Plasma Spray Coating of Red Mud on Metals

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Abstract

Red mud, the gangue produced during alumina extraction, has become a major issue for disposal. In recent years, trials are made / in progress for utilization of this waste / byproduct in some meaningful applications. In the present investigation, efforts are made to use red mud for developing plasma spray coatings (ceramic / cermet) on metal substrates. The raw material used in this study was collected from NALCO, Damonjodi, Orissa. The red mud was sieved for selection of particle size and an average size of 100-150 micron was found to be suitable for spraying purpose. Thermal spray coatings are deposited on various metal substrates viz. S.S., M.S., Cu & Al at different operating power levels (between 6 to 17.5 kW) of the plasma torch. The mechanical aspect such as coating adherence strength & hardness are measured. The maximum adherence strength of ~8 MPa is noted for the coating deposited on Cu substrate. The surface & interface morphology was studied through SEM. It is found that, red mud can be used to deposit ceramic coatings which may be useful for tribological applications.

Key Words: plasma coating, red mud utilization, ceramic coating

1. Introduction

Over the past three decades thermal plasmas have been used for processing of varies types of materials some of which would not have been possible by conventional techniques(1). However the development of plasma technology, especially in the fields of plasma processing has been commercially successful mostly in the field of spray coating. Today plasma spray coatings find wide applications not only in R&D area but also in the industrial work places ranging from textile industries, 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. In thermal plasma it is possible to spray all metallic and non metallic materials such as metal oxides, carbides, nitrides, silicides etc(2,3). The oxides of iron, aluminum and silicon are known to have high hardness, high wear resistance and good corrosion resistance which are obviously desirable of protective coatings. The chemical analysis of red mud shows that its major constituents are Iron Oxide (Fe_2O_3), Aluminum Oxide (Al_2O_3), Titanium Oxide (TiO_2), Silicon Oxide (SiO_2) etc. Since all these are metal oxides, it was felt that red mud which otherwise is a waste can possibly be spray coated. Since red mud is available in plenty the cost involvement will also naturally be very marginal.

Thermal plasma spraying of red mud is carried out on four selected metal substrates e.g. copper, stainless steel, aluminum and mild steel and the coated specimens are subjected to certain tests for characterization. Prior to coating, the composition analysis of the coating material (Red mud) is also made. The experimental findings of various tests are presented and discussed.

2. Experimental

Experiments were carried out using a 40Kw plasma spray system at the Laser & Plasma Technology Division BARC. This is a typical atmospheric plasma spray system working in the non transferred arc mode. The major subsystems of the set up include the plasma spray torch, power supply, powder feeder, plasma gas supply, control console, cooling water and spray booth. Pre spray preparations included sand blasting the specimen by a sand-blasting machine. A current regulated DC power supply was used. Cooling water for the system was supplied by a four stage centrifugal pump at a pressure of $10kg/cm^2$. Argon and Nitrogen were taken from normal cylinders at an outlet pressure of $4kg/cm^2$.

Red mud is plasma sprayed on stainless steel, mild steel, aluminum and copper substrates of dimensions 50x20x3mm. Prior to plasma spray coating the substrates were sand blasted to get the required surface roughness of ~4.2Ra.

3. Results and Discussion

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 analyzer and is found that the particle size ranges from 50 to 200 microns. However the major amount of particles are in the range of 100 to 150 micron.

The most important requirement of any coating is its adhesion on to the substrate. The adherence strength of the coating is measured using coating pull out method. It is found that with the increase in power level there is an increase in the adherence strength up to a certain level of operating power and then it decreases with further increase in the operating power of the torch. Although this trend is observed for all types of substrates the magnitude differs. Fore copper substrates, the strength has varied from 3.21MPa to a maximum of 7.32 MPa at the power level of 9 kW. For aluminum this value ranges from 3.05 MPa to 6.95 MPa with the maximum at 9 kW power level. For stainless steel the adherence strength varies from 3.04 MPa to 5.87 MPa, the maximum being at 9 kW power level. The same trend is found in case mild steel substrate, in which the adherence strength ranges from 2.62 MPa to 6.17 MPa. Here also the maximum strength is recorded for an operating power of 9 kW. This indicates that the thermal conductivity of the substrate might be playing some role in improving interface adhesion.

Hardness of the coating is an important parameter for recommending its use for wear resistance purpose or for similar application . The polished cross sections of the coated samples were subjected to micro hardness measurement using Micro-hardness tester. The hardness measurement [HV] was done with load of 0.5 N along the coating and substrate cross-section. Maximum hardness of 560 HV has been measured on the coating.

The coating interface of all substrates at different power levels are observed under SEM. For mild steel substrates, cracks are observed along the coating-substrate interface, responsible for lower adhesion strength. In the case of copper substrate, the coating is homogenous with smooth interface and no crack is observed at the coating-substrate interface (fig. 2a, b, c and d), at all operating power levels indicating good coating adhesion. The interface and the coating homogeneity may be due to the higher thermal conductivity of copper.

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 210 microns in case of copper substrate. This indirectly indicates that within this power level the deposition efficiency is maximum. The maximum adherence strength of the coatings observed in copper substrate may be due to the higher thermal conductivity of copper, which helps in faster heat transmission of the sprayed particles than for the other metals. For stainless steel and mild steel, where thermal conductivity is low, interface cracks might have developed due to lower rate of heat conduction from the particles giving rise to large temperature gradient across the coating-substrate interface and due to the mismatch in the expansion co-efficient, large thermal stress would have developed. This results in low value of adhesion strength. The coating morphology is homogenous at the intermediate power level, which has also helped for good adhesion to the substrate.

4. Conclusions

Red mud the industrial waste can be used for depositing thermal spray coatings on metals. Maximum coating thickness of about 210 micron is developed. Coating - interface adherence strength of ~ 8Mpa is observed with the coating deposited on copper substrate. The optimum strength is observed at about the power level of 9kW. The coating interface morphology reveals that the coating is homogenous at intermediate power level.

5. References

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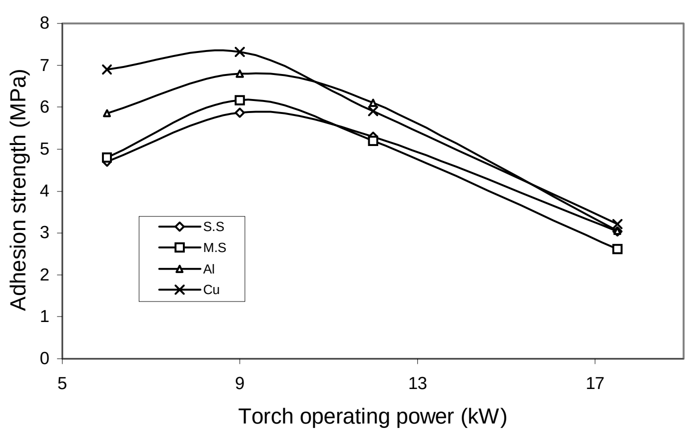

Fig. 1. Variation of adhesion strength with power level for different substrates

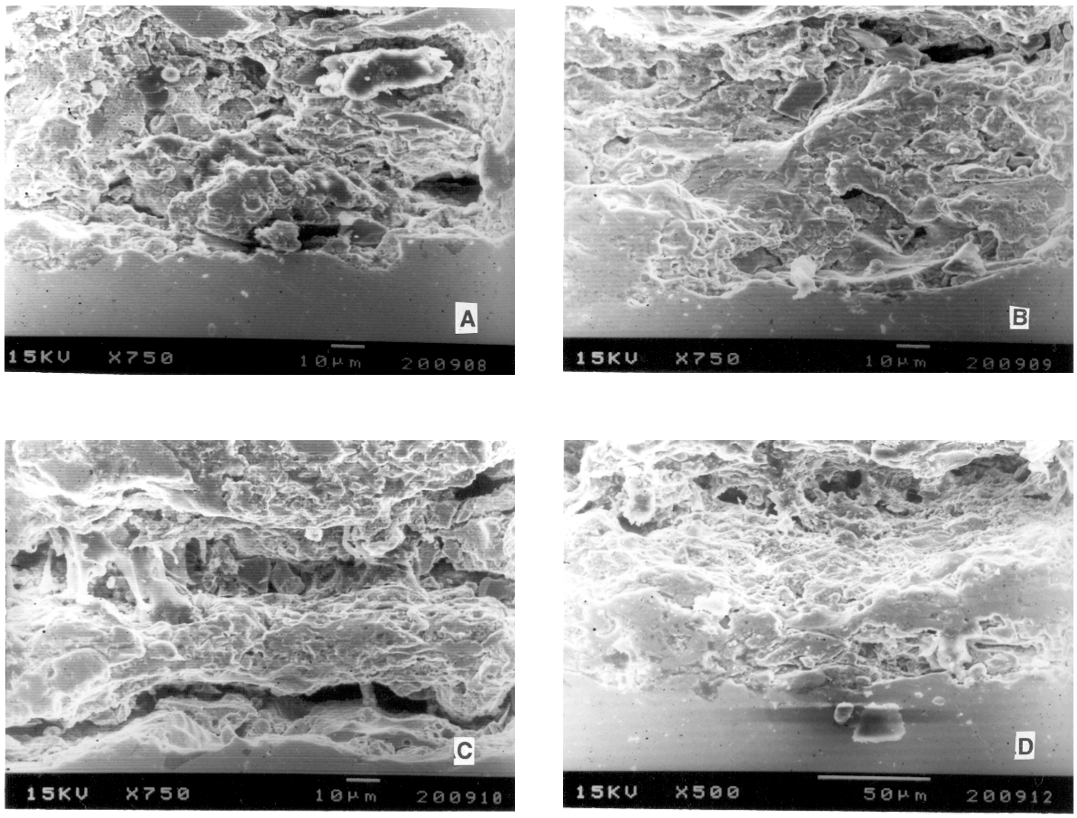

Fig. 2. SEM photographs showing coating interface morphology for specimens A, B, C and D sprayed at 6, 9, 12 and 17.5 kW respectively

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