JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Influences of surface treated and wear resistance of cast iron disc fabricated by PVD coating

M.Shunmuga Priyan*, Kova Anil, M.S.Maneesh, S.Midhun Kumar, Sinto P Sebi

Department of Mechanical Engineering, Loyola Institute of Technology & Science, Thovalai, Tamil Nadu-629302
*Corresponding Author Email:iampriyan25@gmail.com

Abstract : In this work determined the Influences of surface treated and wear resistance of cast iron disc fabricated by Physical Vapor Deposition (PVD) coating. PVD is used to produce many items which require thin films for mechanical, optical, chemical or electronic functions. After the coating process has been completed the roughness of each coated and uncoated material has been carried out. Ensure that the weight of the materials should be checked before the wear test is to be performed. Now the wear performance of the coated and uncoated materials should be carried out, in order to achieve the low co-efficient of friction in coated materials than the uncoated materials by using Pin-On-Disc apparatus (ASTM G99) having Tribological Data Acquisition System, Again the weight of the materials should determine the weight loss of each materials. The results of the tests revealed that Tin Metal Coated exhibited a lower wear compared to the plain Cast iron, additionally, testing of the weight loss of the uncoated and coated specimens were increased or ·decreased due to ·applied load and sliding distances, and also determined low coefficient of friction and wear losses were carried out. The single layered Tin metal powder deposition showed the greatest improvement in tribology performance.

Keywords: PVD, Pin-On-Disc, Co-efficient of friction, Wear loss, Roughness

I. INTRODUCTION

In this paper few selected research paper related to coating. The studies carried out in these papers are mainly concerned with the different substrate and ·different coating material and how these affect the metallurgical properties. In this paper of PVD coating on cutting tool found that the Ti-Al-Ni-Si-N coatings on the tool increase lifetime of the tool by the range of 1.8 to 3.6 times comparing to the uncoated and (Ti,al)-N coated tool. At the same time, the use of Ti-Mo-Al-Ni-Si-N as hardening coatings leads to a decrease in cutting forces by up to 2 and 1.5 times in comparison with the reference samples. The findings are based on observations from the results of durability cutting tool test in the paper considered the structure of Ti-Mo-Al-Ni-Si-N coating deposed by arc-PVD on carbide cutting tool, investigated its mechanical properties, and compared toll life with and without cathodic coatings reported by Josef Daniel et al (2021). Authors investigated (Andressa Baptista et al (2021)) the material of Wear Characterization of Chromium PVD Coatings on Polymeric Substrate for Automotive Optical Components regarding the eventual wear induced in chromium PVD coatings on polymerase substrates stated that the Cr coatings made by PVD on polymeric substrates been subjected to micro abrasion tests, with a view to assessing their wear resistance. Blinkov et al (2021) investigated the Arc-PVD coatings for titanium machining tool presents results of life tests in machining titanium alloy with cutting carbide tool with Ti-Mo-Al-Ni-Si-N, (Ti, Al) N coatings and also determined by the increased physical and mechanical properties of the Ti-Mo-Al-Ni-Si-N coating, its tribological characteristics, and multilayered architecture. Has reported on the wear and corrosion resistance of FeCoCrNiAl high entropy alloys (HEA) alloy treated with laser shock-peening (LSP) and PVD coating. The nano scale FeCoCrNiAl HEA coating on substrate 304 steel and microscale FeCoCrNiAl HEA has been acquired through PVD nanocoating and LSP, respectively. The micro hardness, friction and corrosion properties have been investigated to evaluate the reliability of the material in application reported by Lingyi Liao et al (2021). Author carried out the characterization of the coatings was carried out by using SEM, EDS, AFM, and XRD techniques. Iron (Fe), magnesium (Mg), zinc (Zn), and their alloys are among the studied biodegradable metals, mostly for cardiovascular and orthopedic applications Magnesium and its alloys are low-density metals and have high biocompatibility in the human body by Zarka.M et al (2020). Jie Xiao et al (2020) investigated on Microstructures and Phases of Ytterbium Silicate Coatings Prepared by Plasma Spray-Physical Vapor Deposition. In order to meet the service requirements of next-generation aircraft engines with a high thrust-to-weight ratio, the application of ceramic matrix composites (CMCs) to thermal structural parts of engines. Fox Rabinovich G.S et al (2020) has reported about Thin-Film PVD Coating Metamaterials Exhibiting Similarities to Natural Processes under Extreme Tribological Conditions. Moreover, the hard thin-film TiAlCrSiYN/TiAlCrN nano-multilayer PVD coating, which can efficiently work in an extreme environment, typical for the dry machining of hard-to-cut materials. Sulaiman

M H et al (2019) reported the three PVD hard coatings were characterized in terms of corrosion behavior. The results showed that the DLC/TiAlN coated tool steel has the highest corrosion resistance. Has reported on Smart PVD hard coatings with temperature sensor function. In manufacturing technology, the performance of the tools has to conform to increasingly higher standards. Additionally, recording process data during production is becoming more and more important in the industry 4.0 by Bobzin K et al (2021). PVD coatings are related to their excessive hardness, excessive elastic modulus, excessive fracture strength, true tribological houses, in particular low friction coefficient, true oxidation resistance and thermal resistance, in addition to true fatigue endurance, excessive put-on resistance and additionally true appearance determined by Krella A K et al (2020). Determined about Development of a method of increasing the wear resistance of forging dies in the aspect of tool material, thermo-chemical treatment and PVD coatings applied in a selected hot forging process. It presents the results of an experimental research of a selection of methods to improve the durability of forging tools in an industrial die forging process. Improved durability was obtained by the application of thermo-chemical treatment in the form of nitriding and the use of hybrid layers composed of a nitride layer combined with PVD coatings deposited on the surface by Pawel Widomski et al (2020). Based on the literature studies, it was found that tool wear is a major phenomenon that affects the cutting tool life and the surface roughness of the work piece. Many research studies were carried out to reduce the effect of tool wear on surface roughness and to increase the tool life. The cutting tool life can be improved by coating on the tool surface. Early research studies revealed that coated tool performed better than the uncoated tool. This research work focuses on developing three new cost-effective coatings on cutting tools and studying the effect those newly developed tools by conducting a turning experiment. In this study, an attempt is being made to develop a model for predicting of surface roughness and wear during the machining of cast iron.The study further does a microstructure analysis to compare the improvement in tool wear reduction, tool life and surface roughness.

II. Experimental Procedure

PVD is major process used to produce cutting tool coatings. In PVD, the coating is deposited in vacuum. The specification of PVD equipment details furnished in the table 1. The metal species of the coating obtained evaporation or sputtering, reacts with a gaseous species (nitrogen or ammonia) in the chamber and is deposited onto the surface. The PVD is a low-pressure process, the coating atoms and molecules. Undergo relatively few collisions. PVD is therefore a line-of-sight process that requires moving to fixtures to ensure uniform coating thickness. Some typical compositional ranges for grade 304 stainless steels are given in the table 2. The main difference between PVD and CVD is the formers relatively low processing temperature of PVD which is 500°C. This lower processing temperature resulted in multiple benefits for PVD coatings. PVD coating are essentially free of the thermal cracks that are common in CVD coatings. PVD processing (Fig.1) temperature low enough that eta-phase formation eliminated, alloying deposition of PVD coating on sharp edges. Ability to coat sharp edges is also enhanced by PVD coating relative thickness versus CVD. Coating microstructures depend on processing conditions.

Table: 1 Specification of PVD Equipment

PARAMETERS	DESCRIPTION
Coating chamber material	Stainless Steel (Grade 304)
Coating chamber inner dimension	600mm(w),500mm(D), 760mm(H)
Substrate holder material	Stainless steel dia-400mm
Temperature measurement control	Digital PID controller, K-type thermocouple
Ion-cleaning target supplied	3.5kv-500mA, controlled argon atmosphere

Table: 2 typical compositional ranges for grade 304 stainless steels are given

Grade Wt.%	C	Mn	Si	P	S	Cr	Mo	Ni	N
304	**0.08**	**2.0**	**0.75**	**0.045**	**0.030**	**20.0**	**-**	**10.5**	**0.10**

Fig.1 PVD Coating Process

Experimental Setup of Pin-On-Disc Apparatus

This test method (Fig.2) describes a laboratory procedure for determining the wear of materials during sliding using a pin-on- disk apparatus. Materials are tested in pairs under nominally non-abrasive conditions. The principal areas of experimental attention using this type of apparatus (table 3) to measure wear as described. The coefficient of friction may also be providing a sample determined. The pin-on-disc test has proved useful in providing a simple wear and friction test for low friction coatings such as diamond-like carbon coatings on valve train components in internal combustion engines.

The amount of wear in any machine will, in general, depend upon the number of system factors such as the applied load, system characteristics, sliding speed, sliding distance, the environment, and the fabric properties. The value of any wear test method put on check technique lies in predicting the relative rating of material combinations. Since the pin-on-disc check technique does not longer try to duplicate all of the situations that can be skilled in service (for example: lubrication, load, pressure, contact geometry, elimination of wear and tear debris, and presence of corrosive environment}, there is no endurance that the test will predict the wear rate of the a given material under conditions differing those in the test.

For the pin-on-disc wear test, two specimens are required. One, a pin with a radioed tip, is positioned perpendicular to the other, usually a flat circular disk. A ball, rigidly held, is often used as the pin specimen. The test machine causes either the disk specimen or the pin specimen to revolve about the disk center. In either case, the sliding path is a circle on the disk surface. The plane of the disk may be oriented.

Fig.2 Experimental setup of Pin-On-Disc (Principle)

Table: 3 Specification of pin-on-disc apparatus

Normal Load	01 to 50 N
Friction Force Range	0 to 50 N
Contact Configurations	Pin on Disc, Ball on Disc
Disc Diameter	55 mm
Track Radius	0 to 42 mm
Rotational speed	1 to 1450 rpm
Sliding Velocity	0.007 to 0.7 m/s
Temperature	Ambient to 500°C
Air Heating Power	2.8 kW
Motor	190W dc

Surface Roughness

Surface roughness is a measure of the texture of surface. It is quantified by the vertical deviation of real surface from ideal form. If these deviations are great, the surface is rough, if they are small, the surface is smooth. Roughness is typically considered to be in the high-frequency, short- wavelength component of a measured surface. Surface roughnesses were evaluated before and after wear test in terms of arithmetic average value (Ra) which was by Taylor Hobson Non-contact roughness test (Talysurf CCI 6000) setup mentioned in the Fig.3. In practice, it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for purpose.

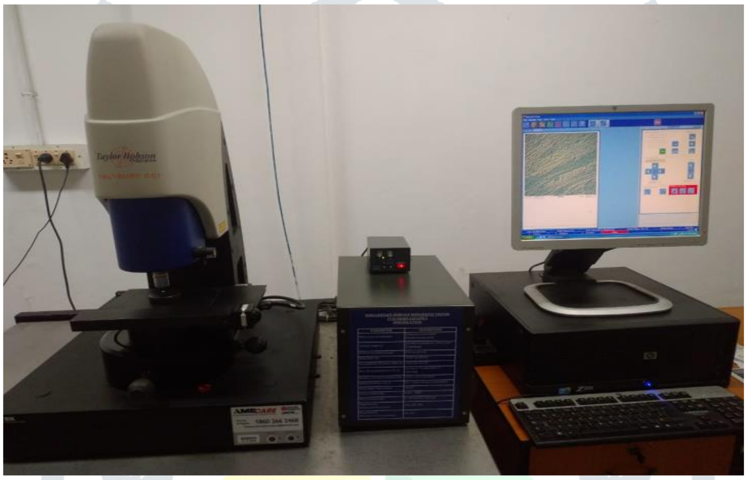


Fig. 3 Non-Contact Surface Roughness Tester

III Results and Discussion

In this chapter is related about influences of COF, weight loss, Surface Roughness of the respective uncoated and coated material are carried out. In this project we are using substrate as a SS 304 and the coated material is Tin metal powder. In that comparison of all coated and uncoated material are carried out.

Coefficient of friction

In this work has been reported the coefficient of friction is might be a low co-efficient friction for Tin metal powder based coated material compare to the uncoated material. The co-efficient of friction value is measured during machining of coated and uncoated material by using Pin-On-Disc apparatus. In theoretical co-efficient of friction is measured by the value of frictional force and load. But in this research, we are using Pin-On-Disc apparatus for measuring co efficient of friction. So, the co-efficient of friction graph is taken by using Tribology Data Acquisition System. The co-efficient of friction of coated and uncoated materials are represented in the below shown.

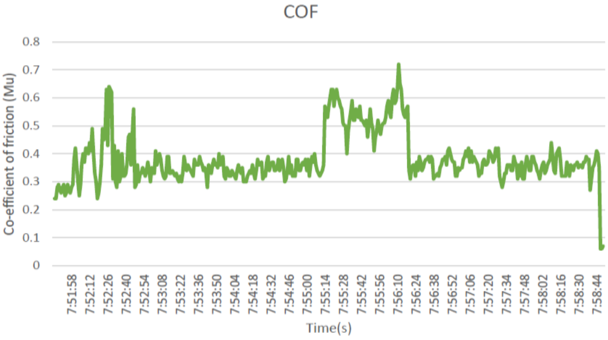


Fig.4 (a) Uncoated COF (1Kg)

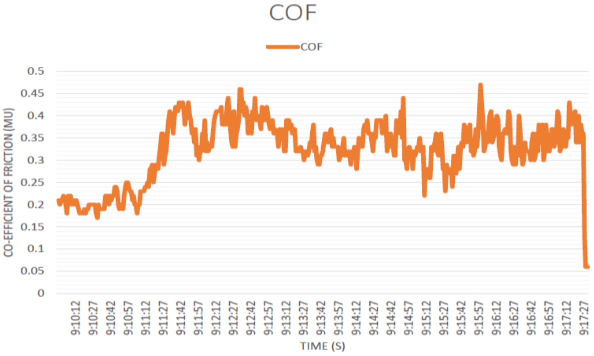


Fig.4 (b) Tin Coated COF (1Kg)

In the above shown in fig. (4(a)) Graphical representation of uncoated material, the co- efficient of friction is increases with increase in time up to 8 min at a constant load of 1kg and the sliding speed of disc at 2.1m/s from the illustration, uncoated material is produced high coefficient of friction due to applied load with dry sliding condition. The surface of the uncoated material is more plastic deformation in which applied load at ambient condition. Metal to metal contact is more surface area at during the sliding condition. In the above shown in fig. (4(b)) Graphical representation of Tin metal powder coated material, the co-efficient of friction varying with time at a constant load of 1kg and the sliding speed of disc at 2.1m/s From the illustration, the co-efficient of friction of the Tin powder is slightly low compared with uncoated material due to applied load with dry sliding condition. The surface of Tin material is less plastic deformation in which applied load at ambient condition compared with uncoated material and also the metal-to-metal contact is less surface area at during the sliding condition.

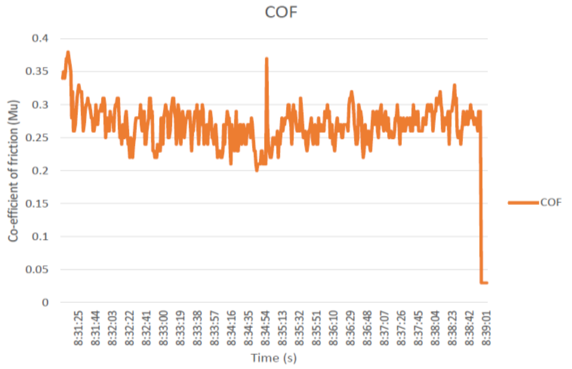


Fig.5 (a) Uncoated COF (2Kg)

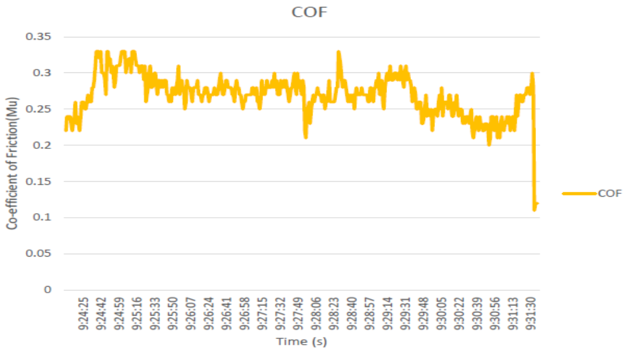


Fig.5 (b) Tin Coated COF (2Kg)

In the above shown in fig. (5(a)) Graphical representation of uncoated material, the co- efficient of friction is increases with increase in time up to 8 min at a constant load of 2kg and the sliding speed of disc at 2.1m/s from the illustration, uncoated material is produced high coefficient of friction due to applied load with dry sliding condition. The surface of the uncoated material is more plastic deformation in which applied load at ambient condition. Metal to metal contact is more surface area at during the sliding condition. In the above shown in fig. (5(b)) Graphical representation of Tin metal powder coated material, the co-efficient of friction varying with time at a constant load of 2 kg and the sliding speed of disc at 2.1m/s. From the illustration, the co-efficient of friction of the Tin powder is slightly low compared with uncoated material due to applied load with dry sliding condition. The surface of Tin material is less plastic deformation in which applied load at ambient condition compared with uncoated material and also the metal-to-metal contact is less surface area at during the sliding condition.

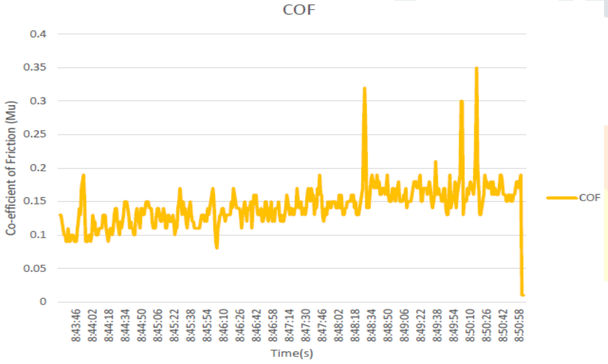


Fig.6 (a) Uncoated COF (3Kg)

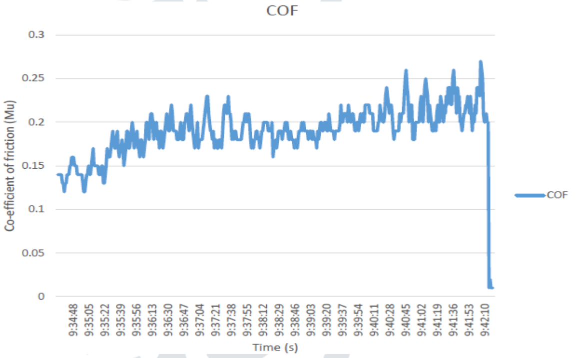


Fig. 6.(b) Tin Coated COF (3Kg)

In the above shown in fig. (6(a)) Graphical representation of uncoated material, the co- efficient of friction is increases with increase in time up to 8 min at a constant load of 3kg and the sliding speed of disc at 2.1m/s from the illustration, uncoated material is produced high coefficient of friction due to applied load with dry sliding condition. The surface of the uncoated material is more plastic deformation in which applied load at ambient condition.

Metal to metal contact is more surface area at during the sliding condition. In the above shown in fig. (6(b)) Graphical representation of Tin metal powder coated material, the co-efficient of friction varying with time at a constant load of 3 kg and the sliding speed of disc at 2.1m/s. From the illustration, the co-efficient of friction of the Tin powder is slightly high compared with uncoated material due to applied load with dry sliding condition. The surface of Tin material is less plastic deformation in which applied load at ambient condition compared with uncoated material and also the metal-to-metal contact is less surface area at during the sliding condition.

Weight loss result

Weight loss of material is calculated by using the value of weight of the material before the wear test and weight of the material after wear test. Wear performance of the coated and uncoated materials is analysis by using loss values of each material expressed from table 4.

Weight Loss = Weight of the material (before wear test) – Weight of the material (after wear test)

Table:4 Comparison of weight loss test before and after wear performance

Materials	Load (Kg)	Weight of material before wear test (g)	Weight of material after wear test (g)	Weight loss (g)
Uncoated	1	183.4572	183.3919	0.0653
	2	183.3362	183.1062	0.23
	3	183.4578	183.3367	0.1211
Coated	1	195.6901	195.6858	0.0043
	2	195.5801	195.5031	0.077
	3	195.6725	195.6003	0.0722

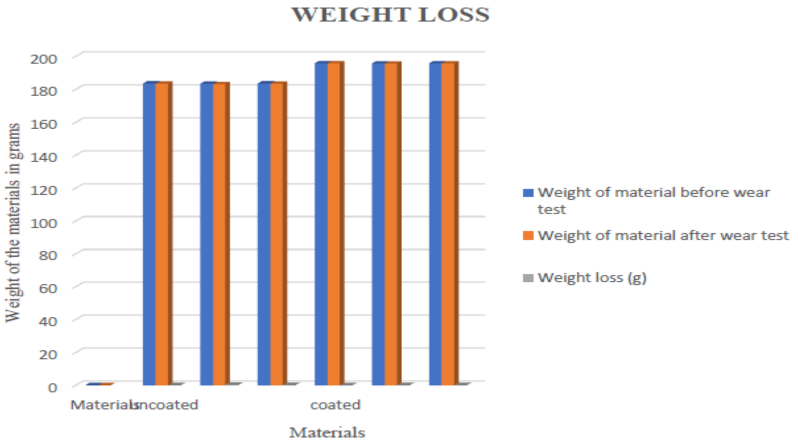


Fig.7 Comparison chart of weight loss both Uncoated and Coated

From the above graph fig.7, we obtained the result that the weight loss of coated material is very low compared to the uncoated material. By comparing uncoated and Tin coated. The weight loss Tin is very low.

Surface roughness

Surface Roughness of the uncoated and coated was found out by using Taylor Hobson surface roughness tester. Normally roughness value was increased on the coated and uncoated specimen due to metallurgical contact on both surfaces and the dry sliding condition will occur, produced high roughness values on a material. Traditional surface finish analysis consists mainly studying the surface texture, consisting of roughness and hardness as shown in fig. 8

The main goal of this analysis is to introduce different substituting load surface to represent the original asperities and to compare their performance in contact behavior. The worm surfaces in order to find out about the characteristics from which conclusion can be drawn to the wear process to find and explanation for the wear phenomena generating the surface from the profile shown in fig. 8.

Fig.9 shows the profile traces of uncoated and coated material of different initial surface roughness. Only the distance between the predominant peaks rather than the average roughness has a significant effect on the percentage of the metallic contact. As the roughness increases, the distance between predominant peaks increases. Roughness values of uncoated and coated material (before and after wear test) shown in table: 5

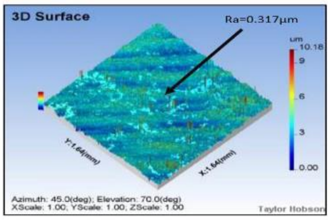
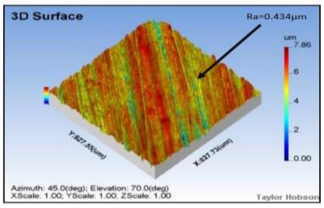
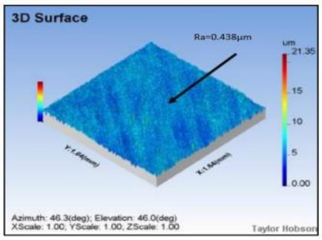
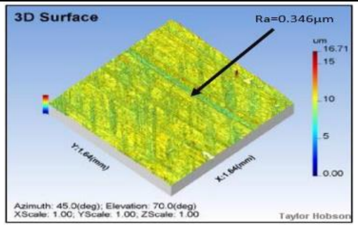
Description	Load (Kg)	Before Wear Test	After Wear Test
Uncoated	1		
Tin Powder Coated	1		

Fig.8 Surface roughness of coated and uncoated materials (3D surface) [Before and after wear test] at different loading condition

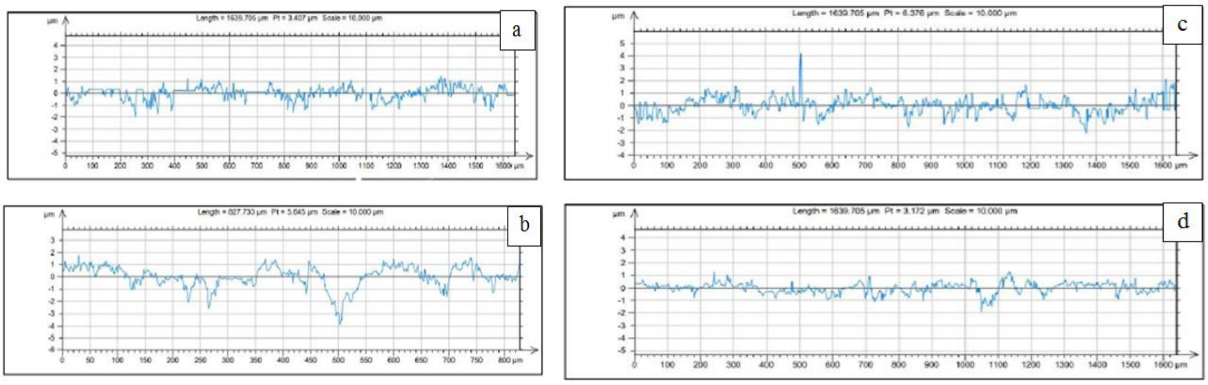


Fig. 9 Surface roughness value pattern of wear test (a) Un coated 1 Kg before test (b) Coated 1 Kg after test (c) Un-Coated 2 Kg before test (d) Coated 2 Kg after test

Table: 5 Roughness values of uncoated and coated materials (Before and after wear test)

Materials	Roughness before wear test (µm)	Roughness after wear test (µm)
Uncoated 1 kg	0.317	0.434
Uncoated 2 kg	0.320	0.557
Tin Metal Powder	0.438	0.346

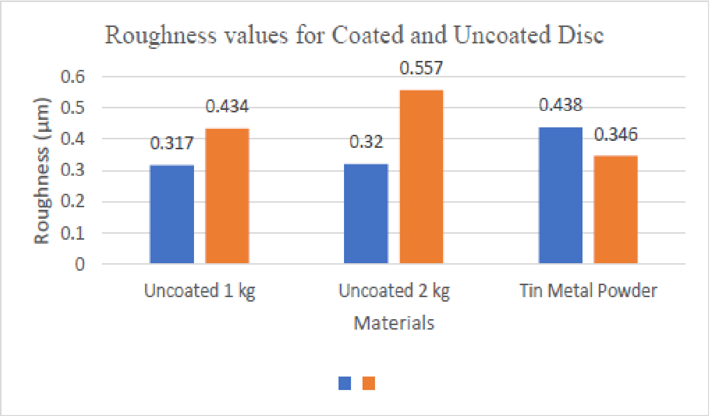


Fig.10 Comparison of Roughness values for coated and uncoated materials

Fig. 10 shows the comparison of roughness values investigated both coated and uncoated materials at ambient conditions. After the result came to the conclusion the Tim powder given better surface roughness due to the better homogeneity micro layer present in the surface. The graph may show the evidence of value exposed after testing the wear performance of coated materials. The further investigated the coated surface revealed (fig.11) mark as groove layer in the surface of both coated and uncoated at different loading conditions.

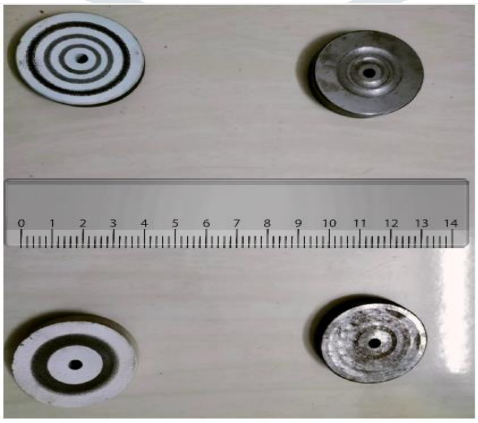


Fig.11 (a) shows the coated disc & Tin Metal powder, (b) coated Cast iron Discs.

IV Conclusion

A study was under taken to establish the wear behavior of PVD coating of Tin metal powder on cast iron substrate. Compositions of Tin metal powder were used and the results were compared.

1. When compared to the cast iron coated material, there is an increase in roughness.
2. When compared to the uncoated material, there is in decrease in roughness of coated materials.

3. Adhesive wear was measured by Pin-on-Disc apparatus. The results suggest that the coefficient of friction decrease at constant speed, load and time. (For both coated and uncoated materials)
4. The wear rate increases at constant speed and load in uncoated materials but in Tin Metal powder coated materials decreases wear.
5. It is finally concluded that Tin metal powder coated on the cast iron substrate reduces coefficient of friction and wear rate of moving parts.

References

1.Josef Daniel et al (2021) Comparison of Lifetime of the PVD Coatings in Laboratory Dynamic Impact Test and Industrial Fine Blanking Process. Materials 2020, 13, 2154;

2.Andressa Baptista et al (2021) Wear Characterization of Chromium PVD Coatings on Polymeric Substrate for Automotive Optical Components. Coatings 2021, 11, 555.

3.Lingyi Liao et al (2022) A study on the wear and corrosion resistance of high-entropy alloy treated with laser shock peening and PVD coating. Surface & Coatings Technology 437 (2022) 128281

4.M Zarka et al (2020) A systematic study of β-type Ti-based PVD coatings on magnesium for biomedical application. vacuum.2020.109850

5.Jie Xiao et al (2020) Microstructures and Phases of Ytterbium Silicate Coatings Prepared by Plasma Spray-Physical Vapor Deposition. Materials 2020, 13, 1721;

6.G. S. Fox-Rabinovich et al (2020) Thin-Film PVD Coating Metamaterials Exhibiting Similarities to Natural Processes under Extreme Tribological Conditions. Nanomaterials 2020, 10, 1720;

7.M H Sulaiman et al (2019) Corrosion resistance of PVD hard coatings for tribological engineering applications. Materials Science and Engineering 670 (2019) 012054

8. I V Blinkov et al (2021) Arc-PVD coatings for titanium machining tool. journal of Physics: Conference Series 2144 (2021) 012025

9. K.M. Doleker et al (2020) Oxidation and hot corrosion resistance of HVOF/EB-PVD thermal barrier coating system. Surface & Coatings Technology 409 (2021) 126862

10. H. Hoche, et al (2019) Corrosion and wear protection of mild steel substrates by innovative PVD coatings. Surface & Coatings Technology 391 (2020) 125659

11. A.K. Krella et al (2021) Cavitation erosion of monolayer PVD coatings – An influence of deposition technique on the degradation process. Wear 478–479 (2021) 203762

12. Beata Kucharska et al (2021) Influence of Different Types of Cemented Carbide Blades and Coating Thickness on Structure and Properties of TiN/AlTiN and TiAlN/a-C: N Coatings Deposited by PVD Techniques for Machining of Wood-Based Materials. Materials 2021, 14, 2740.

13. M. Ahmadi, B. Salgın, B.J. Kooi et al (2021). Outstanding cracking resistance in Mg-alloyed zinc coatings achieved via crystallographic texture control Scripta Materialia 210 (2022) 114453

14. Evandro Paese et al (2020) Assessment of CVD- and PVD-Coated Carbides and PVD-Coated Cermet Inserts in the Optimization of Surface Roughness in Turning of AISI 1045 Steel. Materials 2020, 13, 5231

15. F. Liu et al (2021) Adhesion and machining performance of PVD AlCrN coatings with an ion beam/laser textured substrate. Surface & Coatings Technology 423 (2021) 127607

16. K. Bobzin et al (2021) Smart PVD hard coatings with temperature sensor function. Surface & Coatings Technology 423 (2021) 127631

17. S. Kagerer, O.E. Hudak, M. Schloffer et al (2021) TGO formation and oxygen diffusion in Al-rich gamma-TiAl PVD-coatings on TNM alloys. Scripta Materialia 210 (2022) 114455

18. M. Zarka et al (2021) The Ti3.6Nb1.0Ta0.2Zr0.2 coating on anodized aluminum by PVD: A potential candidate for short-time biomedical applications. Vacuum 192 (2021) 110450