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Study of Wear Characteristics of Heat Treated Ultra High Carbon Steel

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Abstract : Steel is a traditional material used for more machinery in the manufacturing industry. High carbon steel has a character for being especially hard, but the extra carbon also makes it more brittle than other types of steel. Recent studies suggest that spherodization technique can be a method to increase the wear resistance of Ultra High Carbon Steel. Steel specimens are subjected to different heat treatment procedures to achieve various phases i.e. annealed, quenched and forged. Spherodization heat treatment process then made on these various steel specimens. Then the wear test is done on a standard pin on disc wear apparatus under different loads of 0.5, 2, 4 and 6 kg under constant sliding distance. The results showed improved wear characteristics for spherodized steel specimens.
Keywords : Ultra High Carbon Steel, Spherodization, Annealed, Quenched, Forged, Pin on disc wear testing machine.

1. Introduction

Damascus steels are ultrahigh carbon steels that contains from 1 to 2.1% carbon. The modern metallurgical understandings of ultrahigh carbon steel has revealed that remarkable properties can be obtained in these hypereutectoid steels. The results achieved in ultrahigh carbon steel are attributed to the ability to place the carbon, in excess of eutectoid composition, to do useful work that enhances mechanical and wear properties[1]. During the last decays, there has been a great demand for steels with higher mechanical strength, sufficient ductility and toughness. Moreover, the lightness of the steel is attractive, as in the automobile and aircraft applications. These requirements can be achieved by an increase in carbon content in a limited way[2]. Mechanical properties of steel can be changed and improved by various heat treatments for a particular application[3]. Heat treatment can appreciably change the properties of steel, its effect on mechanical properties being most important. Steel as annealed, normalized or tempered consists of lamellar ferrite and carbide inclusions. Ferrite has a low strength and high ductility, whereas cementite has a high hardness and zero values of elongation and reduction. The quantity of carbide particles of a constant size depends on the carbon content in steel (directly proportional to the carbon content in carbon steels). This is why the values of strength in steels increase and the values of ductility diminish with increasing carbon content[4]. Prevention of wear and increase in steel life depends principally on the design and operation on the component, but providing some heat treatment on steel can also improve the quality to a great extent[5].A tribometer is an instrument that measures tribological quantities, such as coefficient of friction, friction force, and wear volume, between two surfaces in contact. Different types of tribometer are four balls, Pin on disc, Block on ring, Bouncing ball and twin disc. The main focus of our research study is pin on disc tribometer, which is an advanced tribometer with precise measuring of friction and wear properties of combination of metals and lubricants under selected conditions of load, speed and temperature[6].The present study was to investigate the effect of spherodization heat treatment on wear characteristics of ultrahigh carbon steel specimens.

2. Experimental procedures

2.1 Materials and processing

As received three samples of high carbon steel with 10 mm thickness. These specimens are then heated treated in an electric muffle furnance. The different heat treatment process are

2.1.1 Annealing

The specimen was heated to a temperature of 900°C and the specimen was held at that temperature for two hours for homogenisation.Then the furnace was switched off so that the specimen temperature will decrease with the same rate as that of the furnace and the specimen is taken out after two days therefore a slow cooling process is achieved. This process led to the formation of Pearlite and Cementite microstructure.

2.1.2 Quenching

The specimen was heated to the temperature of around 900°C and was allowed to homogenize at that temperature for 2 hour.Then for sudden cooling it has been put in an water bath where the sudden cooling takes place.

2.1.3 Forging (Manufacturing process)

Forging is a manufacturing process involving the shaping of metals using localized compressive forces. The specimen is placed inside the furnace and heated to a temperature of about 923° and the material is strike by an hammer.

2.1.4 Spherodization

All the three heat treated specimens are then spherodized by heat treating it again. Here the specimen is heated at about 1150°C and was held at that temperature for a prolonged period of time followed by slow fair cooling. It is then cycled for multiple times till it attains small globular structure.

2.2Preparation of samples for microstructural studies

The samples of height 2.5 cm were ground on different grits of silicon carbide paper from 180, 400, 800, and 1000 grits. Water was poured on the samples regularly for every one to two minutes to carry away heat and to enable fast grinding while the sample was turned through an angle of 90°, after which they were placed on a rotating wheel covered with emery cloth of grits 1200 while a suspension of alumina powder and water was poured on it at regular interval to carry heat away and to enable fast polishing. The samples were polished to mirror-finished image.

2.3 Wear characteristics analysis

Dry sliding wear tests for different number of specimens was conducted by using a pin-on-disc machine. The pin samples were 35 mm in length and 10 mm in diameter. The pin was held against the counter face of a rotating disc with wear track diameter 130 mm. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens was conducted under different loads of 5N, 20N, 40N and 60N and a sliding velocity of 2, 4, 6 and 8 m/s

3. Result and Discussion

3.1 Microstructure Analysis

Figure 1, Figure 2 and Figure 3 shows the microstructure image of annealed, quenched and forged specimen before wear test. The test result showed that the annealed specimen contains spherodized cementite dispersed in the matrix of ferrite and pearlite. It is seen there is reduced interfacial area between ferrite and cementite.The Microstructure image of quenched specimen shows that it contains Spheroidised Cementite uniformly dispersed in the matrix of Ferrite in high magnification. The Microstructure image of forged specimen showed that it consists of Spheroidised Cementite uniformly dispersed in the matrix of Ferrite.

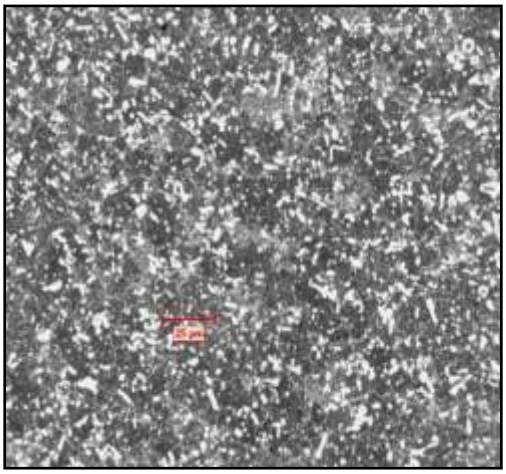

Figure 1.Microstructure of Annealed specimen

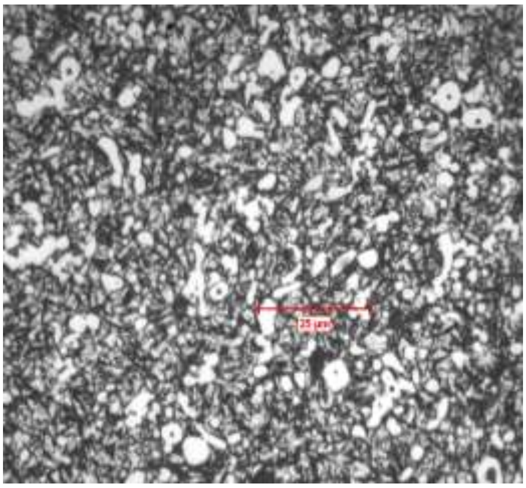

Figure 2.Microstructure of Quenched specimen

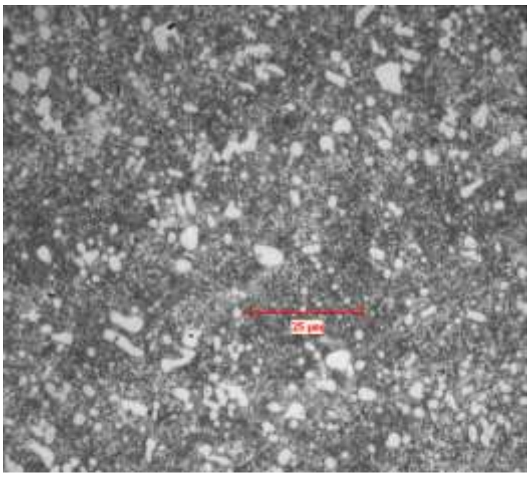

Figure 3.Microstructure of forged specimen

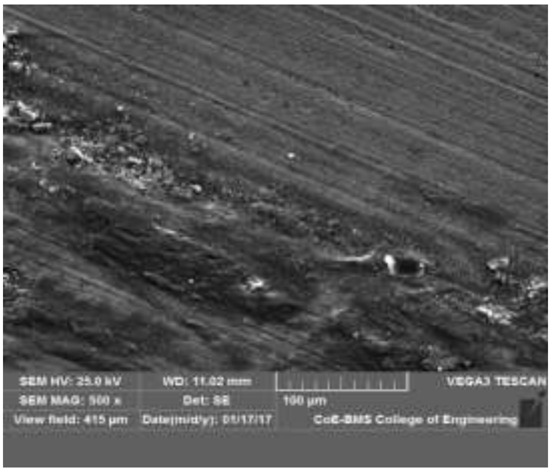

Figure 4.SEM image of annealed specimen

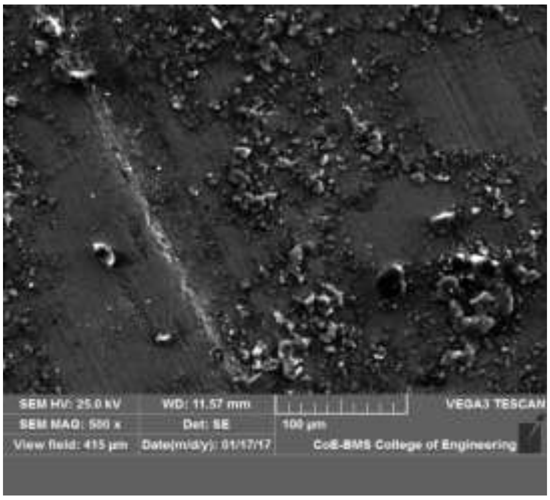

Figure 5.SEM image of quenched specimen

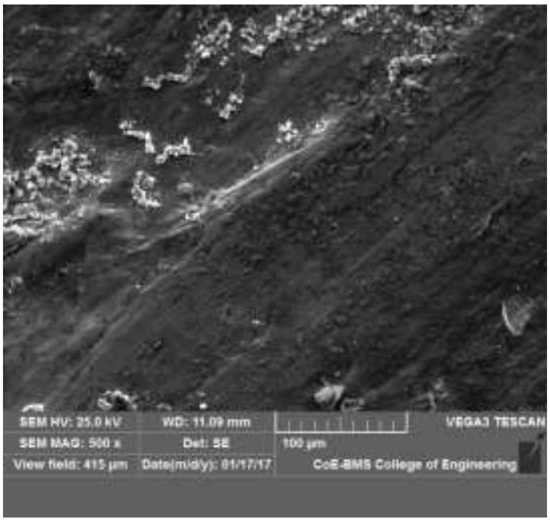

Figure 6.SEM image of forged specimen

Figure 4, 5, 6 shows the SEM image of annealed, quenched, and forged specimen after wear test. It can be clearly seen that in annealed and forged specimen spherodite cementite is still present and has shown resistance to wear while the other remaining parts has worn out surfaces.SEM image of the quenched specimen shows that it has high wear rate compared to annealed specimen as it shows wornouts.

3.2 Wear results in graph

From the Figure 7 and Figure 8 It is observed that with increase in the normal pressure the volumetric wear rate is increased for all the specimens and for almost all the sliding speeds. It can also be observed that volumetric wear rate is high for high operational conditions at about 4 m/s and it is low for low operational conditions of 1 m/s. It is also observed that quenched specimen has high volumetric wear rate compared to the other two volumetric wear rate of annealed and quenched specimens From the Figure 9 and Figure 10 it is observed that volumetric wear rate for quenched specimen is high. It is also observed that volumetric wear rate of all the specimens are equal in speed 4 m/s under normal pressure of 0.75 MPa.

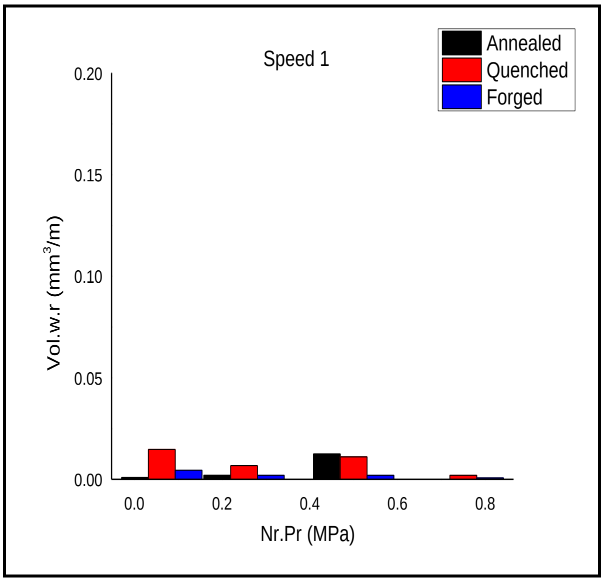

Figure 7.Effect of Speed on Volumetric Wear Rate at Speed = 1 m/s

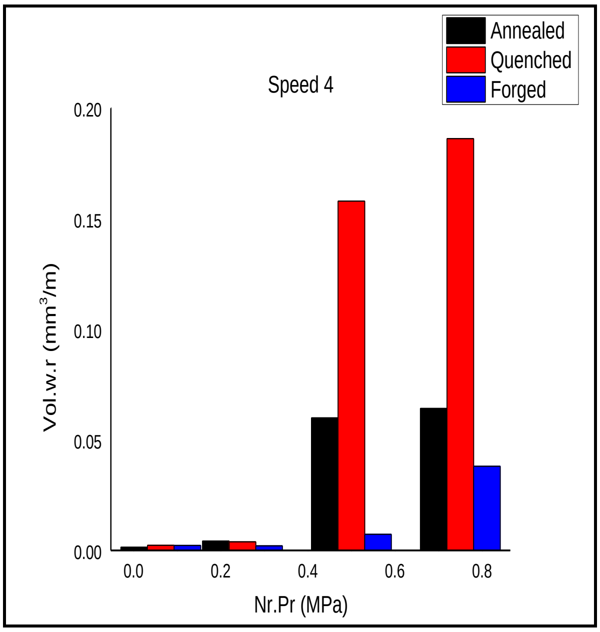

Figure 8.Effect of Speed on Volumetric Wear Rate at Speed = 4 m/s

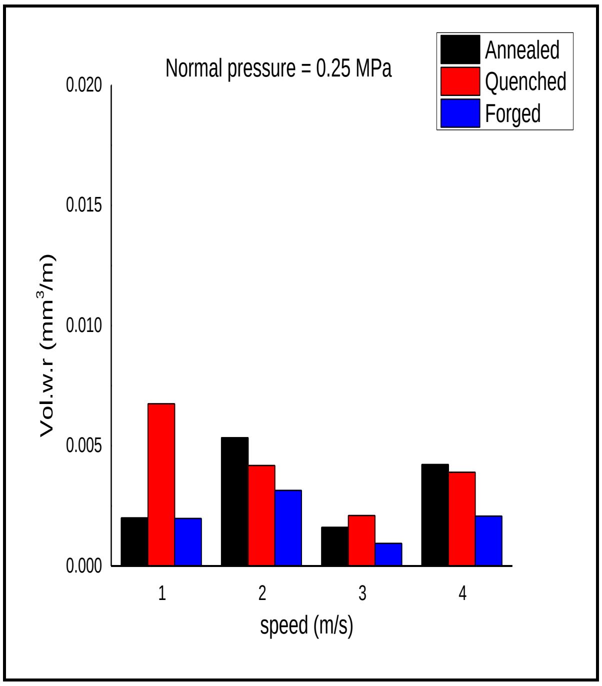

Figure 9.Effect of Speed on Volumetric Wear Rate at Normal pressure = 0.25 MPa

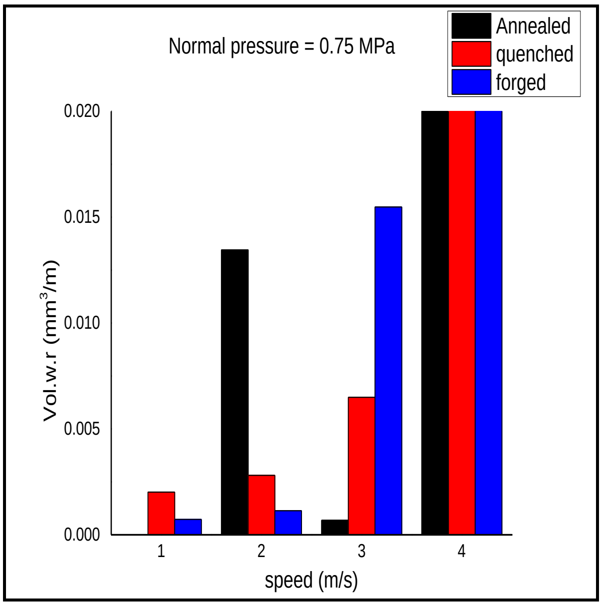

Figure 10.Effect of Speed on Volumetric Wear Rate at Normal pressure = 0.75 MPa

4. Conclusion

From the results, we can clearly see the wear rate of quenched specimen is high compared to annealed and forged specimens. The volumetric wear rate increases with increase in normal pressure. The volumetric wear rate is high during high operational conditions and it is low in low operational conditions. The spherodite cementite microstructure present in all the specimen has shown resistance to wear. Hence sperodization heat treatment process can be used to reduce wear in ultrahigh carbon steels.

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