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Effects of Deep Cryogenic Treatment on Wear Resistance & Life of Nickel Coated Flywheel

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ABSTRACT

The influence of deep cryogenic treatment on wear resistance and life of nickel coated flywheel was studied. Nickel was deposited on to the flywheel workpiece by plating method. The nickel coated pieces were tested at various loads and speeds on a pin-on-disc apparatus, different loading conditions were used in order to compare the wear rate. The pin-on-disc gave ample results on the wear rate of the coating. Then the coated pieces were cryogenically treated at -196°C at various time interval of 8,16 & 24 hours with constant supply of liquid nitrogen. Later the cryogenic treated specimen was tested for wear rates to compare the wear rate results to ultimately find the wear before and after cryogenic treatment. The microstructures of cryogenic and conventionally treated samples were analyzed. Additionally, transformation of retained austenite to martensite played an effective role, i.e. improved hardness values.

Keywords: Flywheel, Nickel coating, Deep cryogenic treatment, Wear resistance

1. INTRODUCTION

1.1. Deep cryogenic treatment

Freezing of metals has been acknowledged for many decades as an effective method for increasing wear life and decreasing residual stress in tool steels. Low-temperature treatment is generally classified as either "Cold Treatment" at temperature down to approximately −80°C (dry ice temperature), or "Deep Cryogenic Treatment" at −196°C (liquid nitrogen temperature) [1]. It should be noticed that cooling and heating rates must be kept constant at about 0.5°C/min to avoid [illegible]ally done at very slow rates, it itself, relieves the brittleness and stress accumulation, however, low-temperature tempering at 150–200°Cafter cryogenic treatment is done to relieve any remained brittleness. [2] According to the previous literatures two metallurgical phenomena are reported as the main reasons for using cryogenic treatment. Firstly, the elimination on retained austenite and secondly the initiating of nucleation sites for subsequent precipitation of large number of very fine carbide particles. In many cases hardness increasing about 1–3 Rockwell points have been claimed; however, some authors reported little increasing in hardness values. There is a little evidence concerning toughness changes. One of the most prevalent claims is the improvement of wear resistance. Effect of deep cryogenic treatment on the matrix structure and abrasion resistance of cast iron subjected to destabilization heat treatment has been investigated. [3] They showed that during cryogenic treatment, the secondary carbides precipitate in the austenite matrix, promote the transformation of the retained austenite to martensite and consequently enhance hardness and wear resistance of the alloy. Following the results of neutron diffraction that the transformation of retained austenite to martensite occurred which, along with possible carbide formation during tempering, is a key factor in improving hardness and fatigue resistance of the cryogenically treated specimens.

1.2. Electro plating of NICKEL

The theory presented has been able to account for the phenomena due to composition and concentration of the electrolyte, to current density, temperature, solvent, colloids, other metals and cathodes. It has not accounted for the effect of acids and alkalis, nor for the effect of oxidizing and reducing agents, but this seems to be due to our ignorance of the chemistry of these solutions rather than to a defect in the theory. No one seems to have been struck by the absurdity of the statement, to be found in most books on plating, that nickel cannot be plated on nickel because it will not adhere.' If this were true it would not be possible to deposit more than an infinitesimally thin film of nickel electrolytically. While it requires a higher voltage to deposit nickel than copper, nickel does not precipitate. copper to any appreciable extent when immersed in a copper sulphate solution. The nickel becomes passive and is probably covered with a thin film of oxide. What people mean is that an "active" nickel containing hydrogen will not adhere to a "passive" nickel. There is nothing surprising or mysterious about this. By making a strip of nickel the cathode in an acid solution for a few minutes before putting it in the nickel bath, Mr. Snowdon has been able to plate nickel on nickel getting a beautifully adherent deposit. The objective of this paper is to study the effects of deep cryogenic treatment on wear resistance and life improvement of nickel coated flywheel. Fig. 1 shows the coated samples.

Fig. 1- Nickel coated samples

2. EXPERIMENTAL METHOD

Chemical composition and relevant properties of the used flywheel (FG150) is presented in Table: 1

Table1: Chemical composition of flywheel

Fe	93.31
C	3.656
Si	1.792
Mn	0.732
P	0.057
S	0.050
Cr	0.107
Mo	0.052

Ni	0.015
Al	0.011
Cu	0.047
Sn	0.010
Ti	0.039
V	0.007
Mg	0.005
W	0.15
Pb	0.050
Nb	0.020
Zn	0.023

2.1. Physical vapour deposition

Physical vapour deposition (PVD) describes a variety of vacuum deposition methods which can be used to produce thin films and coatings. The most common PVD processes are sputtering and evaporation. PVD is used in the manufacture of items which require thin films for mechanical, optical, chemical or electronic functions. Fig. 2 shows process flow diagram of physical vapour deposition.

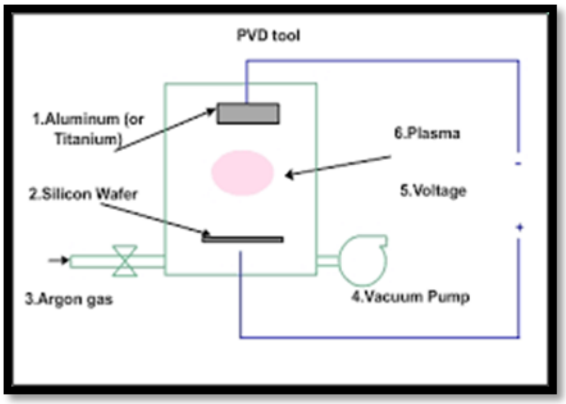

Fig: 2- Schematic diagram of a PVD process

2.2. Deep cryogenic test

Cryogenic treatment was performed by placing the workpieces in an isolated alumina chamber immerged gradually in a liquid nitrogen reservoir by means of an electric motor. The isolated chamber was designed according to heat transfer equations to estimate the thermal gradient of the chamber. Fig. 3 shows cryogenic treatment instrument schematically. Deep cryogenic treatment consisted of slowly cooling the workpieces to approximately −196°C and holding at this low-temperature for 24h and gradually bringing the specimens back to room temperature. In order to avoid thermal shocks from rapid cooling and heating, the specimens were cooled down and heated up slowly, to and from the cryogenic temperature (−196°C), over an 8h period with the temperature being monitored by a thermocouple attached to the specimen. This gives an average heating/cooling rate of 0.5°C/min. Two types of flywheel pieces were tested, reference flywheel pieces with no extra treatment, cryogenic-treated flywheel pieces (CT) and cryogenic with a 1h temper at 200°C treated flywheel pieces (CTT). Fig: 3 shows the heat treatment cycle of each flywheel category. The microstructure of coated flywheel(CT) was studied by a Philips XL 40 scanning electron microscope (SEM).

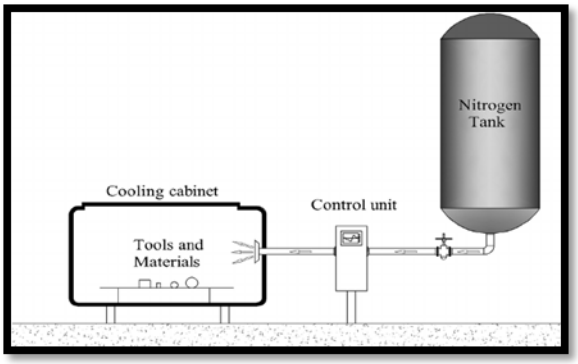

Fig: 3 – Schematic configuration of cryogenic treatment system.

2.3. Hardness test

Hardness test was performed on a Brinell hardness instrument, shown in fig. 4. The Brinell hardness was measured on faces of coated flywheel (CT) using a Wilson4JR hardness tester. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings. Brinell testing often use a very high test load (3000 kgf) and a 10mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies. The coated flywheel (CT) is placed on a hard surface of the instrument and a predetermined test load (F) is applied on the workpiece of fixed diameter (D) which is held for a predetermined time period and then removed.

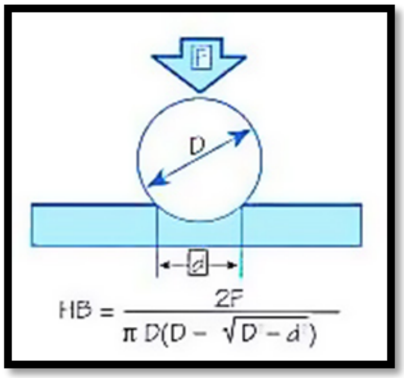

Fig: 4- Schematic representation of hardness test instrument

Test Method Illustration
D = Ball diameter
d = impression diameter
F = load
HB = Brinell result

Hardness Report
Sample ID: Casting cut sample
Hardness value: 229BHN
Indenter: 2.5mm ball
Lod applied: 187.5kgfs

2.4. Pin-on-Disc test

The experimentation is carried out on pin on disc wear testing machine this is a study versatile machine, shown in fig. 5 which facilitates study of friction and wear characteristics in sliding contacts under desired conditions. The coated workpiece is placed as the sitting mass right above the hard surface where the piece is pulled by the hanging mass and pulled on the other direction by the frictional force and the surface keeps spinning at the given rpms. Normal load, rotational speed and wear track diameter can be varying to suit the test conditions. Frictional force and wear are monitored through electronic sensors.

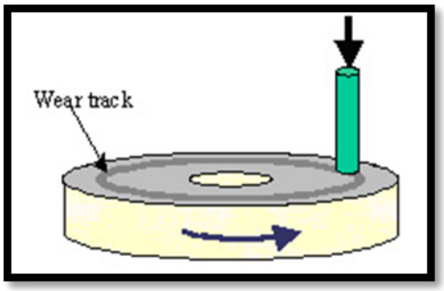

Fig: 5- Schematic representation pin-on-disc test rig

2.5. Microstructure study

The microstructures of cryogenic and conventionally treated samples were analysed by Optical Microscopy (OM). Samples were polished using Sic emery papers grades as follows 600, 800 and 1000 and then super finished using diamond paste on the velvet cloth disc with kerosene as the suspension medium. Etching of these samples was carried out. Micro structures of samples were revealed at a magnification of 500X. Then the micrographs of conventional and cryogenic treated samples were analysed.

3. Results and discussion

The changes due to the cryogenic treatment can be easily differentiated from the comparison results in the below content.

3.1. Microstructural analysis

The microstructural analysis can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behaviour or wear resistance. Micrograph and analysed micrograph of conventionally heat treated sample are shown in the following fig: 6 and 7. Micrograph and analysed micrograph of deep cryogenic treated sample are shown in the following. This microstructure shows larger amount of austenite at tempered condition with finely dispersed precipitated carbide particles. From the

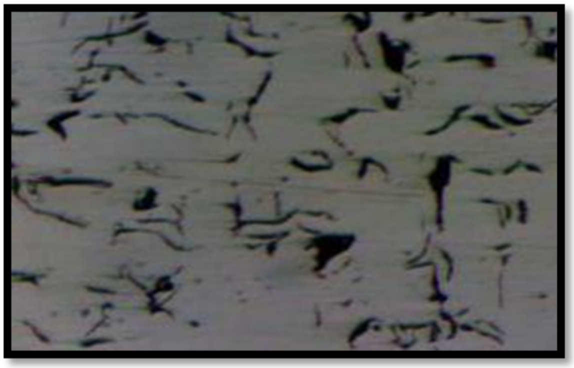

Fig: 6- Micrograph of original sample

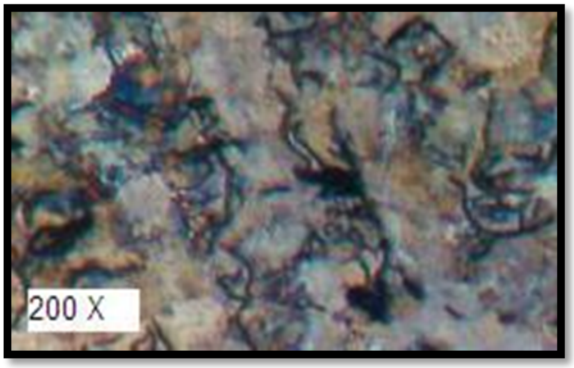

Fig: 7- Micrograph of cryogenic treated sample

3.2. Hardness test results

Table 2: Parameter

S. No.	Material	Sliding Velocity (M/S)	Wear In (MICRON)	COF (AVERAGE)	Frictional Force(N)
1.	FG (NC)	0.8378	0.0076	0.2089	3.524

The hardness values for the conventional, shallow and deep cryogenic treated samples are presented in Table 3. From the results it is clear that the cryogenic treatment improves the hardness.

Table 3: Hardness test result comparison

S.No.	Materials	Hardness values
1.	Fly wheel (CI)	156BHN
2.	Fly wheel (CI) coated with nickel	200BHN

3.3. Wear test result

From the pin on disc test performed to investigate the wear resistance properties of the material it can be confirmed that there are expected improvement in the wear properties in the cryogenic treated flywheel. Table 4 shows the wear results in different conditions.

Table: 4 Represents for different loading conditions

S. No.	Material	Sliding Velocity (M/S)	Wear In (MICRON)	COF (AVERAGE)	Frictional Force(N)
1.	FG (NC)	0.8378	0.0076	0.2089	3.524

2.	FG(C)	1.6755	0.0041	0.0487	3.305
3.	FG(CT)	0.8378	0.0036	0.4214	3.213
4.	FG(CCT)	1.6755	0.0006	0.6831	3.145

4. CONCLUSION

The micro structure result shows that change of austenite structure improve in wear resistance. And the hardness values of Cryogenic treated with Nickel Coated fly wheel material have a significant change in value. The wear rate of the fly wheel is average in 20N load at 200 rpm is 10 micron with average friction force of 3.145N. Hence the coated flywheel shows significantly better wear resistance and life when compared to conventional flywheel.

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