Deposition of Redmud-Graphite Coating on Metals by Plasma Spraying

Alok Satapathy, S.C. Mishra and D.K. Nath
National Institute of Technology
Rourkela - 769008
India
E-mail: scmishra@nitrkl.ac.in, aloksatapathy@rediffmail.com

P.V. Ananthapadmanabhan and K.P. Sreekumar
Laser and Plasma Technology Division
B.A.R.C., Mumbai - 400085
India
E-mail: nairkps@roltanet.com, pvananth@apsara.barc.ernet.in

Abstract

Plasma Spraying is a versatile technique, which has the advantage of being able to deposit metals, ceramics and/or a combination of these, and generating a homogeneous coating and with required microstructures. In the present work, an abundantly available industrial waste viz. *redmud* (the waste generated in the aluminium extraction industry) and graphite were taken, pre-mixed in a definite proportion and the mixture spray coated on commercially available aluminium and copper metals. These coatings were deposited at different operating power levels i.e. at 6. 9. 12 and 16 KW of the plasma torch and then were characterised. It is observed that the quality and structure of the coating arc greatly affected by the input power to the torch. The coating adhesion strengths for different samples were determined by standard pull-out method. A maximum interface bonding strength of ~14 MPa was recorded. It was also observed that adhesion of the coating onto the substrate has been improved with the mixing of graphite powder to redmud. Coating morphologies were studied by scanning electron microscopy.

1.0 Introduction

The current trend in the structural-design philosophy is based on the use of substrates with the required mechanical properties and a thin coating on it that exhibits desired surface properties. Plasma spraying is a versatile surface coating technique, which has the advantage of being able to deposit metals, ceramics and/or a combination of these, generating homogeneous coating with desired microstructures.' It utilises the exotic properties of plasma medium to effect physical. chemical or metallurgical reactions to produce new materials or to impart new functional properties to conventional materials.[2] The surface coatings help in protecting against corrosion and often act as insulating barriers. But despite all its advantages, plasma spraying has found limited application/ adoption. One of the reasons for this is the high cost of the spray grade powders required for coating. This problem can be addressed to by exploring the possibility of using some industrial wastes as coating material. During the last decade. although a large number of investigations have been carried-out on processing of plasma spray ceramic coatings, not much effort has been made to use low grade materials for plasma spray purpose. Mishra and Ananthapadmanabhan, in 1998, made the first successful attempt to spray coat raw fly-ash, the waste of thermal power plants and fly-ash + alumina mixture on metal substrates through plasma processing.' Subsequently Mishra et al. repeated the plasma spraying process with redmud. another abundant waste from alumina

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Table 1. Composition of Redmud

Constituents	Composition (Redmud) wt.%
Al_2O_3	4.5
Fe_2O_3	63.7
TiO_2	2.5
SiO_2	2.81
CaO	0.2
P_2O_5	6.2
Loss on Ignition	6.5

producing units to develop protective coatings of high effectiveness.

Against this background, the present study has been undertaken to produce redmud + graphite composite coatings on metal substrates by plasma spraying. The mixture of redmud with charcoal powder (graphite) in a definite proportion is coated on various metal substrates. Charcoal powder is chosen as the additive for it is ability to of carbo-thermically reduce of metal oxides present in redmud. Conventional atmospheric plasma spray technique were used to develop these coatings. The chemical analysis of the redmud shows that its major constituents are Fe_20_3 $A1_20_3$ $Ti0_2$ etc. Since all these are metal oxides that can melt without sublimation, it was felt that redmud can possibly be spray coated. Moreover. easy availability of redmud makes the cost involvement in coating very marginal.

2.0 Experimental

The raw materials redmud, collected from NALCO. Orissa and graphite) were sieved to obtain a particle size of about 60-100 pm. suitable for spraying. Please refer Table 1 for composition of redmud. Redmud and graphite powders were taken in a ratio 5:1 by weight and were mixed thoroughly in a planetary ball mill to get a homogeneous mixture. This mixture was sprayed on aluminium and copper substrates of dimensions 50 x 20 x 3 mm and the coated specimens were subjected to certain tests for characterisation. Spraying was done using a 40 k\V plasma spray system at the Laser & Plasma Technology Division. BARC. Mumhai. This is a typical atmospheric plasma spray system operating in the non-transferred arc mode. The major components 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 sandblasting of the specimens with a sandblasting machine via compressed air at a pressure of 3 kg/cm^2. A current regulated DC power supply was used. A four stage closed loop centrifugal pump at a pressure of 10 kg/cm^2 supplied cooling water for the system. Primary plasma gas argon and secondary gas nitrogen were taken from normal cylinders at an outlet pressure of 4 kg/cm^2. The plasma input power was varied from 6 to 16 kw by controlling the gas flow rate and arc current. The powder feed rate was kept constant at about 10 gm/min by a turntable type volumetric powder feeder. Operating parameters used in the experiments are given in Table 2. To evaluate the adhesion strength of the coating with the substrates, a special type of jig was fabricated. Cylindrical MS dummy samples of length 25 mm and dia 9.5 mm were prepared. The surface of the dummies were roughened by punching. These dummies were then fixed on the top of the coatings with the help of a polymeric adhesive and were pulled in tension after fixing on the jig. The load at the fracture was recorded for strength calculation. The morphology at the substrate-coating interface was studied using Jeol T-330 Scanning Electron Microscope.

3.0 Results and Discussion

3.1 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 60-100 urn. The powders of such particle sizes are generally found to be suitable for thermal spray coatings.

3.2 Adhesion Strength

The first requirement of any coating mainly depends on its adhesion to the substrates. The adherence strength of the coating is measured using standard pull out method. The variation of adherence strength with operating power and for both the substrates is shown in Figure I. It is found that with the increase in the power level there is an increase in the adherence strength up to a certain level of operating power of the torch. Although this trend is observed for both substrates, the magnitude differs. For copper substrates the strength varied from 5.1 to 13.6 MPa. having a maximum of 13.6 MPa at the power level of 12 kw. But in case of aluminium substrate, a maximum adherence strength of 3.73 MPa was recorded at 9 kw power. In general it can be said that the maximum interface adhesion strength of the coatings can be obtained at an optimum operating power which may vary depending on the substrate material.

3.3 Coating Hardness

The hardness of a coating is an important parameter for recommending its use for wear resistance purpose or for similar applications. The 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 load of 0.5 N along the coating cross-section. Maximum hardness of 1050 HV has been recorded on the coating. There are three optically distinguishable phases observed in the coatings and they bear three different ranges of hardness values. It was seen that with increase in the power level, at which the coating was deposited: there is a change/ increase of the hardness (of all phases). From the XRD

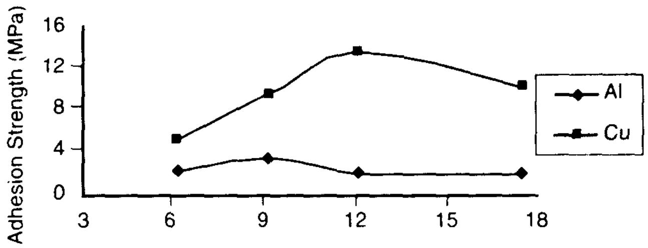

Fig. 1: Variation of adhesion strength with operating power.

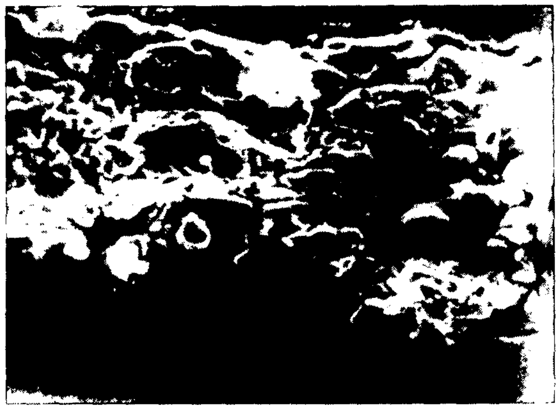

Fig. 2: Coating surface microstructure at 6 kW.

Table 2. Operating Parameters for Plasma Spraying of Redmud Graphite Mixture

Parameter	Range
Operating Power (kW)	6–16
Current (A)	200–400
Voltage (V)	30–45
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)	6

Fig. 3: Coating surface microstructure at 16 kW.

(Figure 5) analysis the major phases present in the coating are identified as alumina, silica and iron oxide (of different mineral forms).[4] It is possible that these phases bear different structures (crystal system), depending on their origin/formation/transformation etc.. which attribute to the hardness. However, the maximum hardness of the phases was recorded on the coatings made at 16 kW (i.e. the highest power level in the present investigation).

3.4 Coating Microstructure

The surface microstructures of the coatings deposited at the lowest and the highest operating powers i.e at 6 kW and at 16 kw are shown in Figures 2 and 3. respectively. The coating deposited at 6 kW shows non-homogeneous distribution of the phase features. With increase in the power level of the operating torch, the coating morphology was observed to be changing. There is a large difference between the size of the phases, their appearance and distribution. The variation in the amount of cavitation can clearly be seen. At the highest power level, although the size of the deposited particles are small, the porosity and their distribution and also the inter particle adherence appears to be poor: for which such structure (morphological distribution) could suffix for the increase of interface adhesion. The metal-coating interface are of the concern for the interface adhesion strength of the coating to the substrate A typical coating-substrate interface for coatings deposited on aluminium substrate at an operating power of 6 kW is shown in Figure 4.

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. At higher operating power, due to high temperature and high enthalpy, more number of particles are fragmented into smaller sizes and had flown 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. The coating morphology is homogenous at the intermediate power level, which might be responsible for good adhesion to the substrate.

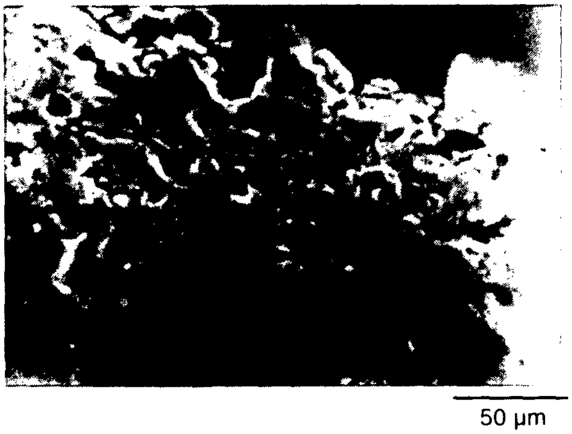

Fig. 4: Interface microstructure at 9 kW.

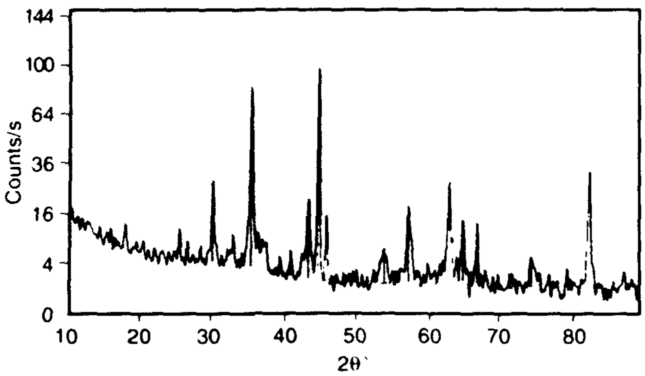

Fig. 5: XRD of redmud graphite coating.

4.0 Conclusions

Plasma sprayed ceramic coatings can be developed on metals with a mixture of redmud and carbon. In such coatings the micro-hardness measurement shows three different ranges of hardness values between 450-1050 HV indicating the presence of various phases.Maximum adherence strength of 13.6 MPa is recorded with such coatings. The coating adherence strength is found to be affected by the operating conditions such as the torch-input power. Better coating homogeneity and adherence are obtained at intermediate power level of about 9 to 12 kW. Hence, attempts can be made to mix carbon at different proportions with redmud to produce coatings with tailor-made properties.

5.0 References

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