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Dry Sliding Wear Behavior Of Carburized 20mncr5 Alloy Steel

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ABSTRACT: *This research is limited to study the wear resistance of carburized 20MnCr5 (SAE 5120) alloy steel, which has wide application in industries like gears, shafts, bearings, pins etc. The abrasive wear study is performed on pin-on-disc tribotester. Sliding velocity of 0.8 m/s, 1.6 m/s, 2.4 m/s, Sliding Distance of 1200 m, 1400 m, 1600 m and Load of 3 kg, 4 kg and 5 kg were used to evaluate the wear resistance.*

KEYWORD: *Carburizing, Abrasive wear*

I. INTRODUCTION

The equation that relates the wear rate with the applied load was at first established by Holm in 1940. This citation can be found in Archard's paper, which is considered as the main reference for the modeling of wear rate in sliding systems. Holm assumed the wear as an atomic process. The wear rate (worn volume per unit sliding distance) W isgiven by

$$W = Z\frac{F}{P_y} \qquad 1$$

Where Z is the number of atoms removed per atomicencounter, F is the applied load, and P_y is the flow pressure of worn surface. Furthermore, the term Z can only be interpreted as a probability of atomic removal. 1

This modeling depends on the kind of deformationassumed for the asperities, which Holm considered theplastic deformation as predominant for the materialremoval. To this problem, Archard demonstrated that tosatisfy a linear relationship between the wear rate and theapplied load, some hypothesis on the shape of debrisshould be made, which implies in a new comprehension onthe effective mechanism of material removal.Greenwood and Williansomadded to the Archardtheory, the nature of deformation, considering the heightsof asperities in contact. Their work and many others applied a probabilistic approach for the roughness of Surfaces in contact. However, there are few models withthis approach for the wear coefficient.

II. ARCHARD MODEL AS AN INITIAL VALUE PROBLEM

The plastic contact area A_y can be defined as,

$$A_y = \frac{F}{p_y} \qquad 2$$

where F and p_y were defined in Eq. (1). Following the Archard model the worn volume V is given by,

$$V = kA_y x \qquad 3$$

where k is the wear coefficient and x is the sliding distance. Putting Eq. (2) in Eq. (3) one can obtain,

$$V = k\frac{F}{p_y}x \qquad 4$$

On the other hand, the worn volume can be defined by the following equation

$$V = Ah \qquad 5$$

where *A* is the apparent contact area and h is an averageheight corresponding to the material removal. Theidentities defined in Eqs. (4) and (5) lead to

$$h = k\frac{P}{p_y}x \qquad 6$$

where p is the average normal stress.

Steel has many practical applications in every aspects of life. The steel is being divided as low carbon steel, medium carbon steel, high carbon steel, Low carbon steel has carbon steel has carbon content of 0.15%-0.45%. As the carbon content increases, the metal becomes harder and stronger but less ductile and more difficult to weld.

20MnCr5 *(SAE 5120)* categorized as the low carbon alloy steel grade.

Category	Steel
Class	Alloy steel
Type	Standard
	United States: ASTM A322, ASTM A331 , ASTM A519 , SAE J404 , SAE J770 , UNS G51200
	France: AFNOR 20 MC 5
Designations	Germany: DIN 1.7147

III. CARBURIZED HEAT TREATMENT

Carburizing, a surface treatment applied to a part to ensure beneficial surface compressive stresses and increased hardness, improves wear and fatigue resistance.In many machine parts it is required to have hard case comparative to the core e.g. Shafts, gears etc. so that the core can stand the shocks, impact and hard case can stand wear as with increase in the hardness materials loses its ductility and weld ability and becomes brittle.
Carburizing introduces a gradient in the surface microstructure and mechanical properties. The hardness and strength of martensite increase with increasing carbon content.

3.1 Sequence of the Heat treatment done on 20MnCr5

Sequence	Process	Temperature
I	Carburizing	900^{0}C, 2 hr
II	Quenching	680 ^{0}C, Oil quenched
III	Tempering	160 ^{0}C , 1.5 hr

3.2 Chemical analysis after Carburizing Heat treatment

Elements	RAW Sample	Carburized Sample
% C	0.17	0.201
% Mn	1.19	1.12
% Cr	1	1.1
% Ni	0.1	0.1
% Mo	0.02	0.02
% S	0.021	0.023
% P	0.024	0.027
% Si	0.25	0.24

IV. SPECIMEN AND TRIBOLOGY

Case carburized Specimens of 20Mncr5 are prepared for 25 mm length and 10 mm diameter.Combination of Tribological conditions i.e. load, sliding velocity and sliding distance were analyzed for studying the wear property of the samples on Pin-On-Disc tribotester.Material Samples were used as a Pin for the experimentation and Alumina used as Counterpart (Disc).Experiment is carried out for the three levels of load, Sliding velocity and Sliding distance

Load (kg)	3	4	5
Sliding velocity (m/s)	0.8	1.6	2.4
Sliding Distance (m)	1200	1400	1600

Taguchi L9 array is selected for carrying out the experimentation and weight loss in grams is measured after every trial.

V. TAGUCHI L9 ARRAY

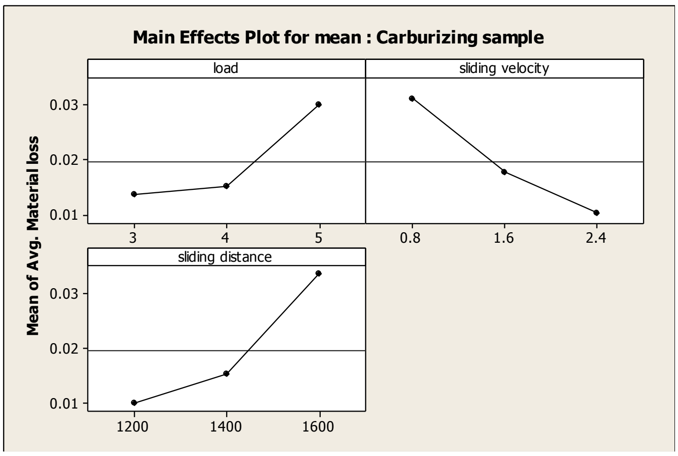
Table 1

Load	Sliding Velocity	Sliding Distance	Material loss
3	0.8	1200	0.0064333
3	1.6	1400	0.0176663
3	2.4	1600	0.0168667
4	0.8	1400	0.0208667
4	1.6	1600	0.0182327
4	2.4	1200	0.0064333
5	0.8	1600	0.0655530
5	1.6	1200	0.0170000
5	2.4	1400	0.0074611

Table 1 Taguchi L9 Array

VI. RESULTS

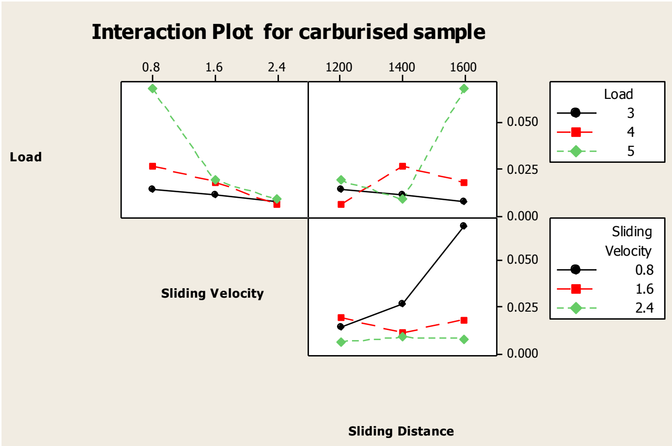
6.1 Main effect Plots



Frommain effect plot it is observed load and sliding distance has direct effect and sliding velocity has inverse effect on material loss.Behavior of wear with respect to load is in compliment with the findings of *Xiaoliang Shieta,Min-Soo Suh eta, H.X. Zhu eta, M. Singh eta.*

Behavior of wear with respect to sliding distance is in compliment with the findings of *Yasin Alemdageta,Min-Soo Suh eta, J.D. Bressan eta, Temel Savaskan eta.*Behavior of wear with respect to sliding velocity is in compliment with the findings of *Xiaoliang Shieta*

6.2 Interaction Plot



Wear is reduced with increase in sliding velocity with decrease in loading condition for different sliding distance conditions.For different load conditions, wear is increased with increase in sliding distance with reduces sliding velocity. Time required for completing a particular wear distance is reduced with increase in sliding velocity. When load is 3 kg and sliding distance is increasing, wear is decreasing. When load is 4 kg and 5kg and increase in sliding distance, wear decreases initially and then increases.Maximum wear is observed when sliding velocity is at minimum and sliding distance is increasing and minimum wear is obtained when sliding velocity is at maximum and sliding distance is increasing.

6.3 ANOVA table

Table 2

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Load	2	0.0035246	0.0035246	0.0017623	20.68	0.046
Sliding Velocity	2	0.0012767	0.0012767	0.0006383	7.49	0.118
Sliding Distance	2	0.0053023	0.0053023	0.0026512	31.10	0.031
Error	2	0.0001705	0.0001705	0.0000852		
Total	8	0.0102741				

Table 2 Anova table

S = 0.00923220   R-Sq = 98.34%   R-Sq(adj) = 93.36%

From table it is observed that the sliding distance is the most effecting parameter followed by load and sliding velocity.

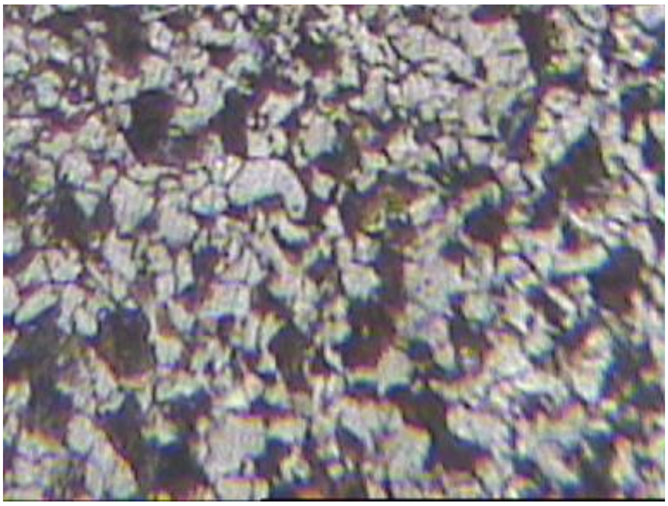
6.4 Regression analysis

Therelationship between the control factors Sliding Velocity, load, Sliding distance and the output performance wear are obtained by regression analysis.

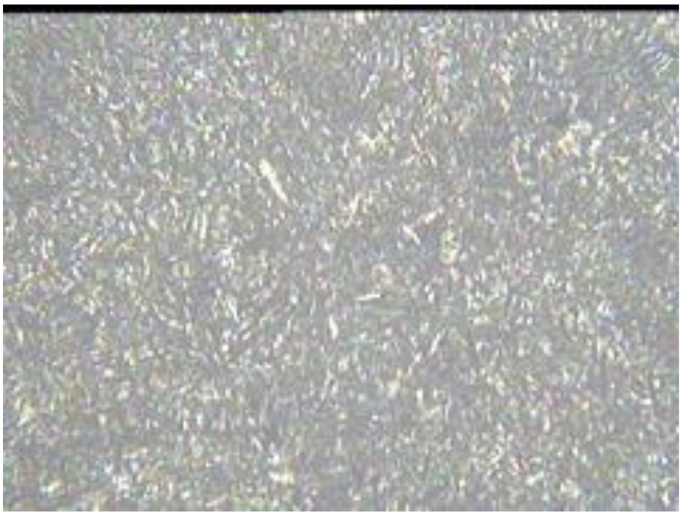
Wear = - 0.0576 + 0.0101 Load - 0.0171 Sliding Velocity + 0.000045 Sliding Distance

VII. MICROSTRUCTURE

7.1 Raw Material



7.2 Carburized Sample



Carburized sample shows Low carbon tempered martensite with bainitic structure& 5 % free ferrite is observed in martensitic matrix.

Raw material shows normalized ferrite

VIII. CONCLUSION

[1] Carburizedheat treatment improves the microstructure and wear property of the material as amount of free ferrite observed in carburized heat treatment is less as compared to rawmaterial.
[2] Carbon percentage is increased after carburizing heat treatment hence carburizing heat treatment is successfully done.
[3] Minimum wear of cryogenically treated samples is obtained when load is 4 kg sliding distances 1200 m and sliding velocity is 2.4 m/s.

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