TRIBOLOGICAL INVESTIGATION OF DETONATION SPRAYED Al_2O_3, Al_2O_3-3TiO_2 AND Al_2O_3-13TiO_2 COATINGS ON GREY CAST IRON TO ENHANCE ITS WEAR RESISTANCE

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ABSTRACT

Within most industry segments, significant financial losses may be incurred due to accelerated wear of various components. In order to minimize the effects of mechanical wear and extend product life, thermal spray coating solutions introduced into production and is further developing them to meet even more demanding wear applications. Applying coatings using thermal spray is an established industrial method for resurfacing metal parts. The process is characterized by simultaneously melting and transporting sprayed materials, usually metal or ceramics, onto parts. Failure of mechanical components due to wear is the most common and unavoidable problem mechanical processing industries. It not only affects the life of a component but also reduces its performances Therefore due to large economic losses associated with wear; this problem has attracted the attention of the researchers worldwide. In this study Al_2O_3 , Al_2O_3-3TiO_2 and Al_2O_3-13TiO_2 coatings were prepared on grade of cast iron (grey iron grade 250). The samples are investigated through standard procedure of pin-on-disk tests. The samples were weighed before and after the test. And the results of coated samples were compared with the uncoated samples.

Keywords: Wear, Grey Cast Iron, Coating, Detonation Gun, Test.

I. INTRODUCTION

The surface characteristics of engineering materials have a significant effect on the serviceability and life of a component, thus cannot be neglected in design. As described by Halling (1985), .Surface engineering can be defined as the branch of science that deals with methods for achieving the desired surface requirements and their behavior

in service for engineering components [1]. Engineering environments are normally complex, combining loading with chemical and physical degradation to the surface of the component. Surface wear damage is a phenomenon which effects how a component will last in service. An example of a component working in an aggressive environment is a cutting tool used in machining processes. The tool experiences high loads, high speeds and friction and, as a consequence, high temperatures. These factors lead to surface wear of the component. Lubrication in tribological applications reduces friction and wear, however conventional liquid lubricants fail under extreme conditions, namely low pressure, oxidative or corrosive environments, high speeds and high loads. Surface coatings can help deal with these circumstances. Improving the tool surface, not only improves the life of the tool, but also improves the surface finish of the machined part. Environmental degradation of the surface phase over time can be caused by wear, corrosion, fatigue and creep [2].

1.1 Wear

According to the German DIN standard 50 320, "*the progressive loss of material from the surfaces of contacting body as a result of mechanical causes*" , i.e., by contact and relative motion of a solid, fluid or gaseous counter body. Signs of wear are small detached wear particles, material removal from one friction body to the other, and material and shape changes of the tribologically loaded material zone of one or both friction partners. The wear is the loss of material and is expressed in terms of volume. Wear is a process of removal of material from one or both of two solid surfaces in solid state contact, occurring when two solid surfaces are in sliding or rolling motion together according to Bhushan and Gupta (1991). The rate of removal is generally slow, but steady and continuous. Wear processes can be classified into different types according to the type of tribological load and the materials involved, e.g., sliding wear, fretting wear, abrasive wear, and material cavitation. Wear is the gradual removal of material obtained at contacting surfaces in relative motion. While friction results in important energy losses, wear is associated with increased maintenance costs and costly machine downtime. Wear is caused due to many factors but friction is most important of them. Few more causes for occurrence of wear can be: Improper component design, Excessive Pressure, Contact area, Inadequate Lubrication, Environment, Material properties. Wear is caused by a number of mechanisms, the following four being especially important: (1) Surface fatigue (2) Abrasion (3) Adhesion (4) Tribochemical reaction More recently, experiments and testing on coated materials have occurred

And some standardized, and experimental test equipment has been produced to meet specifications on wear resistance. To reduce the wear problem, wear resistant coatings are deposited on the grey cast irons. Standard test methods such as pin-on-disc are used extensively to simulate rubbing action in which plastic yielding occurs at the tip of individual asperities. With pin-on disc apparatus are employed to study the wear behavior of the uncoated and coated grey irons as well. Thermal spray processes that have been considered to deposit the coatings are enlisted as: (1) Flame spraying with a powder or wire, (2) Electric arc wire spraying, (3) Plasma spraying, (4) Spray and fuse, (5) High Velocity Oxyfuel (HVOF) spraying, (6) Detonation Gun. Among the commercially available thermal spray coating techniques, detonation spray (DS) is chosen to get hard, dense and consequently wear resistant coatings.

1.2. Detonation Gun Spraying Process

In detonation Gun spraying Process, as shown in (figure 1), a mixture of spray material, acetylene and oxygen is injected into the detonation chamber. A precisely measured quantity of the combustion mixture consisting of oxygen and acetylene is fed through a tubular barrel closed at one end. In order to prevent the possible back firing a blanket of nitrogen gas is allowed to cover the gas inlets. Simultaneously, a predetermined quantity of the coating powder is fed into the combustion chamber. The gas mixture inside the chamber is ignited by a simple spark plug. The combustion of the gas mixture generates high pressure shock waves detonation wave), which then propagate through the gas stream. Depending upon the ratio of the combustion gases, the temperature of the hot gas stream can go up to 4000 deg C and the velocity of the shock wave can reach 3500m/sec. The hot gases generated in the detonation chamber travel down the barrel at a high velocity and in the process heat the particles to a plasticizing stage (only skin melting of particle) and also accelerate the particles to a velocity of 1200m/sec.

These particles then come out of the barrel and impact the component held by the manipulator to form a coating. The high kinetic energy of the hot powder particles on impact with the substrate result in a buildup of a very dense and strong coating. The coating thickness developed on the work piece per shot depends on the ratio of combustion gases, powder particle, size carrier gas flow rate, frequency and distance between the barrel end and the substrate Depending on the required coating thickness and the type of coating material the detonation spraying cycle can be repeated at the rate of 1-10 shots per second [3]. The chamber is finally flushed with nitrogen again to remove all the remaining "hot" powder particles from the chamber as these can otherwise detonate the explosive mixture in an irregular fashion and render the whole process uncontrollable. With this, one detonation cycle is completed above procedure is repeated at a particular frequency until the required thickness of coating is deposited.

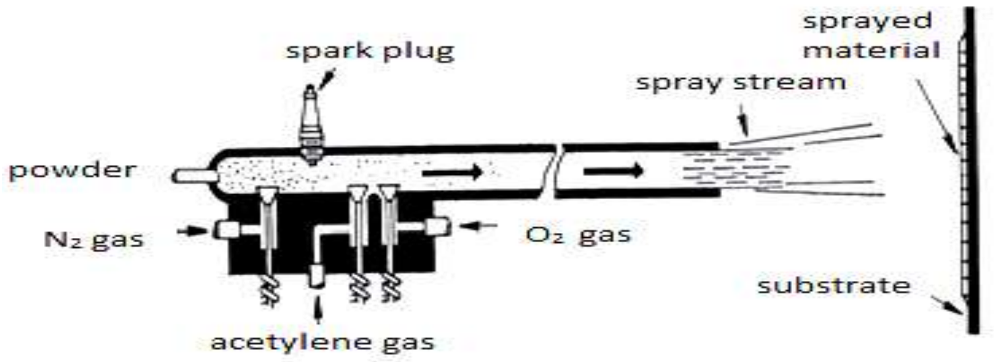

Figure.1 Detonation Gun process

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II. EXPERIMENTAL PROCEDURE

Samples of cylindrical shape, with diameter 8mm and length 30mm were casted with the component of GI250. The grinding of end faces (to be coated) of the pins is done using emery papers and grinding was followed by polishing with 1/0, 2/0, 3/0 and 4/0 grades polishing papers. Three types of coating powders namely (1) Al_2O_3 (2) Al_2O_3-$3TiO_2$ (3) Al_2O_3-$13TiO_2$ are selected for Detonation Spray Coating Process after the literature survey. Powder Al_2O_3 , Al_2O_3-$3TiO_2$ and Al_2O_3-$13TiO_2$ form hard dense and excellent bonded coatings on the samples. The wear tests were performed in a machine (Wear and Friction Monitor Tester TR-201) conforming to ASTM G 99 standard. The wear tests for coated as well as uncoated specimens were conducted under three normal loads of 30 N, 40 N and 50 N and a fixed sliding velocity of 1 m/s. A track diameter of D=40 mm, sliding speed v=1 m/s is kept. Wear tests have been carried out for a total sliding distance of 5400 m (6 cycles of 5min, 5min, 10min, 10min, 20min, 40min duration). Weight losses for pins were measured after each cycle to determine the wear loss. The coefficient of friction has been determined from the friction force and the normal loads in all the cases. The results of coating volume loss are reported.

III. RESULTS AND DISCUSSION

3.1 Comparative Wear Behavior for two coatings

The comparison of wear loss for the coatings; Al_2O_3 , Al_2O_3-3TiO_2 and Al_2O_3-13TiO_2 on GI250 at 30N, 40N, and 50N is as shown in Figure 2. From the bar chart it is clear that Al_2O_3-13TiO_2 shows minimum CVL as compared to Al_2O_3 and Al_2O_3-3TiO_2 coating. CVL for Al_2O_3-13TiO_2 is least at all the three normal loads of 30N, 40N, 50N, whereas highest CVL is found to be in bare GI250 substrate. CVL for all three detonation sprayed coatings is less than that to found in the in bare GI250. The CVL for all the four substrate in increasing order can be given as Bare GI250 > Al_2O_3 > Al_2O_3-3TiO_2 > Al_2O_3-13TiO_2 Which means that Al_2O_3-13TiO_2 coated substrate is most wear resistant among the four substrates and bare GI250 substrate is least wear resistant. The difference in CVL of Al_2O_3 , Al_2O_3-3TiO_2 and Al_2O_3-13TiO_2 coatings is not much but still Al_2O_3-13TiO_2 proves to be better wear resistant among the three at all three loads.

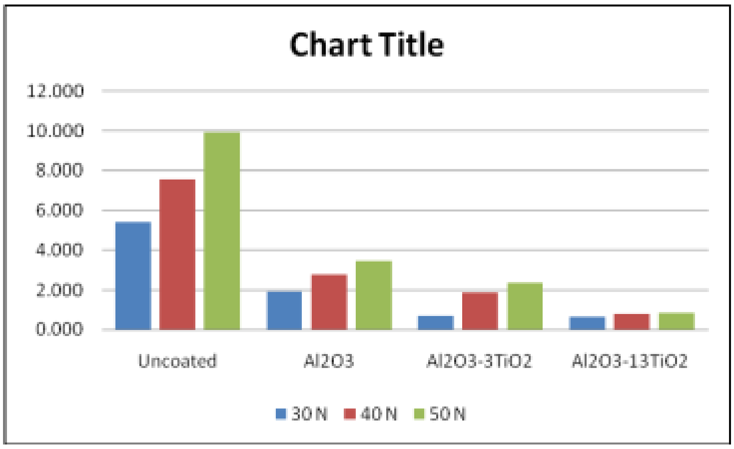

Figure 2: Cumulative Volume loss (mm3) in one cycle for D-gun sprayed coatings and bare GI250 At 30N, 40N and 50N

IV. CONCLUSION

[1] Based upon experimental results obtained in the present work, the following conclusions have been drawn:

[2] Detonation Sprayed Al_2O_3, Al_2O_3-3TiO_2 and Al_2O_3-13TiO_2 coatings have successfully been deposited on GI250 grade of grey cast iron.

[3] The detonation sprayed Al_2O_3 , Al_2O_3-3TiO_2 and Al_2O_3-13TiO_2 coated GI250 specimens showed significantly lower cumulative volume loss as compared to bare GI250 material.

[4] Cumulative Volume loss for detonation sprayed Al_2O_3 , Al_2O_3-3TiO_2 & Al_2O_3-13TiO_2 coated as well as bare GI250 specimens increases with increase in load.

[5] The Cumulative Volume loss for Al_2O_3-13TiO_2 coating was observed to be minimum in the present study.

[6] The Al_2O_3-13TiO_2 coating substrate combination has shown minimum Cumulative Volume loss among all the combinations. The wear resistance for coating–substrate combination in their Increasing order (at 50N) is Al_2O_3-13TiO_2 > Al_2O_3-3TiO_2 > Al_2O_3 > Bare GI250

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