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SLURRY EROSIVE WEAR BEHAVIOR OF MILD STEEL PLASMA SPRAYED WITH TITANIA

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Abstract: Surface treatment technologies present an effective way of combating degradation of materials. The causes of degradation can be phenomenon such as wear, corrosion and oxidation. Surface treatment offers a method of protecting the base material without sacrificing its bulk properties. Among various surface modifications technologies, thermal spraying has emerged as an important tool for achieving tailor made engineering surfaces by depositing coatings on surfaces. In the present investigation, substrates prepared from mild steel are coated with TiO_2 by plasma spraying and evaluated for resistance to slurry erosion. TiO_2 powders with particle size of about 50µm was used and uniform coatings of thicknesses 100µm was obtained. Slurry erosive wear tests were conducted in 3.5% NaCl solution with sand as erodent. The resistance of coated specimen for slurry erosion were found to be higher than the uncoated substrates for identical test conditions.

Keywords: *Plasma spray, Titania coating, Mild Steel, Slurry Erosion*

1. INTRODUCTION

Ceramic materials have great potential for applications as ideal wear-resistant materials at extreme temperatures and in corrosive environments as they possess high hardness and chemical inertness. Nowadays in engineering world, there is a great demand in the marine application. As a result, research is going on erosion-corrosion under simulated conditions. Plasma-spraying is the most important thermal spray processes for ceramic coatings since a coating of 0.3 mm thickness results in about l%-5% porosity [1, 2]. Many studies are reported recently in the literature on wear behavior of different coatings coated on different substrates. Coating evaluations demonstrated significantly higher erosion resistance compared to the base material. Notably, the TiN/TiAlN coating exhibited the highest resistance, while the TiN/CrN coating performed the poorest [3]. When brazing WC/NiCrBSi(Co) composite coatings onto carbon steel substrates, varying wear behaviors were observed under different conditions [4]. During the processing and characterization of plasma-sprayed zirconia-alumina-mullite composite coatings on mild steel substrates, increased wear rates were associated with an inclination angle, sand concentration in the slurry, and radial distance. Radial distance was identified as the most influential factor affecting wear rates, though the angle of inclination and distance traversed also played roles [5]. In a study of slurry erosion on ductile materials under normal impact conditions, velocity and particle size were found to have a substantial impact on erosion wear, while solid concentration had a comparatively weaker effect [6]. Investigating erosion of ceramic coatings which were plasma-sprayed revealed an inverse relationship between erosion and the mean lamellar bonding ratio. The coatings' erosion resistance was primarily governed by their fracture toughness [7]. For different combinations of Co/WC and $NiCr/Cr_3C_2$ on various alloy substrates (Ni, Cr, and Mo), particle erosion speed had no significant effect on coating erosion. The TiN coatings exhibited considerably higher resistance to slurry erosion than uncoated mild steel and AISI 304 SS [8].

Aluminum phosphate sealing was found to have no impact on tribo-chemical wear but improved wear resistance in alumina and chromia coatings under rough contact conditions dominated by brittle fracture [9]. Electrochemical deposition of nickel coatings on aluminum-based composites resulted in high hardness and increased corrosion and erosion resistance [10]. Nanostructured Cr_3C_2-NiCr coatings demonstrated greater resistance to erosion as well as corrosion, individually and in combination, as compared to conventional coatings [11]. A comparative study of erosion wear rates on IN800 superalloys showed that non-conventional dip-coating of sol-gel derived 7YSZTBC outperformed conventional APS YSZ coatings in air jet erosion tests at room and high temperatures [12]. The Ni and SiC composite coatings on turbine steel reduced erosion wear due to their higher Vickers microhardness, which was 40.8% higher than the base substrate [13]. During experimental investigation of erosive wear behavior on plasma-sprayed stainless-steel coatings, Al_2O_3-40%TiO_2 coated substrates displayed superior erosion resistance when compared with uncoated substrates, thanks to higher hardness and lower coating porosity [14]. A study on erosion wear using Slurry Pot Tester revealed that particle velocity had the most significant influence, surpassing impact angle, size, and solid concentration [15]. Developed Fly Ash coatings on marine-grade steel, created via plasma spraying without additives, exhibited varying slurry erosion resistance influenced by sand concentration in slurry and rotational speeds during erosion tests [16].

The main objective of this investigation is studying slurry erosive wear behavior of Titanium dioxide atmospheric plasma sprayed on Mild Steel.

2. EXPERIMENTAL DETAILS

2.1 Materials

In the present work, Mild Steel is used as the substrate and Titanium dioxide powder is used as coating material with the particle size varying from 5µm to 50 µm.

2.2 Coating Procedure

Nickel Chromium powder is used for bond coating. Coating is applied using plasma spray coating technique. The substrate is cleaned to remove all dust particles and grit blasted before plasma spraying to create enough surface roughness to ensure good bond between substrate and coating. Then a layer of bond coat is applied on the substrate. TiO_2 powder is melted and ionized to plasma state and then sprayed using a gun along with hydrogen and argon gas onto the base metal from a distance of about 6 inches. The voltage and current of 60-70 volts and 495 amps respectively maintained during coating. The flow rates of hydrogen and Argon are 100m^3/min each and that of TiO_2 powder is 100 gm/min. Vickers's hardness tester was used to measure the micro hardness and a load of 200 g was applied for 10 seconds. The test was conducted at different locations and the average hardness value was calculated. Wear test of Titanium Dioxide (TiO_2) coating on Mild Steel substrate was conducted using slurry erosive wear testing machine.

2.3 Slurry Erosion Test

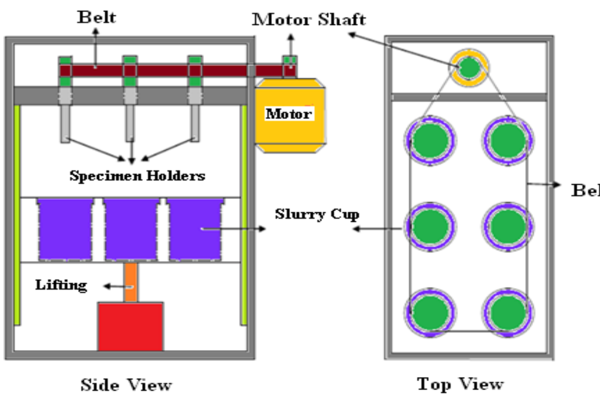

Fig 2.1. Line Diagram Slurry Erosion Wear Tester

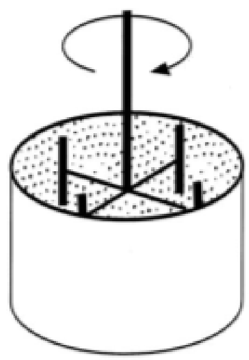

Fig 2.2. Principle of Slurry Pot erosion test

The Slurry Pot test is a non-standardized laboratory method used for measuring erosive wear caused by liquid-borne particles. It simulates the erosion process resulting from the interaction between solid particles suspended in a liquid and a surface. This kind of wear, often referred to as Slurry Erosion, typically occurs in marine environments and on turbine blades in hydroelectric plants. A schematic representation of the Slurry Pot Erosion Tester can be seen in Figure 2.1, while Figure 2.2 illustrates the working principle of this apparatus. In this test, a coupon sample measuring 2.5cm x 2.5cm x 5mm is employed. To create the erosive slurry, silica sand is mixed with water. Additionally, 3.5% NaCl is introduced into the slurry to replicate the corrosive environment found in sea water erosion. The test involves using different particle sizes, specifically 212 µm, 425 µm, and 600 µm. Furthermore, the slurry concentration is varied between 50 g/l and 150 g/l in increments of 50 g/l. The results are presented in terms of mass loss, which is measured after a 5-hour erosion period. Following the completion of the test, the specimen is carefully removed, cleaned with acetone, and its mass is measured.

RESULTS AND DISCUSSION

3.1 Effect of Slurry Concentration

Figure 3.1 illustrates the slurry erosive wear rates of mild steel, both coated with TiO_2 and uncoated, under varying concentrations of silica sand at a fixed slurry rotation speed and time duration. It is evident that an increase in slurry concentration corresponds to higher slurry erosive wear in both the coated and uncoated specimens. This phenomenon can be attributed to the fact that higher concentrations of sand particles in the slurry result in a greater likelihood of sand particles impacting the material's surface, thereby causing more substantial material loss. Furthermore, it is noteworthy that the coated specimens demonstrated superior erosion resistance compared to the uncoated specimens across all studied slurry concentrations."

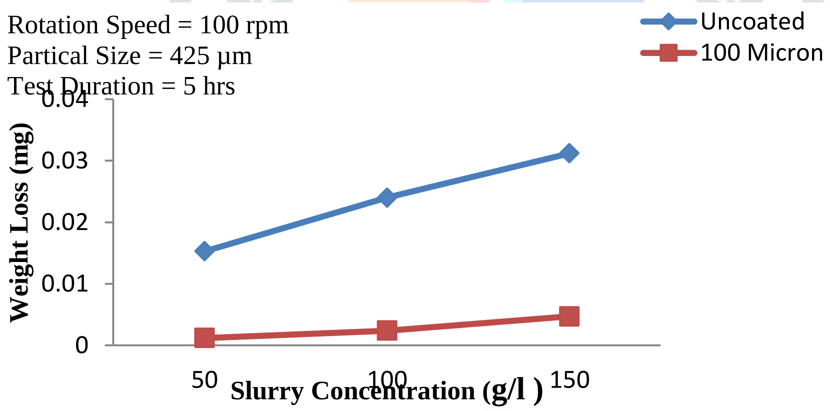

Fig 3.1. Variation of weight loss with slurry concentration

3.2. Effect of Speed

Figure 3.2 displays the slurry erosion wear rates of mild steel coated with TiO2 at different rotation speeds, with constant time duration and slurry concentration. It is notable that an increase in rotation speed results in a slight rise in mass loss for both uncoated and coated mild steel. However, the coatings that have been applied demonstrate a significantly reduced mass loss when compared to the uncoated mild steel. This higher rotation speed leads to an elevated slurry erosive wear rate for all materials. The increased impact velocity brings about greater energy, which can result in severe damage to the material's surface, potentially exposing fresh surface area. Corrosion generally has a detrimental impact on the mechanical properties of materials, making them more susceptible to wear and leading to substantial mass loss, especially in erosion-corrosion conditions when comparing uncoated mild steel to TiO_2 coated specimens. In the case of TiO_2 coated mild steel, the increase in speed primarily accelerates the mechanical removal rate but effectively inhibits corrosion due to the presence of the hard ceramic TiO_2.

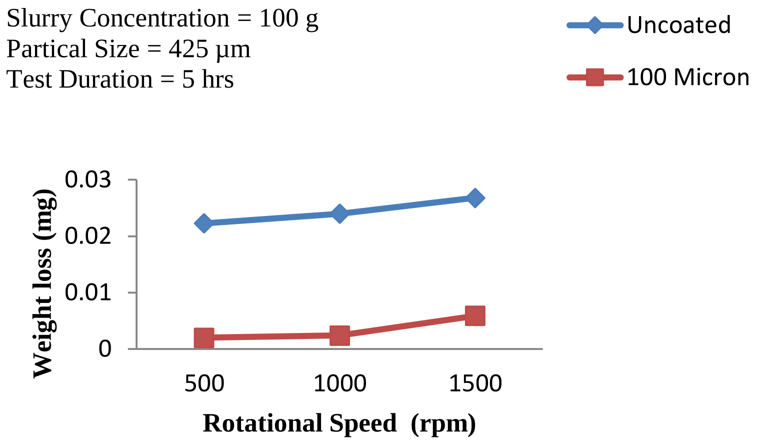

Fig 3.2: Variation of weight loss of with speed of slurry rotation

3.3 Effect of Erodent Grain Size

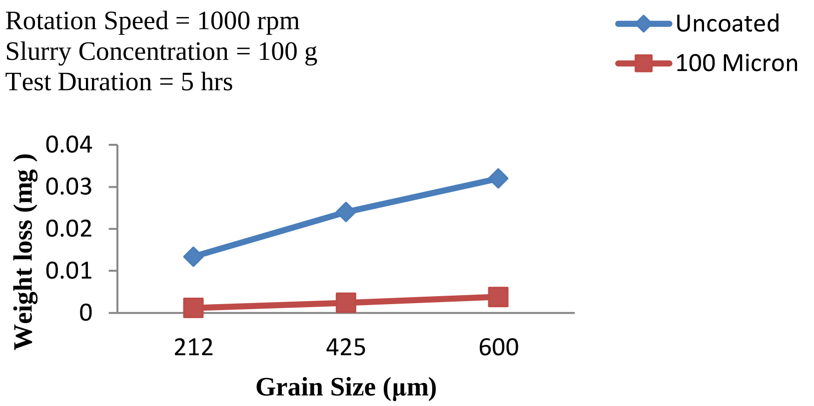

Fig 3.3. Variation of mass loss with erodent grain size

Figure 3.3 presents the slurry erosion wear rates of mild steel coated with TiO_2 for different grain sizes, with a consistent slurry rotational speed and time duration. It's evident that an increase in sand particle size corresponds to an increase in mass loss for both uncoated and TiO_2 coated mild steel. The highest weight loss is observed when using 600 µm grain size. This phenomenon occurs because larger particle sizes result in greater contact areas with the specimen surface, leading to more extensive surface damage due to increased abrasive action. However, it's worth noting that the developed coatings exhibited only a minor increase in mass loss compared to mild steel, even when very coarse sand particles were employed. This can largely be attributed to the enhanced hardness of the developed coatings.

4. CONCLUSIONS

From the above discussion, it can conclude that

- Plasma spray coating of Titanium Dioxide on Mild Steel is done effectively.
- With increase in sand concentration, wear of test specimen increases.
- With increase in speed, wear of test specimen increases.
- With increase in sand grain size, wear of test specimen increases.
- Wear of coated Mild Steel is less than uncoated Mild Steel.

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