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Effect Of Cryogenic Treatment On Wear Resistance Of Astm A387 Alloy Steel

M. Karthikeyan
Assistant professor
DEPARTMENT OF MECHANICAL ENGINEERING
VEL TECH MULTI TECH Dr.RR Dr.SR ENGINEERING COLLEGE, CHENNAI.

Abstract

Cryogenic treatment is a supplementary process to conventional heat treatment process. It is an inexpensive one time permanent treatment affecting the entire section of the alloy steel unlike coatings. The pin on disk wear test apparatus was used to find out the wear resistance of the engineering component materials of low alloy steel. And correlate the wear resistance of engineering component materials before and after cryogenic treatment. A study on the improvement in wear resistance and the significance of treatment parameters in different materials has been made. It is found that cryogenic treatment imparts nearly 70% improvement in wear resistance.

Keywords: *Cryogenic treatment; Wear resistance; Alloy steel*

1. Cryogenic treatment

Cryogenic treatment of metal parts consists of cooling-down these parts at a predetermined rate, up to a given cryogenic temperature, maintaining the parts at that lowest temperature for a given duration of time and then allowing these parts to warm-up at a given warming-up rate.Therefore, the main variables of the cryogenic treatment are:

1. The rate of cooling (degrees Kelvin per minute)
2. The lowest temperature that the specimens attain and at which these are maintained or soaked for a given duration (degree Kelvin).
3. The duration for which the specimens are maintained at the lowest temperature i.e. soaking time (number of hours).
4. The rate of warming-up (degrees Kelvin per minute)

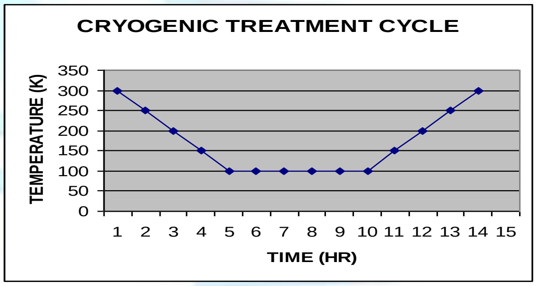

Figure 1 .Cryogenic treatment cycle.

It should be noted that freshly formed martensite is also brittle and only tempered martensite is acceptable. To further aggravate this problem the transformation of austenite to martensite yields a 4% volume expansion causing distortion which cannot be ignored. This cryogenic treatment being add-on process to convectional heat treatment is recommended by many researchers to be done before high temperature tempering.

Cryogenic treatment creates denser molecular structure of cutting tools in a larger contact surface area that reduces friction, heat and wear. Cryogenic treatment converts almost all the soft retained austenite into hard martensite and the martensite is tampered as the metal returns to room temperature. It forms micro-fine carbide fillers, that the dispersed in martensite structure between the larger carbide particles present in steel. This structural matrix resists penetration of foreign particles and so improves abrasion resistance. It decreases the residual stresses in tool steel. It improves the entire structure of the cutting tool, not just the surface. Subsequent refinishing operations or regrinds do not affect permanent improvements.

Cryogenic treatment is one permanent process and does not need repeated treatments. It does not lead to changes in dimensions or surface finish. Cryogenic treatment is expected to enhance abrasive wear resistance, toughness, tensile strength and reduce the brittleness.

The values of these variables will depend upon, the desired properties expected in the treated parts, costs affordable for the cryotreatment, cryogenic facilities available and also upon the shape and size of the metal part.

1.1. Soaking

The chamber was filled-up with liquid nitrogen so that the specimens were submerged. The chamber was topped-up at 4 hour intervals so that the specimens remained at -77 degrees Kelvin.

1.2 Warm-Up

After about 12 hours of soaking, the insulation chamber was left undistributed such that it warms-up slowly form the atmospheric heat leaking through the foam insulation. The chamber warmed-up to room temperature in about 60 minutes and hence the warm-up rate was -3.5 degrees Kelvin per minute.

1.3 Sliding Wear

The material considered for this test is ASTM A387 samples which is used for boiler parts. A pin on disk wear test was conducted as per ASTM guidelines. The sample was made as the pin and a grinding wheel of 50mm diameter was chosen as the disk. The test setup can cause either the disk or pin to revolve about the disk center. The speed of revolution also can be conducted with the following parameters.

1. Load;
2. Speed;
3. Sliding distance.

Two tracks viz. at 42mm and 20 mm PCD were set on the grinding wheel and the load 50N are considered with each one corresponding to a particular track. The specific linear sliding speed is also considered for a load condition. After making the setting, the wheel-setting was checked for flatness using a vernier dial gauge of 0.01mm accuracy.

The samples were randomly selected to avoid any biased conditions and the test was conducted totally for 10 number of ASTM A387 samples. The observations of the above tests are discussed. A test of statistical significance for the observations in sliding wear test was also conducted.

The wear of any tool is a complex function of load and speed. Hence these two variables were considered for the study and the wear resistance has been calculated as a non-dimensional parameter incorporating the load, the velocity of slide, the volume loss.

2. Pin on disk wear test

This test method describes a laboratory procedure for determining the wear of materials during sliding using a pin-on disk apparatus. Materials are tested in pairs under non-abrasive condition. The principal areas of experiments attention in using this type of apparatus to measure wear are described.

For the pin-on disk wear test, two specimens are required. One, a pin with a radiused tip, is positioned perpendicular to the other, usually a flat circular disk. The test machine causes either the disk specimen or a 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 either horizontally or vertically. The pin specimen is pressed against the disk at a specified load usually by means of an arm of lever and attached weights. Other loading methods have been used, such as hydraulic or pneumatic.

Wear results are reported as volume loss in cubic millimeters for the pin and the disk separately. The amount of wear is determined by measuring appropriate linear dimensions of both specimens before and after test.

Wear results are usually obtained by conducting a test for a selected sliding distance and for selected values of load and speed. One set of conditions that was used in an interlaboratory measurement series is given. Other test conditions may be selected depending on the purpose of the test.

Wear results may in some cases be plots of wear volume versus sliding distance using different specimens for different distances. It is not recommended that continuous wear depth data obtained from position-sensing gages be used because of the complicated effects of wear debris and transfer films present in the contact gap, and interferences from thermal expansion or contraction.

The materials consider for this test is low alloy steel sample.

The sample was made of 8mm diameter and 30mm length.

The track of 20mm and 42mm and 50N load was used.

Wear Resistance WR=$FV/ WH_{V.}$

F is the load in Newton.

V is the linear velocity in m/s.

W is the volume loss of the material in m^3/s due to wear.

H_V is the Vickers hardness in N/m^2.

2.1 Pin on Disk Wear Test Procedure

Weigh the specimen to the nearest 0.0001g.

Insert the disk securely in the holding device so that the disk is fixed perpendicular to the axis of revolution.Insert the pin specimen securely in its holder and, if necessary adjust so that the specimens are perpendicular to the disk surface when in contact, in order to maintain the necessary contact condition.Add the proper mass to the system lever to develop the selected force pressing against the disk.Start the motor and adjust the speed to the desired value while holding the pin specimen out of contact with the disk. Stop the motor.

Begin the test with the specimens in contact under load.

Tests should not be restarted.

Remove the specimen and clean off any loose wear debris.

Reweigh the specimens to the nearest 0.0001g

2.2. Specifications for pin on disk wear test for untreated sample:

Track diameter	20mm
Load	50N
Sliding velocity	0.2m/s
Speed	190rpm

2.3. Specifications for pin on disk wear test for cryogenically treated sample:

Track diameter	42mm
Load	50N
Sliding velocity	0.2m/s
Speed	190rpm

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2.4. Pin on disk wear test graph of untreated specimen

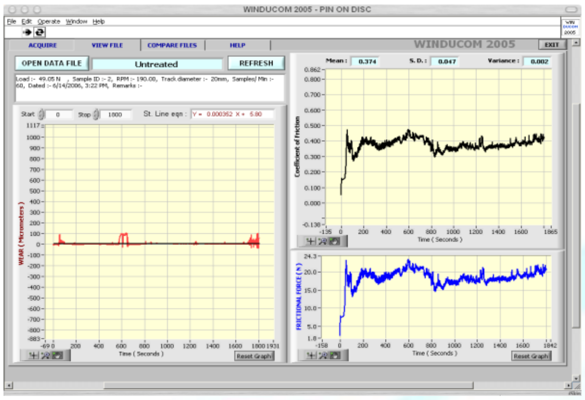

Figure2. Pin On Disk Wear Test Graph of Untreated Specimen

2.5. Pin on disk wear test graph of cryogenically treated specimen

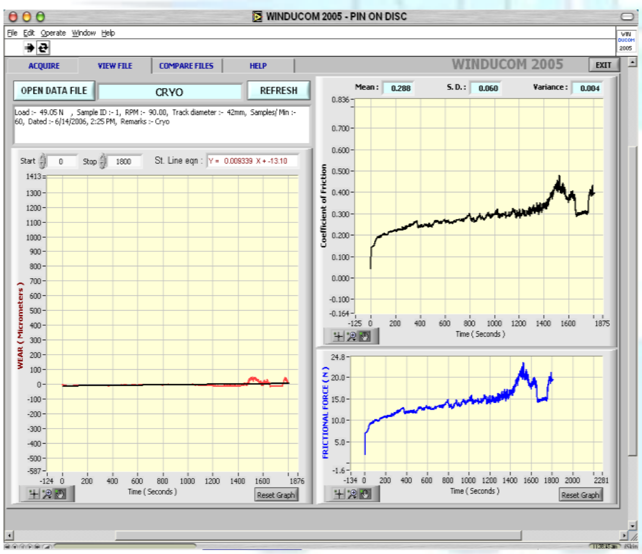

Figure3. Pin On Disk Wear Test Graph of Cryogenically Treated Specimen

2.6. Comparison of coefficient of friction of untreated and cryogenically treated sample

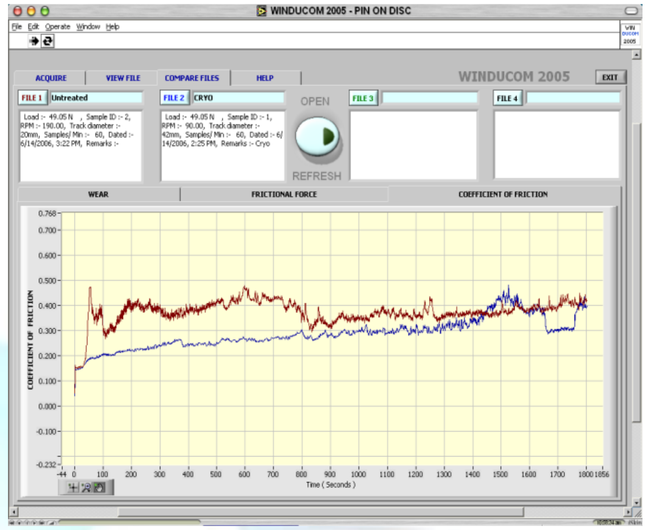

Figure4. Comparison of Coefficient Of Friction of Untreated and Cryogenically Treated Sample

2.7. Comparison of frictional force of untreated and cryogenically treated sample

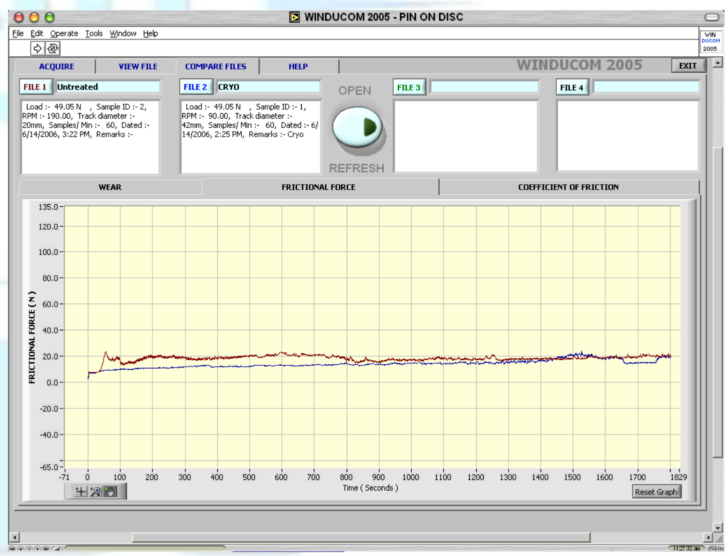

Figure5. Comparison of Frictional Force of Untreated and Cryogenically Treated Sample

2.8. Comparison of wear of untreated and cryogenically treated sample

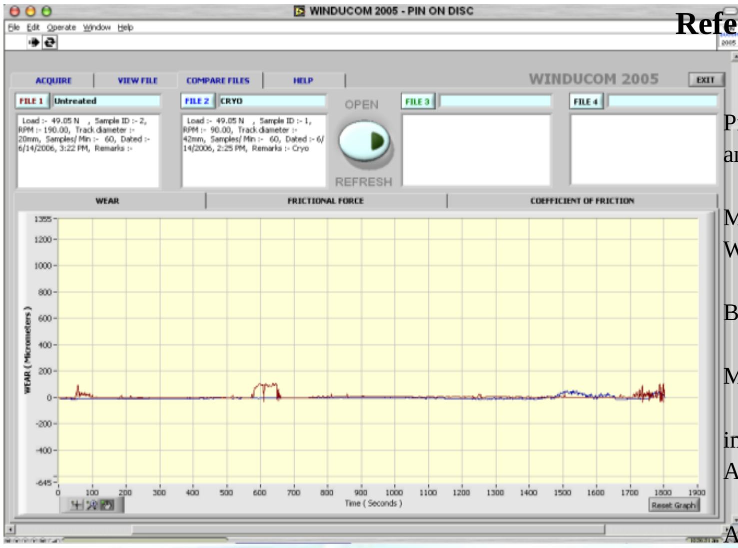

Figure6. Comparison of Wear of Untreated and Cryogenically Treated Sample

Wear resistance of untreated sample=244.
Wear resistance of cryogenically treated sample=391.

Improvement in wear resistance=
(391-244)/244×100

Improvement in wear resistance= **60.016%.**

3. Conclusions

Cryogenic treatment no doubt to improves the resistance to chipping of tools and to a less significant extent, improves flank wear resistance.

From the pin on disk wear test results the wear of cryogenically treated specimen ASTM A387 is less as compared to the untreated specimen.

The frictional force of the untreated specimen is high as compared to the cryogenically treated specimen.

The wear resistance of cryogenically treated specimen is improved by 60% also coefficient of friction of cryogenically treated specimen is less as compared to the untreated specimen.

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