Presented in National Conference on Materials and Related Technology, TIET, 2003 Patiala, India

satapathy.alok@gmail.com

PLASMA SPRAYING OF RED MUD-FLY ASH MIXTURE ON METALS : AN EXPERIMENTAL STUDY

Alok Satapathy*, S.C.Mishra,
Umaprasad Mohanty, Tapan Kumar Mishra and Pratyusha P. Raulo
National Institute of Technology, Rourkela- 769 008.

K.P. Sreekumar, P.V.Ananthapadmanabhan and R.U.Satpute
Laser and Plasma Technology Division, B.A.R.C. Bombay -400 085

ABSTRACT

In spite of all its advantages, plasma spray coatings find limited applications/ 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. The present work aims at developing and studying the coatings of two abundant industrial wastes (Redmud and Flyash from aluminium extraction industries) on metal substrates. Conventional atmospheric plasma spray technique has been used to develop coatings of these materials. Coatings of various operating parameters were prepared and characterized. The studies conducted on the coating include X-ray diffraction technique, Microhardness measurement, etc. It is observed that the coating hardness improves with increase in coating power level.

This work establishes Redmud-Flyash mixture as a potential coating material, suitable for plasma spraying and for wear resistant applications . It also opens up a new pathway for value added utilization of these industrial wastes.

INTRODUCTION

Over the past few 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 to even medical applications. In the automotive industries of many industrially advanced countries, plasma sprayed coatings are used to improve the wear resistance, thermal resistance and resistance to 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 desirable properties for protective coatings. The chemical analysis of red mud and fly ash shows that major constituents in these industrial wastes 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 a mixture of red mud and fly ash can possibly be spray coated. Since red mud and fly ash are available in plenty the cost involvement will also naturally be very marginal. Moreover. during recent years, 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 this purpose. Mishra and Ananthapadmanabhan, in 1998 ,made the first successful attempt to spray coat raw fly-ash and fly-ash+alumina mixture on metal substrates through plasma processing[3]. They further repeated the plasma spraying process with fly-ash mixed with ilmenite, graphite and aluminium powder respectively in different proportions leading to development of protective coatings of high effectiveness [4]. Again in 2002, Mishra et al. reported some of the findings of their experimentation on the plasma spraying of raw red mud, collected from NALCO site on various metal substrates [5] .

Against this background, the present study has been undertaken to produce redmud+ flyash composite coatings on metal substrates by plasma spraying. Conventional atmospheric plasma spray technique has been used to develop these coatings.

2. Experimental

Plasma spraying of red mud- fly ash mixture in 1:2 weight ratio I was carried out on aluminium and copper substrates of dimensions 50x20x3mm and the coated specimens were subjected to certain tests for characterization. Spray coating was done using a 40 kW plasma spray system at the Laser & Plasma Technology Division, BARC, Mumbai. 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 sandblasting the specimen with a sand-blasting machine via compressed air at a pressure of $3kg/cm^2$. A current regulated DC power supply was used. A four stage closed loop centrifugal pump at a pressure of $10kg/cm^2$ supplied cooling water for the system. Primary plasma gas argon and secondary gas nitrogen was taken from normal cylinders at an outlet pressure of $4kg/cm^2$. Plasma spray coatings of red mud-fly ash (2:1) in the size range of approximately 50-100μm are deposited over metal substrates. The plasma input power was varied from 6 to 17 kW by controlling the gas flow rate and arc current. The powder feed rate was kept constant at about 3.5gm/min by a turntable type volumetric powder feeder.

Operating parameters used in the experiments are given in table 1.

Table 1: Operating parameters for plasma-spraying of redmud-flyash mixture

Parameter	Range
Operating Power (kW)	6-17
Current (Amps)	150-385
Voltage (V)	40-45
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)	3.5-6
Powder carrier gas (Argon) flow rate (lpm)	6

3. Results and Discussion:

Spheriodisation of the coating material was carried out at 17kW power level. Immediate observation under optical microscope at 200X magnification shows good spheroidization. Figure 1 shows typical photographs of redmud-flyash before and after spheroidization. It was found that the extent of spheroidisation increased with the operating power.

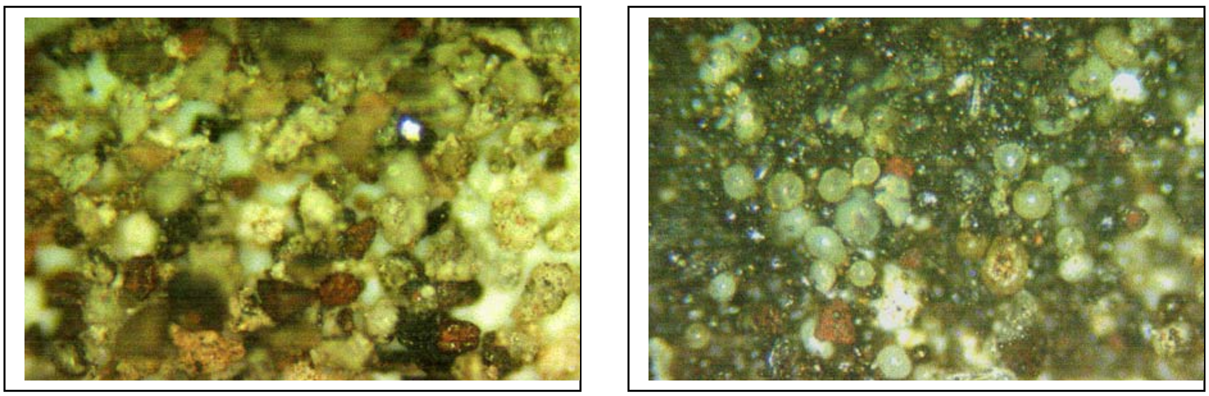
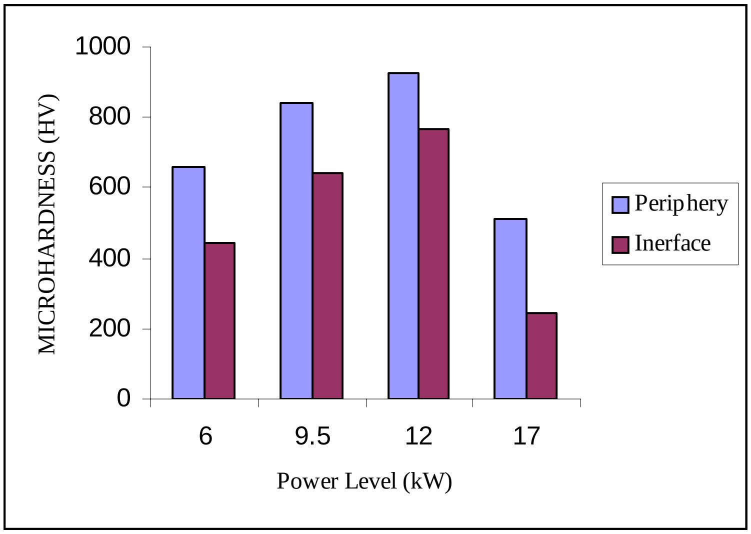
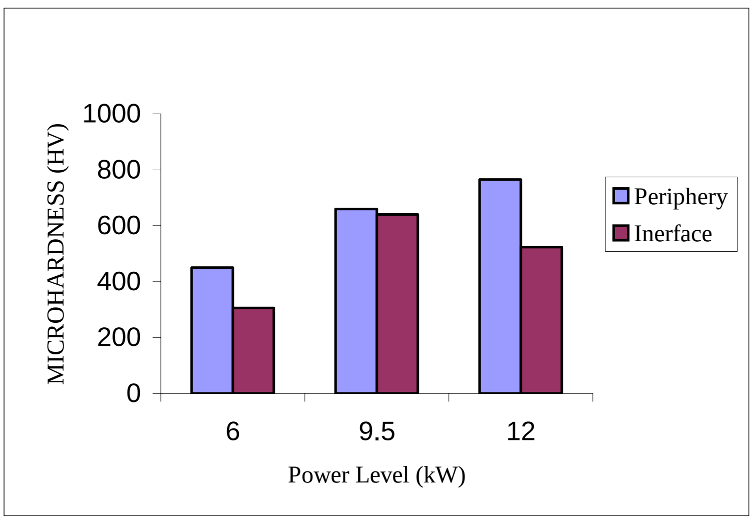


Fig.1. **Typical Optical Microscopic Photographs (at 200 X) of Redmud-Flyash Mixture before and after spherodisation**

X-ray powder diffraction technique was used to identify the phases present in the raw material as well as in plasma sprayed samples. Ni filtered Cu Kα radiation was used for X-ray diffraction. Typical X–ray diffraction pattern of redmud-flyash mixture before and after spheriodisation are shown in Figure 2. These indicate that the phases present in the raw powder and spheroidised powder are different. As seen from the diffraction patterns, Fe_2O_3 in the raw powder has been converted to Fe_3O_4 during spheroidisation. This is due to the high temperature reduction of Fe_2O_3 in the plasma jet.

The hardness of the 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 Leitz 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 945 HV has been measured on the coating.





4. Conclusions

Plasma sprayed coatings of alumina are used for wide ranging applications including thermal barrier, chemical barrier and electrical insulation. Characterization of the coatings is highly relevant in the context of coating developmental studies as well as process optimization. The coatings have been characterized for phase composition, microstructure, hardness and coating adhesion. The study shows that coating properties vary widely with operating conditions.

5. References

[1] Robert B.Hiemann, Plasma-Spray Coating-Principles and Applications, VCH Publishers Inc., New York, NY, USA, (1996)

[2] Lech Pauloski, The Science and Engineering of Thermal Spray Coatings, John Wiley and Sons, (1995)

[3] K.P.Sreekumar, P.V.Ananthapadmanabhan, A.K.Das, N.Venkatramani, and S.C. Mishra., Parameter Optimization for Plasma Spraying Using Fractional Factorial Testing., Paper No. F-1, XI PSSI Nat. Symp. on Plasma Sci. & Technology, PLASMA-96, Bhopal, October(1996)

[4] K.P.Sreekumar, J.Karthikeyan, P.V.Ananthapadmanabhan, N.Venkatramani and U.K.Chatterjee., Plasma Spray Technology : Process Parameters and Applications, BARCReport No.1551, Pub. Lib. & Inf. Divn. Bhabha Atomic Research Centre, Bombay, India.(1991)

[5] S.C. Mishra, Alok Satapathy , R.K.Behera, R.K.Dhar,K.P. Sreekumar & P.V.A. Padmanabhan Plasma Spray Coating of Red Mud on Metals Proceedings of DAE-BRNS Symposium on Applications of Plasmas, Lasers and Electron Beams in Advanced Materials Processing 2002