subsystems of these set up include the plasma spray torch, power supply, powder feeder, plasma gas supply, control console. cooling water and spray booth. A current regulated IX' supply was used. A four stage centrifugal pump at a pressure of 10 kg/cm^2 supplied cooling water for the system. Argon and Nitrogen taken from normal cylinders at an outlet pressure of 4 kg/cm^2, were used as plasma gas and carrier gas respectively. Plasma spray redmud coatings are thus deposited over the selected substrates of dimensions 50 x 20 x 3 mm. Prior to coating all the substrates were sand blasted to get the required surface roughness. The powder feed rate was kept constant at about 10.0 gm/min. The operating parameters used in the experiments are presented in Table I.

Table 1. Operating Parameters for Plasma Spraying of Redmud

Parameter	Range
Operating Power (kW)	6–17.5
Current (A)	200–350
Voltage (V)	30–50
Primary Plasma Gas (Argon) Flow Rate (lpm)	20
Secondary Gas (Nitrogen) Flow Rate (lpm)	2
Torch to Base Distance (mm)	100
Powder Feed Rate (g/min)	10
Powder Carrier Gas (Argon) Flow Rate (lpm)	7

3.0 Results and Discussion

3.1 Composition Analysis

The redmud available from NALCODamanjodi. Orissa is used as the raw material. After sieving the received material i.e. redmud. chemical composition analysis was carried out again. The variation in the percentage of the major constituents in the composition of the material available from the site and that of after sieving is presented in Table 2.

Table 2. Composition of Redmud

Constituents	Composition of the Redmud as Collected from NALCO (wt.%)	Redmud Used for Coating (after Sieving) (wt.%)
Al_2O_3	5.4	4.5
Fe_2O_3	65.2	63.7
TiO_2	6.8	2.5
SiO_2	12.4	2.81
Na_2O	0.5	-
CaO	0.02	0.20
MgO	-	-
LOI*	6.5	6.3
P_2O_5	0.4	-

*LOI - Loss on Ignition

3.2 Particle Size Analysis

The particle size of the sprayed powder plays an important role for deposition of the coating. The particle size analysis of raw material used for coating is carried out with laser particle size analyser and the major amount of particles are in the range of I00 to 150 um. The powders of such particle sizes are generally found to be suitable for thermal spray coatings.

3.3 Coating Thickness

The variations of coating thickness at different operating power levels are plotted in Figure l. From the figure it is found that maximum thickness of about 2I0 um is obtained in case of the copper substrate at the 12 kw power level. With increase in power level, the coating thickness is increased in the case of all substrates but showing a decreasing trend at very high (17.5 kw) operating power level. This implies that the deposition rate is affected by operating power. The deposition efficiency may be low at higher power level due to fly off of the sprayed powder at that condition. This explains the reason for the reduces coating thickness at 17.5 kw operating power.

3.4 Coating Adhesion Strength

The first requirement of any coating mainly depends on its adhesion on to the substrate. The adherence strength of the coating is measured using coating pull out method and is plotted in Figure 2. It is found that with the increase in input power of the plasma gun there is an increase in the adherence strength up to a certain level of operating power and then it

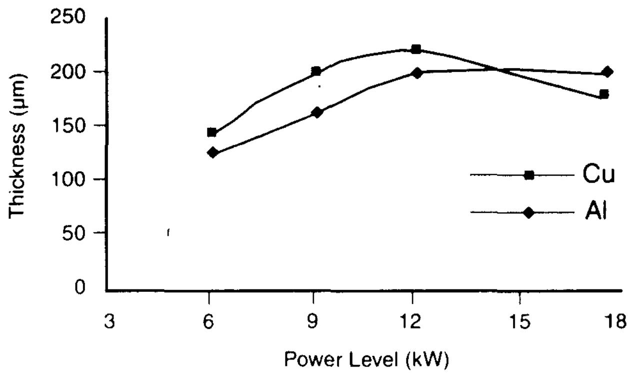

Fig. 1: Variation of coating thickness with power level.

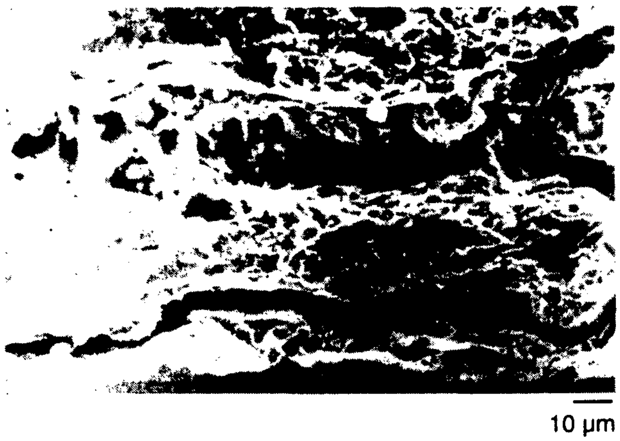

Fig. 3: *Coating interface microstructure at 12 kW.*

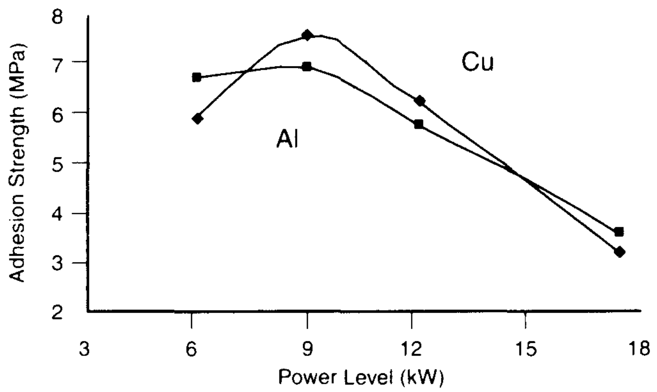

Fig. 2: Variation of adhesion strength with operating power.

decreases with further increase in the power level. Although this trend is observed for all types of substrates the magnitude differs. For copper substrates the strength has varied from 3.21 MPa having a maximum of 7.32 MPa at the power level of 9 kW. For aluminium substrate, this value ranges from 3.05 to 6.95 MPa with the maximum at the 9 kW power level. This indicates that the thermal conductivity of the substrate might be playing some role in improving the overall interface adhesion.

3.5 Coating Hardness

The hardness of the coating is an important parameter for determining its use for wear resistant applications polished cross sections of the coated samples were subjected to micro hardness measurement using a Leitz Micro-hardness tester. The hardness measurement [HV] was done with a load of 0.5 N along the coating and substrate cross-section. Maximum hardness of 560 HV has been recorded on the coating.

3.6 Coating Interface

The interface structures for coatings deposited at different power levels are observed to be smooth and no crack is observed at the interface even for higher operating power levels. Longitudinal cracks seen at the inter-particle layers of coating deposited on the copper substrate (as shown in Figure 3) at 12 kW. reduce the adhesion strength. The interface homogeneity may be due to the higher thermal conductivity of copper that helps in faster rate of conduction of heat from the sprayed powders to the substrate.

Development of plasma spray coatings depends on various parameters to obtain a good quality coating and better adherence with the substrates. The coating efficiency also depends on particle shape, size and the distribution, flow rate, torch to substrate distance and operating power level etc. In the present study, the optimum coating thickness is observed at a power level between 9 to 12 kW with a maximum of 2 l0 um in the case of copper substrate. This indirectly indicates that within this power level the deposition efficiency is a maximum. At higher operating power, due to high temperature and high enthalpy, more number of particles are fragmented into the smaller sizes and have blown off causing less deposition. The maximum adherence strength of the coatings observed in copper substrate may be due to the higher thermal conductivity of copper which has helped in faster heat transmission of the sprayed particles to the substrate than for the other metals. The coating morphology is homogenous at the intermediate power level, which may be the cause for good adhesion to the substrate.

4.0 Conclusions

- Redmud. the industrial waste can be used for depositing plasma spray coatings on metals.
- A maximum coating thickness of about 210 (um is obtained.
- A maximum coating adhesion strength of ~8 MPa is observed with copper substrate at an operating power of 9kW.

- The coating interface morphology reveals that the coating is homogeneous at intermediate power level.

5.0 References

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