Sliding Wear Behavior of Alumina/Tic Coated Steel Produced by Plasma Spray Technique

M. Mruthunjaya and K.I. Parashivamurthy

Abstract--- *Carbide coatings exhibit good resistance to wear and has an increased hardness which increases the service life of equipments generally when the surfaces are exposed to critical atmosphere like in thermal power plants. The hard Alumina-Titanium carbide (Al_2O_3/TiC) carbide coating is developed on the steel by using thermal plasma spray technique. The composition of Al and TiC are varied in the ratio of 70/30, 65/35 and 60/40. Coated samples are analyzed using optical microscope, hardness test, sliding wear and corrosion test. Hard-faced samples are shows uniform distribution of Al_2O_3/TiC particles on the surface of steel. Surface hardness increases with increasing volume fraction of TiC. The coating of Al_2O_3/TiC with volume fraction of 30% TiC shows good corrosive resistance compared to other two coating specimens and coating with 40% of TiC has shows good wear resistance than the other two coatings.*

Keywords--- *Corrosion, Microstructure, Plasma Spray, Sliding Wear*

I. INTRODUCTION

The uses of carbide coating on steel surface have received considerable attention in recent years. Carbide coated steel have recognized as one of the important wear resistant materials for structural, wear and thermal applications in industries [1-4]. Development of new hard faced materials with high wear *resistance*, hardness and corrosion resulted development of Al_2O_3/TiC on the surface of steel. In recent years, Al_2O_3/TiC coated steel have gained wide applications due to its high hardness, good wear resistance and corrosive resistances [5,6]. Till today, many carbide coatings are developed by welding technology. Carbide coating produced by welding is suffers from uneven coating, non-uniform distribution of carbides, oxidation of reinforcement etc. Reduce to such disadvantages; many investigators [2,3, 7, 8] are developed carbide coatings using thermal spray technique. Stoica et al [9] have developed Al_2O_3/TiC coated hard face for assessing wear behavior of steel. Poh Koon Aw et al.[10] developed WC coated samples to assessing corrosion, erosion [11,12]behavior of steel.

Al_2O_3/TiC is one of the refractory materials using for hard coating on steel surface. Advantages of Al_2O_3/ TiC coated steel using thermal spray technique is clean surface reinforcement, i.e. free from gas absorption, oxidation, and stronger matrix-filler bond at the interface. This paper reports the systematic investigation of microstructure characterization, wear behavior and corrosion resistance [13] of Al_2O_3/ TiC coated steel with varying volume fraction of TiC. The alloying elements of boron, chromium and carbon in these alloys will produce the hard phases of borides, carbides and hence rise the cavitations and wear resistance of the coatings. The direct addition of hard compound, such as TiC can also significantly improve the tribological properties of coatings[14]. The plasma spray coatings techniques are increased life expectancy of components, stronger bonding, improved surface finish, increased heat and wear resistance, greater flexibility and impact resistance, Superior corrosion and acid resistance, cleaner for the environment. Also, plasma spray coating techniques forms microstructures with fine equated grains and without columnar boundaries.

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II. MATERIALS AND EXPERIMENTAL PROCEDURE

Base metal used was eutectoid steel. The chemical composition is determined using a vacuum emission spectrometer method and tabulated in Table 1.

Table 1: Chemical Composition (In Weight Percent) of Base Metal

C	Si	Mn	Sulphur	Phosphorus	Fe
0.83	0.10	0.32	0.03	0.02	99.02

Al_2O_3/TiC powder was used to coat on the steel in varying volume fraction of TiC. The chemical composition and volume fraction(in %) of Al_2O_3/ TiC is shown in the table 2. Alumina used in this experiment was 96 % purity and TiC is about 94% purity. High Velocity Oxygen Fuel (HVOF) method is adopted and during the process, a feedstock material is heated and allowed spray particles on to the surface by jet spray using oxygen and propone gas as fuel at high velocity. Combusted gas accelerated to supersonic speed and heated Al_2O_3/TiC particles are feed through this stream. Sprayed particles stick on the surface by force and diffusion bond and built up in to a laminar structure of thermal coating of Al_2O_3/TiC.

Table 2: Volume Fraction of Reinforcement

Sample No.	Al_2O_3/TiC	Volume fraction of TiC in%
S_1	70/30	30
S_2	65/35	35
S_3	60/40	40

Hard faced samples are examined for microstructure using optical microscope. Hardness test was carried using both

Rockwell and Micro hardness measuring technique. Sliding wear test was carried out using pin-on disc testing machine as per ASTM G 99. Corrosion test[14,15] was conducted as per ASTEM-B-117. For corrosion test the chamber size will be 400 liters capacity. The detail of corrosive test conducted is shown in the table 3.

Table 3: Salt Spray Test Details

1.	Concentration of solution	5% NaCl (AR grade) in distilled water
2.	Test temperature in °c	35± 1
3.	Volume of test solution collected ml/hr/80cm^3	1.82
4.	Consternation of the salt solution collected (%)	5.52
5.	Ph value of the collected solution	6.73
6.	Cleaning procedure (after the test)	Washed with running tap water and distilled water

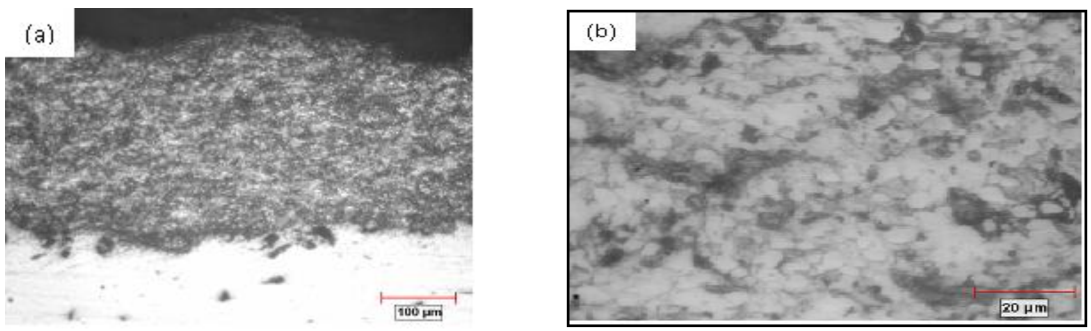

Figure 1: Optical Microstructure Sample (a) indicates Al_2O_3 on Base Metal, (b) Coated Al_2O_3 at Higher Magnification

III. Results and Discussion

Fig.1 shows the optical micrograph of Al_2O_3/TiC coating and its composition. Micrograph reveals that there is fairly uniform distribution of Aluminum Titanium carbide on mild steel. As observed from the structure, reinforcements are uniformly distributed on the surface of the metal. Microstructure confirms establishing of good bond between matrix and reinforcement phase.

Rockwell hardness test of Al_2O_3 were evaluated using diamond indenter and 150 Kg of load. Similarly, Vickers hardness was evaluated using computerized Vickers hardness testing machine with using the test load of 0.3 kg. Hardness of the Al_2O_3 coated steel specimens are depicted in the figure 2. Sliding wear test was conducted using pin-on disc wear testing machine under controlled conditions. For comparisons, both un-coated and coated samples are used under un-lubricated conditions. Wear results of Al_2O_3 hard-faced specimens as a function of wear loss is presented in Fig.3. From the graph, wear resistance of the coating increase with increasing TiC volume fraction. Un-coated samples shows more wear than coated samples.

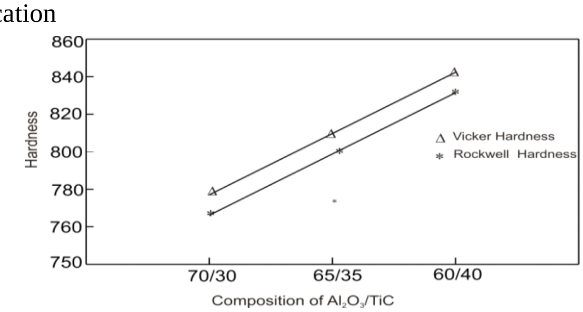

Figure 2: Graph of Hardness vs. Composition of Al_2O_3

It indicates that, TiC volume fraction enhances the wear resistance of the coatings. The hardness as a function of wear loss is shown in the fig.4. It was observed that, the hardness of the samples plays more roles in the wear resistance. The sample S_3 shows the high wear resistance compared to other three samples due to high Rockwell as well as Vickers hardness. The Volume fractions of TiC enhance the hardness of the coating and subsequently wear resistance.

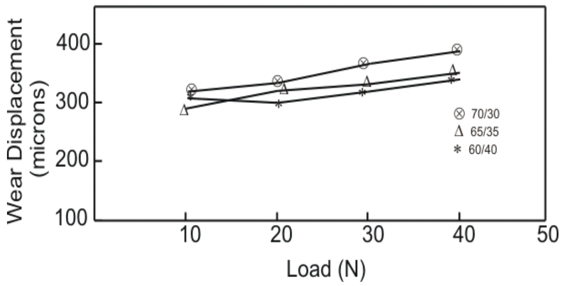

Figure 3: Wear Displacement Against Load Applied

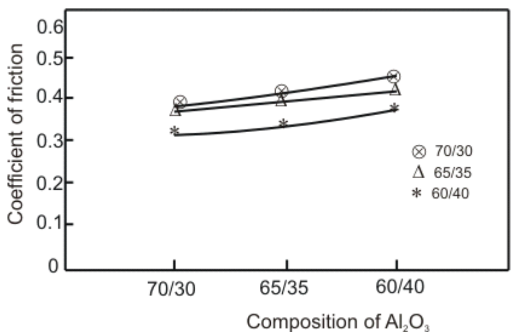

Figure 4: Graph of Coefficient of Friction vs. Composition of Al_2O_3

Effect on load on wear rate of different volume fraction of TiC results are shown in the Fig. 5. From the data it can be observed that the wear rate decrease with increasing volume fraction of TiC. This indicates the wear rate is significantly decreased at higher volume fraction of TiC. This is because of high hardness of the TiC particles resist the wear of the coatings. Also Wear rate of the coated samples are evaluated by varying load shown the fig.5. It is observed from the graph, the wear rate rapidly increase from 10 N to 40 N for base metal and gradually increase with increasing of load. This is because, large volume of hard particles slides in the soft matrix and increase the wear loss by varying load. The co-efficient of friction is directly proportional to pressure between the matrix and reinforcements. At higher the load, wear behavior was erratic owing to the opposing effects of materials wear behavior.

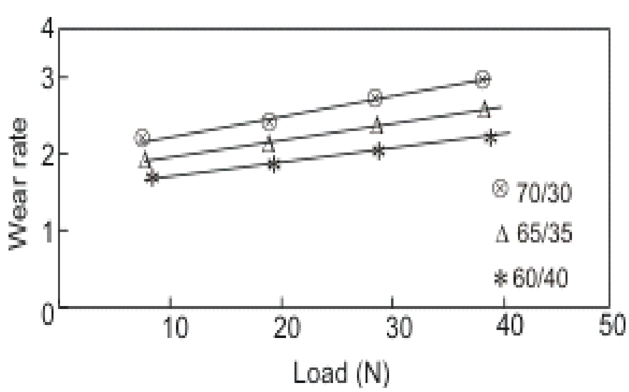

Figure 5: Graph of Wear Rate Against Load Applied

Corrosion of coated samples are tested in a closed chamber using salted solution contain 5% NaCl. This produces a corrosive environment and parts exposed in it are subjected to strong corrosive condition. Results of corrosive behavior are shown in the fig.6. Red rust is observed for the sample at 19.12 hours and in the case of sample S_1 and it was 15:36 for sample S_3 at 14.24 hours. It indicates that, the sample S_1 is low corrosive resistance than the other two.

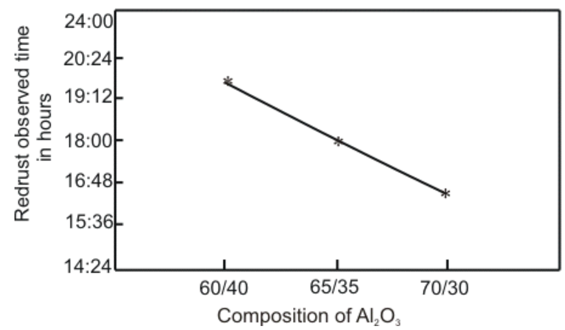

Figure 6: Red Rust Observed in Hours vs. Composition Al_2O_3

Above corrosion analysis gives clear indication of corrosion resistance of Al_2O_3/TiC carbide coating in environment. Corrosive resistant of Al_2O_3/TiC in the ratio 60/40 having high resistance for corrosion. This is because of Al_2O_3 having good resistance for corrosion resistance and TiC in low volume fraction. It is observed that red rust formation occur early on coated surfaces having more TiC percentage and red rust formation delays as Al_2O_3 percentage increases in coated surface.

IV. CONCLUSION

The results obtained from various tests we came to the following conclusions.

- The surface hardness increases with the increased percentage volume fraction of TiC.
- Al_2O_3/TiC uniformly distributed on the surface of the metal.
- Wear rate decreases with increasing in volume fraction of TiC
- Coefficient of friction increases with decreasing in volume fraction of TiC.
- Corrosion resistance increases with the increasing in TiC

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