International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Dry Sliding Wear behavior of Cryogenic Treated 20MnCr5 Alloy Steel

Sandeep S Kadam[1], Prof. S. D. Ambekar[2]

[1]Research Scholar Post graduate Student, Mechanical Engineering Department, Government College of Engineering Aurangabad
[2]Asst. Professor, Mechanical Engineering Department, Dr. Babasaheb Ambedkar University Aurangabad, India

Abstract: ***This research is limited to study the wear resistance of cryogenically treated 20MnCr5 (SAE 5120) alloy steel, which has wide application in industries like gears, shafts, bearings, pins etc. Cryogenics is used as a supplement treatment that is performed after carburizing. The abrasive wear study is performed on pin-on-disc tribotester. The counter face disc was kept same for both the heat treatments (carburizing and cryogenics).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.***

Keywords: Cryogenic Treatment, Sliding Wear behavior, Alloy Steel

1. 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 is given by

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

Where Z is the number of atoms removed per atomic encounter, 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 deformation assumed for the asperities, which Holm considered the plastic deformation as predominant for the material removal. To this problem, Archard demonstrated that to satisfy a linear relationship between the wear rate and the applied load, some hypothesis on the shape of debris should be made, which implies in a new comprehension on the effective mechanism of material removal. 1

Greenwood and Williansom added to the Archard theory, the nature of deformation, considering the heights of asperities in contact. Their work and many others applied a probabilistic approach for the roughness of Surfaces in contact. However, there are few models with this approach for the wear coefficient. 1

2. 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. 1

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 [5].

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

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

3. Cryogenic Heat treatment

Cold treatments or subzero treatments are done to make sure there is no retained austenite during quenching. Cryogenics is a relatively new process and to eliminate retained austenite, the temperature has to be lowered. In cryogenic treatment the material is to be deep freeze temperatures of as low as -185°C (-301). The austenite is unstable at this temperature and the whole structure become martensite. Cryogenics is a supplementary process which is performed after conventional heat treatment; the research includes the carburized heat treatment followed by cryogenics heat treatment.

3.1 Sequence of the Heat treatment done on 20MnCr5

Sequence	*Process*	*Temperature*
I	Tempering	150 ^{0}C , 4 hr
II	Cryogenics	Cooled to -200 ^{0}C, 24 hr
III	Tempering	150 ^{0}C , 4 hr

4. 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

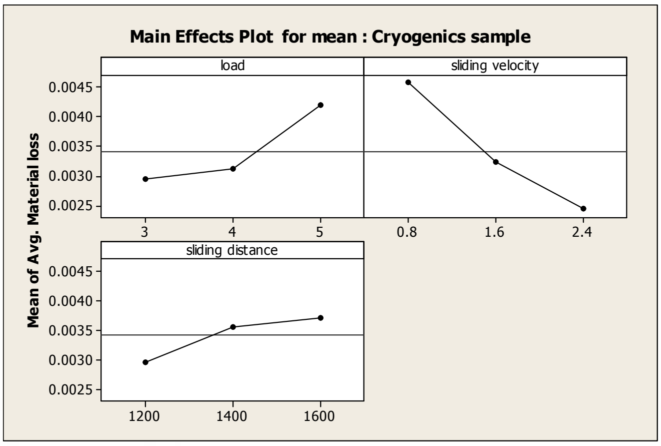
Taguchi L9 array is selected for carrying out the experimentation and weight loss in grams is measured after every trial.

5. Taguchi L9 array

Load	*Sliding Velocity*	*Sliding Distance*	*Material loss*	*S/N ratio*
3	0.8	1200	0.0034333	49.2115
3	1.6	1400	0.0030000	49.3738
3	2.4	1600	0.0024333	52.9357
4	0.8	1400	0.0045667	46.7097
4	1.6	1600	0.0030000	47.1824
4	2.4	1200	0.0017667	55.0538
5	0.8	1600	0.0057222	43.5311
5	1.6	1200	0.0037222	49.7191
5	2.4	1400	0.0031222	50.4098

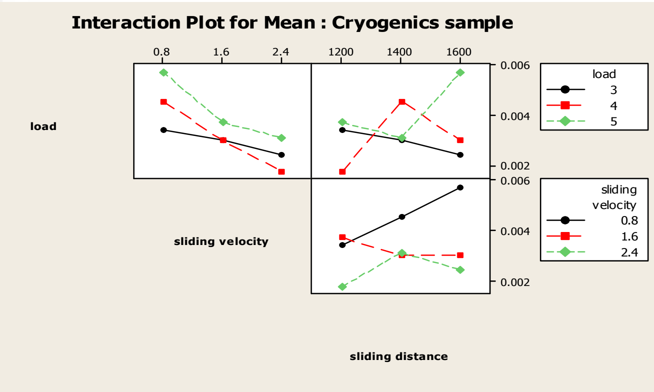
6. Results

6.1 Main effect Plots



From main 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 a condition, 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

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Load	2	0.0158133	0.0158133	0.0079066	65.77	0.015
Sliding Velocity	2	0.0058088	0.0058088	0.0029044	24.16	0.040
Sliding Distance	2	0.0364007	0.0364007	0.0182004	151.41	0.007
Error	2	0.0002404	0.0002404	0.0001202		
Total	8	0.0582632				

S = 0.0109640 R-Sq = 99.59% R-Sq(adj) = 98.35%

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

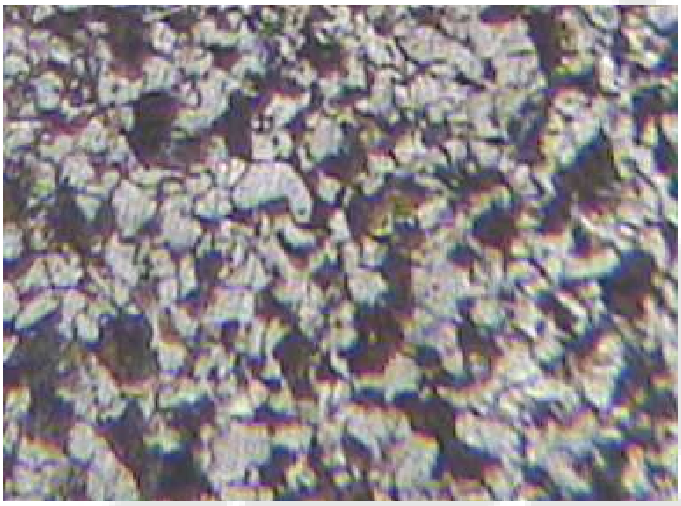
6.4 Regression analysis

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

Wear = - 0.00173 + 0.000629 Load - 0.00158 Sliding Velocity + 0.000004 Sliding Distance

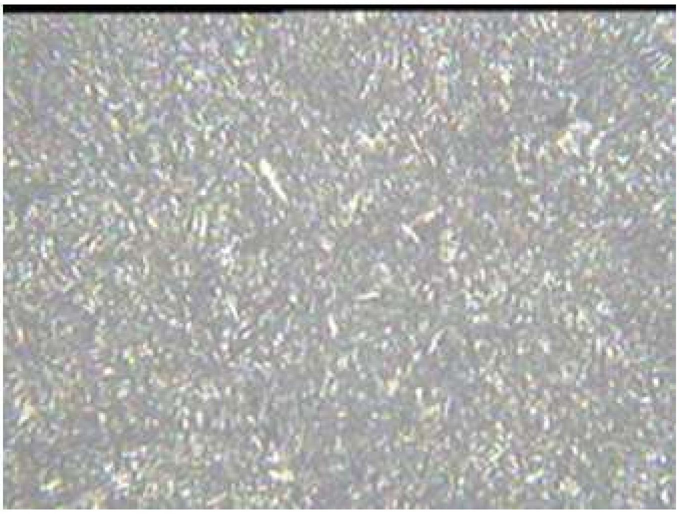
7. Microstructure

7.1 Raw Material



Raw material shows normalized ferrite

7.2 Carburized Sample



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

7.3 Cryogenics Sample

8. Conclusion

- Cryogenics heat treatment improves the microstructure and wear property of the material as amount of free ferrite observed in cryogenics heat treatment is less as compared into carburizing heat treatment.
- 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.

References

[1] Claudio R. Avila da Silva Jr., Giuseppe Pintaude, "Uncertainty analysis on the wear coefficient of Archard model" , Elsevier ,Tribology International 41 (2008) 473–481

[2] J.P. Wise, G. Krauss, D.K. Matlock, "Microstructure and Fatigue Resistance of Carburized Steels", 20th ASM Heat Treating Society Conference Proceedings, 9-12 October 2000.

[3] P. Rangaswamy, C.P. Scherer, M.A.M. Bourke, "Experimental measurements and numerical simulation of stress and microstructure in carburized 5120 steel disks", Materials Science and Engineering A298 (2001) 158–165, Elsevier.
[4] Xiaoliang Shi, Mang Wang , Wenzheng Zhai, Zhiwei Zhu,Zengshi Xu, Qiaoxin Zhang, Siyuan Song, Jie Yao, Abid Qamar ud Din, " Friction and wear behaviour of NiAl-10wt%Ti_3SiC_2 composites", wear 303(2013) 9-20,Elsevier.
[5] H.X. Zhu, S.K. Liu, X.J. Bai, Z.J. Li, "Sliding wear behaviour of planar random zinc-alloy matrix composites", wear 199 (1996) 82-88, Elsevier.
[6] Min-Soo Suh, Young-Hun Chae, Seock-Sam Kim, "Friction and wear behaviour of structural ceramics sliding against Zirconia", wear (2008) 800-806, Elsevier.
[7] M. Singh, D. P. Mondal, O. P. Modi, A. K. Jha, "Two-body abrasive wear behaviour of aluminium alloy-sillimanite particle reinforced composite", wear 253 (2002) 357-368, Elsevier.
[8] Yasin Alemdag, Temel Savaskan, "Mechanical and tribological properties of Al-40Zn-Cu alloys", Tribology International 42(2009) 176-182, Elsevier.
[9] J.D. Bressan, D. P. Daros, A. Sokolowski, R. A. Mesquita, C.A. Barbosa, " Influence of hardness on the wear resisitance of 17-4 PH stainless steel evaluated by the pin- on-disc testing", Journal of material processing technology 205 (2008) 353-359, Elsevier.
[10] Temel Savaskan, Osman Bican, Yasin Alemdag, "Developing aluminium-zinc-based a new alloy for tribological application", J Mater Sci (2009) 44:1969-1976

[11] Temel Savaskan, Osman Bican, "Dry sliding friction and wear properties of Al-25Zn-3Cu-3Si alloy", Tribology International 43(2010)1346-1352, Science direct.
[12] Paul Stratton, Michael Graf, "The effect of deep cold induced nano-carbides on the wear of case hardened components", Elsevier, cryogenics 49 (2009) 346-349.
[13] K.C. Raipurkar, Pravin L.Sarode, "Cryogenic treatment of metals and enhancement of mechanical properties", A National Conference on Advances in Mechanical Engineering (NCAME-2012)", World Journal of Science and Technology 2012, 2(4):53-59