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Case Study

Tribological analysis of WC–10Co–4Cr and Ni–20Cr_2O_3 coating on stainless steel 304

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ABSTRACT

Centrifugal slurry pump is widely used for transportation of solids through pipeline in many chemical and mining industries. Erosion wear considered as one of the important parameter which plays significant role in slurry transportation system by affecting both initial cost and life of its components. In the present work, erosion wear due to solid–liquid mixture has been investigated using a slurry erosion pot tester. The erosion tests have been conducted on centrifugal slurry pump material stainless steel (SS304) to establish the influence of rotational speed, particle size, solid concentration and time duration. Sand and fly ash were taken as erodent materials with solid concentrations ranging from 30 to 60% (by weight). The experiments were performed at four different speeds namely 600, 900, 1200 and 1500 rpm with time duration of 90, 120, 150 and 180 minutes. WC–10Co–4Cr and Ni–20Cr_2O_3 coating powders were used to increase the erosion wear resistance. Coating powders are deposited on pumping material by supersonic flame of high velocity oxygen fuel (HVOF) coating. Experimental results indicate that erosion wear has high dependence on rotational speed, time duration and nature of erodent solid particles. Significant improvement in erosion wear resistance was also observed by using WC–10Co–4Cr coating over Ni-20Cr_2O_3.

1. Introduction

Centrifugal slurry pump are widely used for transportation of homogeneous as well as heterogeneous solid–liquid mixture at medium and shorter distances. The material of pump and its components play a vital role in reliable transportation of solid–liquid mixture. Stainless steels or cast iron are universally accepted pumping materials [1]. Many of the fluid contain abrasives and oxides which raises the material degradation problem such as abrasion, erosion and corrosion. In initial years, the scientific researchers focused on corrosive wear but erosion is the more critical factor than corrosion [2]. The parts of slurry transportation system such as pipes, impeller, shafts, casing etc. internally damages under the mechanical action of erosive particles [3–6]. The erosion wear in such components can be controlled by increasing the surface hardness of materials [7]. Researchers had used various Tungsten and Nickel powders with different coating techniques and heat treatment processes to improve the hardness of materials [8–11]. Wheeler and Wood [12] performed an experimental study to analyze the erosion wear of AISI 1020 steel coated with 86WC–10Co–4Cr powder. They carried out the laboratory scale experiments on a slurry jet erosion tester with sand slurry. Results showed that erosion resistance of diatec HVOF 86WC–10Co–4Cr coating was twice than d-gun HVOF coated specimen. Mann et al. [13] studied erosion wear of X20Cr13, 17Cr–4Ni pH steels and Ti6Al4V titanium alloy coated with WC–10Co-4Cr, Stellite 6 and 12 powders using HVOF coating. They found that TiAlN PVD coated with WC–10Co–4Cr powder showed better tribological characteristics as compared to other. Maiti et al. [14] studied the erosion wear performance of AISI 304 stainless steel with WC based HVOF coatings. They had prepared the different composition of coating powders by adding 0, 10, 20 and 30% of WC powder in WC–9Co–5Cr. They found that the hardness of WC–9Co–5Cr was increased 26% with the addition of 20% WC powder. Sidhu et al. [15] investigated the erosion behaviour of GrAl steel with NiCr and Stellite-6 powder using HVOF coating. They performed the erosion wear experimentation on air jet erosion tester. It was found that Stellite-6 coated GrAl steel show higher erosion resistance than NiCr. Lee et al. [16] performed the erosion wear experimentation on S45C steel coated with WC–10Co–4Cr using HVOF technique. They used a pin-on-disk wear tester to perform erosion wear experiments at ambient temperature. It was concluded that the fracture toughness and wear resistance of base material improved after depositing multiparticulate coating powder due to formation of low porosity layers. Singh et al. [17] have studied the erosion wear performance of SS304 steel coated with CC3T and NC3T

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powder using plasma sprayed and nano coatings. Results show that erosion wear resistance of nano coating was found approximate twice than plasma sprayed coating. Hong et al. [18] performed erosion wear experimentation on $13Cr_4Ni$ steel coated with Cr_2O_3–NiCr powder using HVOF coating. They observed that micro hardness of base material improved due to presence of Cr_2O_3, Cr_7O_3 and (Cr, Ni) phases in coating.

From the literature, it was found that WC and Cr are the harder materials which improved the erosion wear resistance. HVOF coating technique is universally acceptable in literature for its good mechanical strength, corrosion resistance and low porosity. In present work, an attempt has been made to investigate the erosion wear behaviour of centrifugal pump material namely SS304. Erosion wear experimentation was performed with the variation of different influencing parameters like speed, solid concentration and time duration. WC–10Co–4Cr and Ni–$20Cr_2O_3$ coating powders were used to increase the erosion wear resistance.

2. Material and methods

2.1. Base material

SS304 was used as base material. The sample specimen was cut into of rectangular shape having dimension 76.2mm × 25.4 mm × 6.35 mm with a central hole of 8.5 mm diameter for holding purpose in rotating spindle of the tester. The geometry of sample specimen is shown in Fig. 1. The microhardness of SS304 was measured with digital micro hardness testing equipment (manufactured by Metatech MVH-1 Pune, India). Experimental repeatability was accounted by testing the microhardness in ten trails. Average microhardness of the SS304 was found as 237 Hv (50 kgf). The nominal chemical composition of SS304 is summarized in Table 1. SS304 was composed with iron and carbon in the percentage of 69.94 and 0.08 respectively.

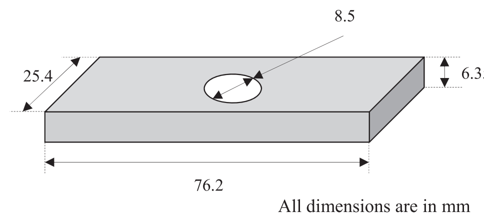

Fig. 1. Geometry of sample specimen.

Table 1
Compositional analysis of SS304 substrate material (in percentage).

Fe	Cr	Ni	Mn	Si	C	Others
69.94	18.04	7.96	3.64	0.31	0.08	0.03

Table 2
Parametric details of HVOF spray coating process.

Spray parameter	WC–10Co–4Cr	Ni–$20Cr_2O_3$
Air flow rate (SPLM)	640	690
Air Pressure (kg/cm^3)	6	6
Oxygen flow rate (SLPM)	260	245
Oxygen Pressure (kg/cm^3)	10	10
LPG Fuel flow rate (SLPM)	60	70
Fuel Pressure (kg/cm^2)	7.5	7.5
Powder feed rate (g/min)	30	25
Spray distance (mm)	150	150

2.2. Coating powder deposition

Commercial WC–10Co–4Cr and Ni–$20Cr_2O_3$ coating powders were used to analyze tribological behaviour of SS304. These coating powders are deposited on SS304 by HVOF spraying system (HIPOJET 2700) at M/S Metalizing Equipment Company private Ltd. Jodhpur (India). The details of operating parameters for HVOF coating deposition are given in Table 2. The coating layers of 170–180 µm were deposited on surface of base material. Afterwards, the sprayed specimens were cooled with jet of compressed air.

2.3. Slurry preparation

Fly ash and sand were selected as erodent materials. Fly ash was collected from GGSS Thermal Power Plant Ropar, Punjab (India) whereas sand was collected from Naptha Jhakri Dam Kinnaur, Himachal Pradesh (India). Fly ash and sand were dried in microwave oven for removal of wetness present in samples. Afterwards, gold coating was performed on erodents with the help of Auto fine coater manufactured by JEOL (Model: JFC-1600). Gold coating helps in facilitating the conduction behaviour to insulated erodent particles. Fig. 2 represents the morphological structure of fly ash and sand particles. From micrographs, it is visualize that sand particles are irregular in shape whereas fly ash particles are spherical in shape. The EDS maps shown in Fig. 2(a) and (b) represent the presence of different compositional elements in Fly ash and sand respectively. In Fig. 2(a), EDS data of sand show the presence of Na_2O, Al_2O_3, SiO_2, K_2O and FeO as 1.18%, 14.94%, 77.74%, 3.16% and 2.98% respectively. In Fig. 2(b), EDS data of fly ash show the presence of CO_2, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, CuO and ZnO as 35.94%, 24.24%, 29.52%, 0.71%, 5.06%, 1.49%, 1.78% and 1.27% respectively. Sieve analysis was carried out to obtain the particle size distribution of fly ash and sand particles. Fly ash particles are having finer in nature. Only 12.30% particles of fly ash are coarser than 150 µm and 72.8% particles are finer than 75 µm. Sand particles are coarser in nature. About 16.8% particles are coarser than 250 µm, 71.5% particles are in the range of 75–250 µm and only 5% particles are below 75 µm. Fixed amount of water were added with solid particles to obtain desired solid concentration of slurry suspension. The solid concentration of slurry was varied from 30% to 60% (by weight). The rheological characteristics of sand and fly ash slurry were measured by using Rheometer (manufactured by Rheolab Q-C, APC Ltd. Germany). Fly ash slurry suspension show Newtonian behaviour at 30% solid concentration (by weight) beyond this it depicts non Newtonian flow characteristics. However, sand slurry suspension show Newtonian behaviour up to 50% solid concentration (by weight) beyond this it depicts non Newtonian flow characteristics.

3. Experimental investigation

The Erosion wear experiments were performed on erosion pot tester (Model: TR-401) manufactured by Ducom instruments, Bangalore (India). It consists of a cylindrical pot, rotating spindle and screw jack. Digital meter was provided on tester which enables to control the spindle speed and time duration. Propeller is fixed to prevent the settling of erodents at bottom of pot (120 × 120 mm^2) which rotates at same speed as sample specimen. The circulation of water around pot cup removes the heat generated during experiments. Screw jack provided at bottom of pot enables the height adjustment. The schematic diagram of the