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 [ijirset@gmail.com](mailto:ijirset@gmail.com)

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# Investigation of Sliding Wear Behaviour of TiO<sub>2</sub> Coated on Mild Steel

<sup>1</sup>Dr. Banakara Nagaraj, <sup>2</sup>Darshan Kumar G, <sup>3</sup>M A Mustafa Khazi, <sup>4</sup>M S Irfan Ali, <sup>5</sup>Mudassir

<sup>1</sup>Associate Professor, Department of Mechanical Engineering, Ballari Institute of Technology and Management, Ballari, Karnataka, India

<sup>2,3,4,5</sup>U.G. Student, Department of Mechanical Engineering, Ballari Institute of Technology and Management, Ballari, Karnataka, India

**ABSTRACT:** The present study focuses on exploring the sliding wear behavior of TiO<sub>2</sub> coated on mild steel surfaces. Wear resistance is a crucial aspect in numerous industrial applications, particularly in machinery components subjected to sliding contact. Titanium dioxide (TiO<sub>2</sub>) is known for its remarkable properties such as high hardness, chemical stability, and biocompatibility, making it a promising candidate for wear-resistant coatings. In this research, mild steel substrates were coated with TiO<sub>2</sub> using a cost-effective and environmentally friendly sol-gel method. The coated samples underwent comprehensive characterization employing scanning electron microscopy (SEM), X-ray diffraction (XRD), and atomic force microscopy (AFM) to analyze the microstructure, phase composition, and surface topography. Furthermore, sliding wear tests were conducted using a pin-on-disc tribometer under various sliding conditions to evaluate the wear resistance of the TiO<sub>2</sub>-coated mild steel samples. The results revealed significant improvements in wear resistance for the TiO<sub>2</sub>-coated specimens compared to the uncoated ones, attributed to the enhanced surface hardness and reduced friction coefficient provided by the TiO<sub>2</sub> coating. Moreover, the effects of coating thickness and sliding parameters on wear behavior were systematically investigated and analyzed. This study contributes valuable insights into the application of TiO<sub>2</sub> coatings for enhancing the wear resistance of mild steel surfaces, offering potential solutions for extending the service life and performance of industrial components operating under sliding contact conditions.

**KEYWORDS:** Coated Mild steel, TiO<sub>2</sub>, Alloy, Plasma spray coating.

## I. INTRODUCTION

Mild steel is a type of steel alloy that contains a high amount of carbon as a major constituent. An alloy is a mixture of alloys and non-metals, designed to have specific properties. Plasma spray coating is a unique process. It uses high direct current (DC) and voltage according to power range to produce plasma flame for melting high temperature of material. During process, the molten powder accelerates towards the substrate, cools and anchors together to form a strongly adhered coating with the principle technique of mechanical bonding adhesion.

Understanding the plasma system and coating process are the most important to develop and improve the adherent bonding and quality of coating. Selected TiO<sub>2</sub> coating material for specific application such as for wear and thermal resistance application, type of metal substrate to reduce the constraint to manufacture components from very high cost bulk material, surface preparation for the strong adherence bonding between coating material and metal substrate.

The processing plasma spraying parameters are related to each other in achieving the high performance and high quality of coating. Selection and application of bond coating layered between ceramic and mild steel substrate are also important in order to improve high adherence coating bonding. The analysis of phases exist and microstructures of coated samples are important in order to determine the coating behaviour, coating structure and condition of powder particles after plasma spray coating process. Taguchi tables help to reduce experimentation in finding the conditions of various parameters affecting the dry sliding wear behaviour at which wear rate is minimum.

## II. RELATED WORK

Plasma spray is regarded as the most versatile of all the thermal spray processes e.g. flame spraying, arc spraying. The plasma spraying process involves the latent heat of ionised inert gas being used to create the heat source.

The most common gas used to create the plasma is argon as the primary gas and hydrogen or helium as the secondary gas. However the gas usage depends on the type of material to be sprayed and coating application.

Plasma spray is able to use and melt any variety of ceramic materials. The plasma spray system consists of an electronically controlled power supply, a PLC-based operator control station, a gas mass flow system, a closed-loop water chilling system, a powder feeder and a plasma gun. A primary inert gas, such as argon is injected between two water-cooled electrodes (anode and cathode) in the gun, where it is ionised to form a plasma jet when ignited. Any powders is injected into the plasma flame will melt and subsequently deposited onto the component to form a coating.

Most of the ceramic materials used in plasma spray coatings are chromium oxide, TiO<sub>2</sub>, zirconium oxide and aluminium oxide. The particle velocities of plasma spraying are higher than for those flame and arc spraying which produce denser coatings and finer surface roughness. Figure 2.7 shows a typical gun and plasma spray coating process.

The versatility of plasma spray has been widely recognised in many numbers of industries. The unique features that characterise plasma spray processing are listed below:

- It can be used to deposit a wide range of ceramics and metals and any combinations of the materials.
- It is able to develop homogeneous coating without composition change with coating thickness.
- High deposition rates are possible without extreme investments in capital equipment.
- Plasma spray can be applied at any environment conditions (air, vacuum and underwater).

Plasma system can be classified into RF plasma and DC Plasma. The processes are described as below:-

- RF plasma – The gas is passed through a radio frequency field so that electrical coupling occurs and energy is transferred to the gas.
- DC plasma – The gas is used as a medium in which a direct current arc is established between two or more electrodes.

In RF plasma, no electrode is necessary to produce the flame, no contamination of the working gas or materials injected into plasma occur during coating process.

Air plasma spray system used for the study is classified as DC plasma. The air plasma spray consist of several principle components to form a complete system in order to generate plasma flame, bring coating material to the plasma flame and produce a coating onto a substrate. In general, the air plasma system consists of:

- Plasma torch
- DC power supply
- Control and instrumentation system
- Cooling water system
- Gas supply system
- Material feeder system

The principle components of the plasma spray system are arranged and linked together in an optimum way in order to ensure maximum efficiency at minimum power, pressure and space. Figure 2.8 shows a flow diagram of plasma spray operation.

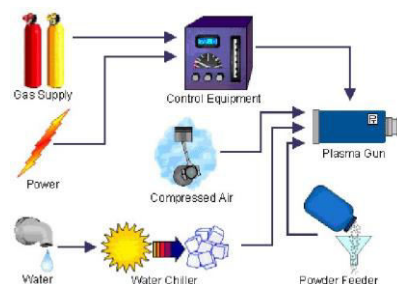


Figure 2.1: Basic system (gases, power, cooling, controller, feeder and plasma torch) of the plasma spray equipment.

### III. METHODOLOGY

METHODOLOGY IS FOLLOWED AS:-

- Prepare mild steel pins for pin on disc test
- Develop TiO<sub>2</sub> coatings on the flat surface of the pins using plasma spray technique
- Conduct Sliding wear tests on uncoated and coated specimen
- Plot graphs for wear and friction
- Compare the results of uncoated and coated specimen

Pin on Disc Experiment Base metal: Mild Steel Coating material: TiO<sub>2</sub> Stage 1

Preparation of specimen by firstly cutting, then turning and then finishing by filing process in workshop. Stage 2

Specimens are prepared to size to the following size 10mm diameter, 20 mm length Stage 3

The coating material was plasma sprayed on the base metal to a thickness of 100µm Stage 4

Various tests are to be conducted Stage 5

Each test is conducted with all possible accuracy taking each specimen at a time. Stage 6

Data of each test is noted down to arrive at the result and necessary graphs are plotted. Stage -7

To study the micro structure of uncoated and TiO<sub>2</sub> coated mild steel using Optical microscope Stage 8

The results are analyzed with Taguchi's tables SPECIMEN PREPARATION:



Fig 3.1: Before Coating



Fig 3.2: After Coating WEAR TEST



Figure 3.3: The pin on disc Wear test Apparatus.



Table No:3.1: Specifications

Pin size	3 to 12mm
Disc size	Dia.120mmx8mm thick
Wear tack radius	20mm to 60mm
Sliding speed range	26m/s to 6m/s
Disc rotating speed	100 to 2000rpm
Normal load	Maximum 200N
Frictional force	0-200N digital readout
Wear measurement range	4mm digital readout
Input power	230V,5A,Iphase,50Hz

Dry sliding wear tests were carried out on a pin on disc wear testing machine. Figure1 shows the wear test configuration.

The wear test was performed under the following conditions: Track radius of 30 mm

Speed : 200 rpm, 400 rpm Load : 20N, 30N, 40N,50N

The wear of the test specimen was recorded during the wear test.

**IV. EXPERIMENTAL RESULTS**

Evaluating Wear using Pin on Disc Wear Tester:

Track radius : 30mm

Speed : 200 rpm and 400rpm

Load : 20-50N (steps of 10N)

Formula used:

Sliding Velocity (V) =  $\pi D N / 60,000$  where D=Track Radius in m, N=Speed in rpm For 200 rpm,  $V = \pi \times 60 \times 200 / 60000 = 37.7 \text{ m / min}$

For 400 rpm,  $V = \pi \times 60 \times 400 / 60000 = 75.4 \text{ m / min}$  Sliding Distance (L) = Sliding Velocity\*Time (V\*t) in m

Wear Rate =  $(\text{Wear} \times \text{Area}) / (\text{Sliding Distance} \times \text{Normal load})$

Table 4.1: Wear data for uncoated mild steel at 200 rpm

Specimen No.	Time in min	Sliding distance in m	Load in N	Wear in $\mu\text{m}$	Wear rate in $\text{mm}^3 / \text{N-m}$	Weight loss in gms
1	5	188.5	20	3	6.25E-05	0.004
	7.5	282.75	20	5	6.94E-05	
	10	377	20	6	6.25E-05	
	15	565.5	20	8	5.55E-05	
	20	754	20	10	5.21E-05	
	22.5	848.25	20	11	5.09E-05	
	25	942.5	20	12	5.00E-05	
30	1131	20	13	4.51E-05		
2	5	188.5	30	4	5.55E-05	0.007
	7.5	282.75	30	6	5.55E-05	
	10	377	30	10	6.94E-05	



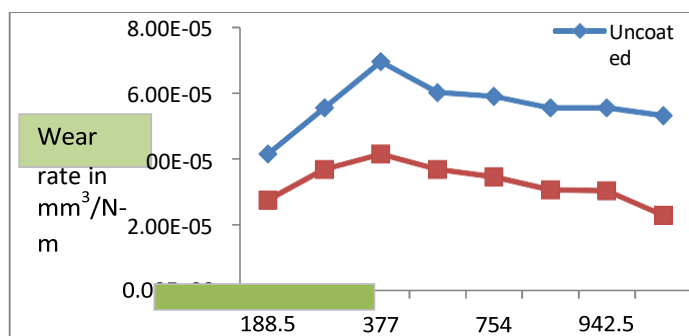
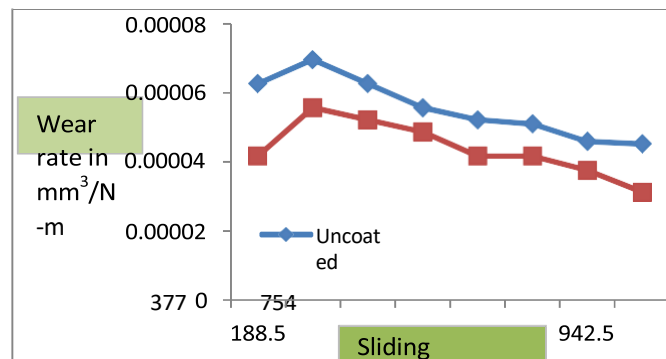
	15	565.5	30	13	6.02E-05	
	20	754	30	17	5.90E-05	
	22.5	848.25	30	18	5.55E-05	
	25	942.5	30	20	4.63E-05	
	30	1131	30	23	5.55E-05	
3	5	188.5	40	7	7.29E-05	0.012
	7.5	282.75	40	13	9.03E-05	
	10	377	40	15	7.81E-05	
	15	565.5	40	17	5.90E-05	
	20	754	40	20	5.21E-05	
	22.5	848.25	40	22	5.09E-05	
	25	942.5	40	24	5.00E-05	
	30	1131	40	27	4.69E-05	
4	5	188.5	50	10	8.33E-05	0.014
	7.5	282.75	50	15	8.33E-05	
	10	377	50	20	8.33E-05	
	15	565.5	50	23	6.39E-05	
	20	754	50	28	5.83E-05	
	22.5	848.25	50	33	6.11E-05	
	25	942.5	50	35	4.86E-05	
	30	1131	50	37	8.33E-05	

Table4.2: Wear data for uncoated mild steel at 300 rpm

Specimen No.	Time in min	Sliding distance in m	Load in N	Wear in $\mu\text{m}$	Wear rate in $\text{mm}^3 / \text{N}\cdot\text{m}$	Weight loss in gms
1	5	282.78	20	4	5.55E-05	0.005
	7.5	424.17	20	5	4.63E-05	
	10	565.56	20	7	4.86E-05	
	15	848.34	20	10	4.63E-05	
	20	1131.12	20	13	4.51E-05	
	22.5	1272.51	20	15	4.63E-05	
	25	1413.90	20	18	5.00E-05	
	30	1696.68	20	19	4.40E-05	
2	5	282.78	30	5	4.63E-05	0.008
	7.5	424.17	30	7	4.32E-05	
	10	565.56	30	11	5.09E-05	
	15	848.34	30	14	4.32E-05	



	20	1131.12	30	17	3.93E-05	
	22.5	1272.51	30	19	3.91E-05	
	25	1413.90	30	21	3.89E-05	
	30	1696.68	30	23	3.55E-05	
3	5	282.78	40	8	5.55E-05	0.014
	7.5	424.17	40	13	6.02E-05	
	10	565.56	40	16	5.55E-05	
	15	848.34	40	19	4.40E-05	
	20	1131.12	40	22	3.82E-05	
	22.5	1272.51	40	24	3.70E-05	
	25	1413.90	40	26	3.61E-05	
	30	1696.68	40	30	3.47E-05	
4	5	282.78	50	11	6.11E-05	0.019
	7.5	424.17	50	16	5.93E-05	
	10	565.56	50	21	5.83E-05	
	15	848.34	50	25	4.63E-05	
	20	1131.12	50	32	4.44E-05	
	22.5	1272.51	50	37	4.57E-05	
	25	1413.90	50	40	4.44E-05	
	30	1696.68	50	43	3.98E-05	



## V. CONCLUSION

Based on the tests carried out to study the effect on wear, Mild Steel coated with TiO<sub>2</sub> as explained in the previous chapter and with in the scope of this investigation the following conclusion have been drawn.

1. Plasma spray coating of TiO<sub>2</sub> on mild steel is effectively done for the thickness of 100microns.
2. Wear loss of the specimens decreases effectively when compared to uncoated specimens.
3. In Pin on disc wear test,
  - a) with increase in speed of the disc wear of uncoated specimen and coated specimen increases
  - b) By increasing the load on the specimen, wear increases.
  - c) With increase in sliding distance, the wear rate decreases.
  - d) The effect of speed is greatest in case of both uncoated and coated mild steel
4. The wear of uncoated mild steel is characterized by scratches, wear tracks and plastic deformation while the wear of coated specimen is characterized by pits due delamination.

## REFERENCES

1. M. Azzi, M. Benkahoul, J.A. Szpunar, J.E. Klemberg-Sapieha, L. Martinu, Tribological properties of CrSiN-coated 301 stainless steel under wet and dry conditions, *Wear*, 267, 882–889, (2009).
2. S. kalidass, P. Palanisamy, Prediction of Surface Roughness for AISI 304 Steel with Solid Carbide Tools in End Milling Process Using Regression and ANN Models, *Arab J SciEng*, 39:8065 8075, (2014)
3. Huang Chen, Chuanxian Ding, Pingyu Zhang, Peiqing La, SooWohn Lee(China), Wear of plasma-sprayed nanostructured zirconia coatings against stainless steel under distilled-water conditions, *Surface and Coatings Technology*, 173, 144 1492003, (2003).
4. In-WoongLyo, Hyo-SokAhn, Dae-Soon Lim, Microstructure and tribological properties of plasma-sprayed chromium oxide molybdenum oxide composite coatings, *Surface and Coatings Technology*, 163 –164 , 413–421, (2003)
5. Ajitbehera , S. C. Mishra, Prediction and Analysis of Deposition Efficiency of Plasma Spray Coating Using Artificial Intelligence Method, *Open Journal of Composite Materials*, 2, 54-60, 2012.
6. S. Tailor, R. M. Mohanty, P. R. Soni, A Review on Plasma Sprayed Al-SiC Composite Coatings, *Journal of Materials Science & Surface Engineering Vol. 1 (1)*, 2013, pp 15-22.
7. N.L. Parthasarathi, Muthukannan Duraiselvam, High temperature tribological properties of NiCrBSiCFe plasma- sprayed coating on austenitic stainless steel substrate, *Journal of Alloys and Compounds*, Volume 505, Issue 2, 3 September 2010, Pages 824-831
8. L.C. Betancourt-Dougherty , R.W. Smith, Effects of load and sliding speed on the wear behaviour of plasma sprayed TiC NiCrBSi coatings, *Wear* Volume 217, Issue 1, 15 April 1998, Pages 147-154
9. Hani Aziz Ameen, Khairia Salman Hassan and Ethar Mohamed Mhdi Mubarak, Effect of loads, sliding speeds and times on the wear rate for different materials, *American Journal Of Scientific and Industrial Research*, 2(1): 99-106, (2011)
10. D.I Pantelis, P Psyllaki, N Alexopoulos, Tribological behaviour of plasma-sprayed Al<sub>2</sub>O<sub>3</sub> coatings under severe wear conditions, *Wear*, Volume 237, Issue 2, February 2000, Pages 197-204





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