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RESEARCH ARTICLE

Experimental and Finite Element Analysis of Tribological Behaviour of Heat Treated 40 C 8 Steel in Dry Sliding Test Using Pin on Disc Apparatus

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Abstract

In this work medium carbon steel of the type 40C8 was used subjected to Normalising and tempering heat treatment process to achieve different levels of hardness. Heat treated samples have been experimentally analysed in the pin on disc wear testing apparatus to study the dry sliding wear characteristics under different loading conditions and at constant sliding velocity. In performance of this analysis Archard's wear theory was used as basis. This work also presents the wear simulation using finite element software PTC CREO Simulate Version 3.0. The purpose of finite element method was to analyse the state of stress and strain generated during pin on disc test with pin material as 40C8 steel against high carbon low alloy steel disc hardened up to 60 HRC. The experimental study shows that wear resistance of tempered steel is less than normalised. The Finite Element method shows satisfactory results for state of stress and strain when compared with analytical results.

INTRODUCTION

Tribology is the science of surface interaction among different material bodies in relative motion with each other.
As there are many types of failure linked with the steel components, wear presents unique challenge to the developer of product. Wear is intricate process as it is a system property and not material property. Steel might wear out in different modes such as abrasion adhesion erosion, surface Fatigue and corrosion. Out of these modes adhesive and abrasive wear are commonly detected in steel component. With large number of variables like load, sliding speed, hardness, composition etc. (1)
In this work the pin material used for experimentation is Medium-Carbon steel. It has more carbon and is stronger than low carbon steel. It contains 0.3 to 0.6 % carbon. Medium carbon steel is used for bolts, shafts, car axels, rails and other parts or tools that require strong metal. There are different wear cases associated with bolts, car axels, forgings, and casting components. This wear are generally of adhesion type here an attempt is made to analyse the wear characteristic of carbon steel casting under dry sliding wear.
Over the Years, the mechanics and impact of wear are becoming better understood and the calculation and Reduction of wear is becoming critical for some applications, including biomedical applications. With the arrival of modern high performance computers, considerable computational efforts have been made, especially using the Archard's Wear model. (2)

$$\frac{V}{s}=K\frac{F_N}{H}$$

The question of great practical standing is, how much of the material will be lost throughout the given operation time. The surface shapes vary due to their functions, manufacturing tolerances, etc. and will be changed as a result of wear and plastic deformation. The pressure distribution is then strongly reliant on those phenomena. A finite element method (FEM) is a multipurpose tool to solve the stress and strain problems irrespective of the geometry of the bodies. A FEA Program PTC CREO Simulate 3.0 has been used in this paper for the contact pressure determination as well as wear simulation. (3)

On the basis of these studies here, an attempt is made to study the Tribological Behaviour of plain carbon steel containing 0.36% carbon experimentally as well as using Finite Element Method.

EXPERIMENTAL SET UP

In this experiment Medium carbon steel of Hypo Eutectoid Composition (C 0.36%, Mn 0.83%, Si 0.21%, S 0.01%, P 0.015%) was subjected to Normalising and tempering process.

Sample Preparation

Sample of size 40mm Length and 8mm diameter were cut from carbon steel bar. Two sets comprising of four pins in each set were taken for carrying out heat treatment. Both the sets of samples were kept in a cylindrical furnace at 850^0C for an Hour. Out of these two sets one set was taken out and was oil quenched and then it was further subjected to tempering at 425^0C temperature for next 1.5 Hour. The first set of sample was allowed to cool inside the furnace up to the Room temperature.

Macro hardness of Two Sets of Heat treated samples was checked on Vickers hardness tester using diamond indenter and found to be Normalised 217; and Tempered 554.

Checking of Wear Behaviour

For wear test polished samples up to 400 grade emery paper were used before testing these samples were cleaned in acetone and dried. Wear characteristics of these two sets of samples were checked on pin on disc machine TR 20LE Made by DUCOM, Bengaluru (INDIA). It consist of stationary pin hold against rotating disc made of EN 31 hardened steel up to 60 HRC. Before conducting each Test disc surface and pin surface which were going to slide on each other cleaned them with Acetone to remove any dirt. A digital electronic mettle balance was used to measure the weight loss of the pin after each run to estimate the volume loss during wear.

Initially, the weight loss was measured after every 3 minute of sliding up to 18 min and thereafter, at an interval of 15 min for total sliding period of 1.5 Hour. The tests were conducted at various loads of 4, 5.5, 7 Kg at constant sliding velocity of 2.5 m/s.

EXPERIMENTAL RESULTS

Following Tables and Graphs show the variation of wear volume with increasing sliding distance, variation of wear rate with increasing load and Also Values of Wear Coefficient at Different loads for Both Heat Treated Samples.

Time In Sec	Sliding Distance In Meter	Volume Loss at Different Loads for Normalised(mm^3)			Volume Loss at Different Loads for Tempered(mm^3)		
		4 Kg	5.5Kg	7Kg	4Kg	5.5 Kg	7Kg
900	22.5 X 10^2	5.34	16.02	26.7	8.05	24.15	40.25
1800	45 X 10^2	7.47	18.156	28.836	11.27	27.37	43.47
2700	67.5 X 10^2	9.61	20.292	30.972	14.49	30.59	46.69
3600	90 X 10^2	11.74	22.428	33.108	17.71	33.81	49.91
450	112.5 X	13.8	24.56	35.244	20.9	37.0	53.13

0	10^2	7	4		3	3	
540 0	135 X 10^2	16.0 2	26.7	37.38	24.1 5	40.2 5	56.35

Table 1. Showing Volume at Various Loads Vs Sliding Distance.

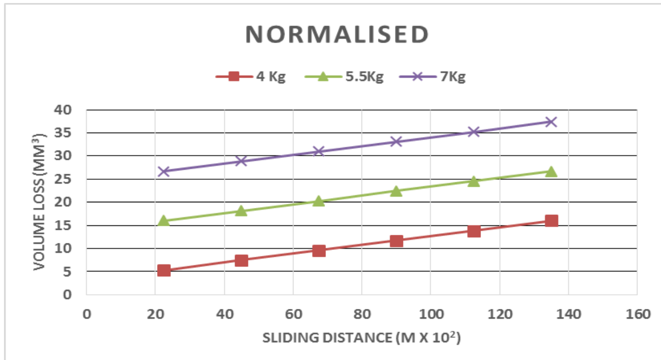

Fig 1. Variation of Wear Volume with Sliding Distance at different Loads for Normalised Specimen.

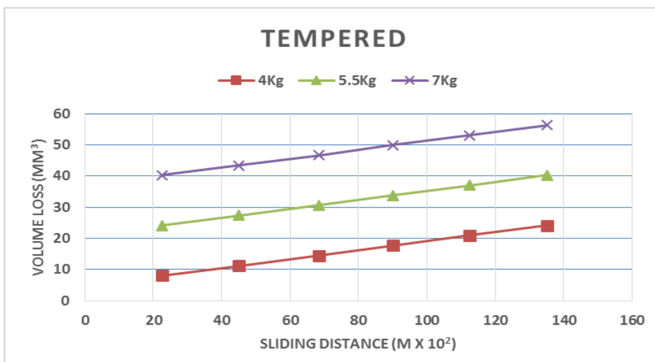

Fig 2 Variation of Wear Volume with Sliding Distance at different Loads for Tempered Specimen.

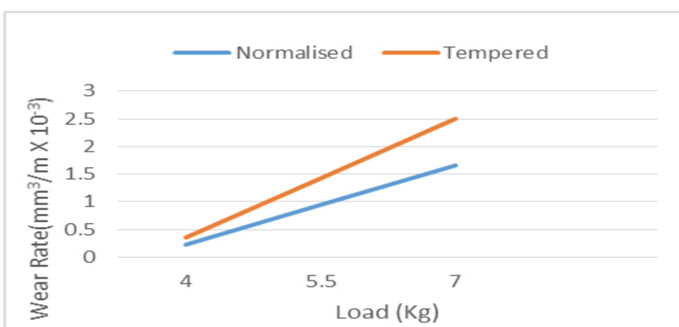

Fig 3. Variation of Wear Rate at different Loads for Both Normalised and Tempered Specimen.

Wear Coefficient (K) for Heat treated Samples at different Loads. (K X 10^{-4})				Average Wear Coefficient
Loads	**4 Kg**	**5.5 Kg**	**7 Kg**	**(K X 10^{-4})**
Normalised	**2.57**	**3.74**	**4.40**	**3.57**
Tempered	**9.91**	**14.4**	**16.9**	**13.73**

Table 2. Showing. Wear Coefficient at Different Loads for Heat Treated Samples

Fig. 4. Experimental Pin on Disc Lab Set Up

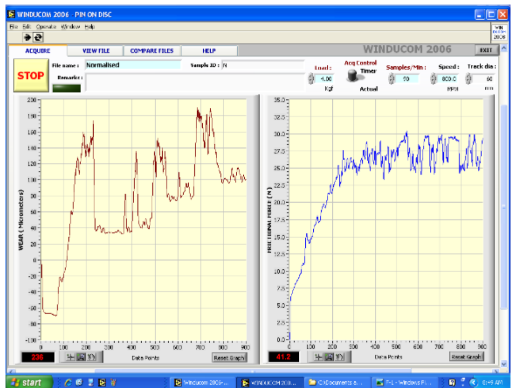

Fig 5. Wear & Frictional Force graph For Normalised Specimen at 4 Kg.

Fig 6. Wear & Frictional Force graph for Tempered Specimen at 4 Kg.

MODELLING AND FINITE ELEMENT ANALYSIS

Linear systems are far less complex and generally don't consider plastic deformation. Nonlinear systems consider for plastic deformation, and many also are proficient of testing a material all the way to fracture. The main task of the Finite Element Analysis is to recognize the nonlinear behaviour such as interaction of pin on disc material.

Pin on Disc contact problem are considered as nonlinear because of the stiffness, loads, deformation and contact boundary conditions. The FE wear calculations comprise solving the general contact problem with the area of contact amongst the bodies not known in advance. The analysis is therefore non-linear.

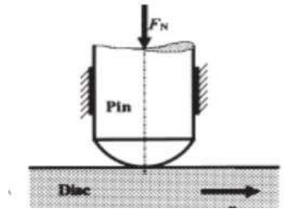

Fig. 7. Pin On Disc Hertz Contact

The state of stress and state of strain results obtained are shown in the following Table and Figures.

Mesh Size, mm	**Load N**	**Max. Von Mises Stress N/m^2**	**Max. Contact Press.(FEA) N/m^2**	**Max Cont. Pressure (N/m^2) Analytical**	**% Error**
25	40	8.11×10^6	3.54×10^6	2.00×10^6	15.4 %
20	40	6.95×10^6	3.10×10^6	2.00×10^6	11 %
15	40	5.79×10^6	2.66×10^6	2.00×10^6	6.6 %
10	**40**	**4.64×10^6**	**2.21×10^6**	**2.00×10^6**	**2.1 %**

Table 3. Comparison between Analytical and FEA Results of different mesh sizes.

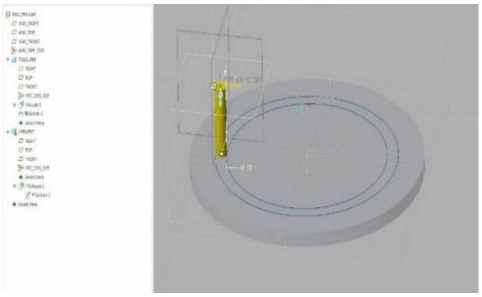

Fig 8. Modell of Pin on Disc

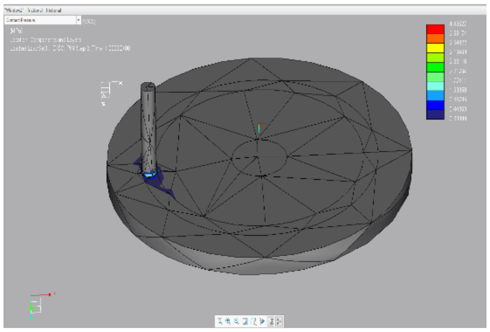

Fig 9. Contact Pressure between Pin and Disc

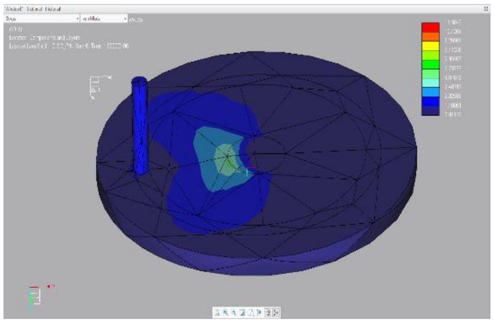

Fig 10. Von Mises Stress between Pin on Disc

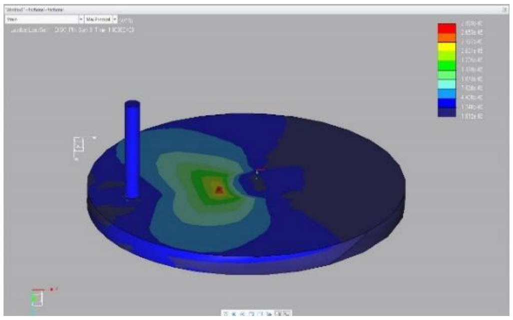

Fig 11. State of Strain between Pin and Disc

FEA Discussion

In the starting elastic FEA was carried out to estimate the maximum contact pressure between the pin and the disc. The FEM model was analytically established and optimum mesh size for the contact elements was determined by relating the maximum contact pressure from elastic analysis results with analytical effects from Hertz contact theory applied to ball on flat surface. Consequently Elastoplastic FEA of pin on disc was completed with constant load on the pin and several friction conditions.

Conclusion

(1) Wear characteristic of both heat treated samples were studied under normal loads of 4, 5.5, 7 Kg and at constant velocity of 2.5 m/s exhibited a loss in volume with increasing load.
(2) It is observed that contact pressure obtained in both Experimental and FEM analysis was almost close to each other. This study will be useful for further development into the contact pressure analysis problems.

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