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ENHANCING WEAR RESISTANCE OF GREY CAST IRON BY CALCIUM FLUORIDE COATING

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ABSTRACT

Grey cast iron has wide range of engineering application due to its high tensile strength and hardness. But it will be subjected to wear and the material is easily affected by corrosion. By making surface coating over cast iron with Calcium Fluoride (CaF2), the wear rate of the grey cast iron is highly reduced and the corrosion resistance is enhanced. This surface coated material has wide range of applications as Calcium Fluoride does not react with any chemicals and the Calcium Fluoride powder has very high melting and boiling points. In our project grey cast iron is surface coated with Calcium Fluoride by Physical Vapour Deposition (PVD) method using Electron beam gun. The experimental sample is then analyzed using Brinell hardness test and PIN on DISC apparatus to study the reduction in wear of the grey cast iron material. The wear tests were performed in a pin on disc apparatus as per ASTM G-99 standard. The wear resistance of coated and uncoated Grey Cast Iron was evaluated through pin on disc test using a sliding velocity of 0.35 m/s under normal load of 20 N, 30 N, 40 N at the controlled condition of temperature and humidity. The surface hardness, coefficient of friction, wear loss were observed on samples. Based on the results of the wear test, Calcium Fluoride coated samples exhibited the lowest average coefficient of friction and the lowest wear loss.

NOMENCLATURE

Ra = Surface Roughness
HB = Brinell Hardness C-Scale
μ = Coefficient of friction

INTRODUCTION

Wear is related to interactions between surfaces and specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface. In materials science, wear is erosion or sideways displacement of material from its derivative and original position on a solid surface performed by the action of another surface. Wear of metals occurs by the plastic displacement of surface and by the detachment of particles that form wear debris. The size of the generated particles may vary from millimeter range down to an ion range. This process may occur by contact with other metals and nonmetallic solids. The study of the processes of wear is part of the discipline of tribology. The complex nature of wear has delayed its investigations and resulted in isolated studies towards specific wear mechanisms or processes. Some commonly referred to wear mechanisms include Adhesive wear, Abrasive wear, Surface fatigue, Fretting wear, Erosive wear,

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Corrosion and oxidation wear A number of different wear processes are also commonly encountered and presented in the literature, Impact, cavitation, diffusive and corrosive wear. These wear mechanisms, however, do not necessarily act independently and wear mechanisms are not mutually exclusive. Industrial Wear are commonly described as incidence of multiple wear mechanisms occurring in unison. Another way to describe Industrial Wear is to define clear distinctions in how different friction mechanisms operate, for example distinguish between mechanisms with high or low energy density. Wear mechanisms and sub mechanisms frequently overlap and occur in a synergistic manner, producing a greater rate of wear than the sum of the individual wear mechanisms.

EXPERIMENTAL PROCEDURE

Grey Cast Iron contains 1.5-4.3% carbon and 0.3-5% silicon plus manganese, sulphur and phosphorus. It is brittle with low tensile strength, but is easy to cast. Its Tensile strength is 260 N/mm2.

Grey cast iron grade 260 is sand casted for required length and diameter. This grey cast iron is casted with some extra dimensions to meet the tolerances. The cast iron which is casted has bristle like structures over the surface of the material because of the sand casting. This casting takes one day of time for cooling. The grey cast iron is very hard and brittle material which is mostly used in engineering applications. Then the grey cast iron grade 260 produced is to be machined to obtain good surface finish.

The cast iron produced is machined to 6 disc like structures for the coating process of 55 mm diameter and 10 mm thickness with a hole of 10 mm diameter on the centre. This machining process needs more accuracy in order to have the surface coating perfectly. CaF_2 is a white insoluble solid. It occurs as the mineral fluorite (also called fluorspar), that is common deeply coloured owing to impurities.

Pellet Making Process

In Pellet making process of calcium fluoride (CaF_2), the calcium fluoride powder is taken in very small quantity and made into very small diameter and height of required dimensions. In box type vacuum coating unit, the Pellet used for surface coating should be in a size of 20mm diameter and 15mm thickness. These Pellets which are in cylindrical shape can be easily burnt inside the crucible of electron beam gun coating. The solid Pellet is converted into vapor when electron beam is incident to it which makes the calcium fluoride to burn easily and then it is condensed on the surface of the material which is to be coated. For Pellet making, Hydraulic press is used which has the pressing capacity of 10 ton load. And after pressing the calcium fluoride powder in this hydraulic press, the Pellets formed is take out after few minutes and then it can be used for Physical Vapor Deposition method in the electron beam gun surface coating.

2.2. Physical Vapour Deposition

Physical vapour deposition (PVD) describes a many vacuum deposition methods which can be used to produce thin films and coatings. PVD is specified by a process in which the material goes from a condensed phase to a vapour phase and then back to a thin film phase. The most common PVD processes are like sputtering and evaporation. PVD is used for mechanical, optical, chemical or

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electronic functions. Common industrial coatings applied by PVD are titanium nitride, zirconium nitride, chromium nitride, titanium aluminum nitride. The source material is unavoidably also deposited on most other surfaces interior to the vacuum chamber, including the fixtures used to hold the parts.

2.3. Electron Beam Surface Coating

The grey cast iron grade 260 which is to be surface coated is taken and fixed on to the rotating disc of Box type Vacuum coating unit. In this Box type Vacuum coating unit up to 4 discs can be surface coated in a single time. In our project we are using two cast iron material pieces for coating. After fixing this cast iron material on to the coating unit, Calcium fluoride (CaF2) powder which is used as the coating material is taken in pellet form and placed into the crucible of this Vacuum coating unit. After that coating unit is locked and then the pressure is increased which takes 30 minutes of time. The Electron Beam from the gun is directed on to the Calcium fluoride pellet in the crucible. And by this electron beam, heat is produced and so the Calcium fluoride pellet is melted and converted into vapor. In the meantime, the disc in which the cast iron material fixed is made to rotate. And when the Calcium Fluoride vapor touches the Cast iron material, the calcium fluoride vapor condenses uniformly on the surface of the cast iron due to the continuous rotation of the disc.

The surface coating is done up to 2 microns of calcium fluoride and the coated cast iron is cooled inside the Vacuum coating unit. And then the Calcium fluoride coated Cast iron is removed from the Vacuum coating unit. This surface coating process takes around 6 hours to complete the coating. A Brinell hardness result measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load, for a given length of time. Typically, an indentation is made with a Brinell hardness testing machine and then measured for indentation diameter in a second step with a specially designed Brinell microscope or optical system.

The resulting measurement is converted to a Brinell value using the Brinell formula or a conversion chart based on the formula. generally, a Brinell test will use 3000 kgf load with a 10mm ball. If the material aluminum, frequently performed with a 500 kgf load and 10mm ball. Brinell test loads vary from 3000 kgf down to 1 kgf. Ball indenter diameters vary from 10mm to 1mm. Generally, the lower loads and ball diameters are used for convenience in combination testers, like Rockwell units, that have a small load capacity. The specimen test standard identifies a time of 10 to 15 seconds, although shorter times can be used if it is known that the shorter time does not affect the result. There are other conditions that must be met for testing on a specimen, spacing of indentations, minimum thickness of test specimens, etc.

RESULT AND DISCUSSION

By comparing Brinell Hardness Number of Uncoated and coated sample gives a difference of 14.19 BHN. Thus the hardness of the material is increased upto 15 BHN by Calcium Fluoride surface coating. The results are listed below in table 1.

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Description	Load, N	BHN
Uncoated Samples	15	144.42
	25	146.2
	30	148.63
Coated Samples	15	158
	25	161.11
	30	162.66

Table1:Brinell Hardness Value for Calcium Fluoride Coated and Uncoated samples

A pin on disc tribometer consists of a stationary pin and rotating disc. A stationary pin under an applied load in contact with a rotating disc. The pin is in round shape to simulate a specific contact. Coefficient of friction is calculated from the ratio of the frictional force to the loading force on the pin. The pin on disc test has proved useful in providing a simple wear and friction test for low friction coatings like diamond-like carbon coatings on valve train components in internal combustion engines. By holding this Pin in the Pin on Disc apparatus, the grey cast iron material is set to rotation at 640 rpm for 5 minutes using various loads. Both the coated and uncoated grey cast iron material is set to rotate to compare the results and to make the wear analysis effectively. The results can be obtained in the computer which is connected to the Pin on Disc apparatus.

Figure1:Pin on Disc apparatus

Description	Load, N	Coefficient of friction
Uncoated Samples	20	0.503
	30	0.425
	40	0.373
Coated Samples	20	0.425
	30	0.318
	40	0.360

Table2: Pin on Disc Results

From the above table it is clearly identified that the Calcium Fluoride coated sample enhances wear resistance highly when compared to the uncoated samples. And thus it has many future engineering applications as the cost of Calcium Fluoride is less.

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CONCLUSION

The friction coefficient decreases as the load increases. A certain increase in friction coefficient for coated pin at higher loads can be attributed to partial loading and local scuffing. Wear volume also increases as load increases, because of high localized pressure and rise in temperature. This calcium fluoride coated cast iron enhances wear resistance significantly. These coated materials have high melting and boiling points which makes this material to be used in a place where more heat is produced. Calcium fluoride does not react with any chemical reagents and so it can be used in many places in future.

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