ANALYSIS OF WEAR BEHAVIOR OF D6 TOOL STEEL BY INFLUENCE OF CRYOGENIC TREATMENT

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Abstract - *In Present work, the special effects of cryogenic treatment on the wear performance of D6 tool steel are noted. For present work, : -63` C as shallow cryogenic temperature and -185`C as deep cryogenic temperature are used. The special effects of temperature (deep & Shallow, time (at 20 and 40 h) on the wear performance of D6 tool steel are studied. Wear tests are performed using a pin-on-disk wear tester to which different loads & velocities are applied. The results show that the treatments decrease the retained austenite and hence get better the wear hardness & resistance. Due to more homogenized carbide allocation as well as the exclusion of the retained austenite, the profound cryogenic action demonstrated more enhancement in wear resistance & hardness weigh against with the shallow cryogenic treatment. By increasing the custody time at temperatures, supplementary retained austenite is transformed addicted to martensite; thus, the wear resistance is enhanced and further hardness are observed. The blend of heat treatment has to be optimised. For that reason DoE is performed. The DOE is done with minitab 16. Developed optimum runs with help of RSM by Box-Behnken design.*

Key Words: **D6 tool steel, cryogenic treatment (CT), wear behaviour, DOE, RSM**

1. INTRODUCTION

Tribology is the study of the friction, wear and lubrication deals with engineering surfaces with understanding surface interfaces in detail and then proposing improvements for specific applications. One of the important objectives in tribology is to regulate magnitude of frictional forces per the requirement of minimum or maximum frictional force in application. To regulate the fictional force we should understand the fundamentals of frictional process and should obtain for all conditions of sliding velocity, temperature, surface finish and material properties.

Years of research in tribology explains the friction and wear properties of a given material are not its intrinsic properties, but governed by on many factors correlated to a specific application. Quantitative values for friction and wear in the forms of wear rate and coefficient of friction governed by the following basic group parameters:

- The structure of the system, i.e. its components and their relevant properties;
- The operating variables, i.e. temperature, load (stress), time and kinematics;
- Mutual interface of the system components.

2. AISI D6 TOOL STEEL

Tool steels are urbanized to resist wear at temperatures of forming as well as cutting applications. Tool steel is used on a ample range of applications where wear resistance, toughness and other properties are noted for optimal performance. They are mostly alienated into six categories: high speed, cold and hot work, shock resisting, mould and special function tool steels [1].

Commonly, many more tool steels accomplish the requirements for a certain application, so final selection is directed by considering the tool life, cost of material and fabrication. Practical factor affecting the tool life is adhesion wear [1].

Even if the high abrasion resistance of D6 tool steels is pleasing for cold-work applications, turning and milling operations during manufacturing of finished dies and moulds are complicated.

3. APPLICATIONS OF D6 TOOL STEEL

Forming rolls, Measuring tools, slitting cutters, master tools, blanking, thread rolling, forming, extrusion, drawing lamination , coining dies ,heading tools, edging rolls, beading rolls, intricate punches, long punches, decorative knives, spinning tools, mill rolls, moulds for pressing abrasive powders, hunting knives, etc.

4. LITERATURE REVIEW

In tool steels, after the conventional heat-treatment a low percentage of austenite is retained and noted as ‘‘retained austenite”. Due to the retained austenite in soft phase could reduce the product life in steels and, can be transformed into martensite in working conditions. The transformed martensite may cause numerous problems in working tools.

Bourithis et.al [1] studied AISI D2 and O1 i.e. commercial cold work tool steels. The above said tool steels was given heat treatment in order to obtain the same hardness 700VHN i.e. 60 HRC and consequently tested in three different modes of wear, namely in adhesion, three-body and two-body abrasion, by using pin-on-disk, dry sand/rubber wheel apparatus and pin abrasion on SiC, respectively.

O. Barrau et.al [10] explained the contribution deals with the wear mechanisms of the AISI H11 tool steel under high-temperature and dry-sliding wear. The investigations were carried out wear test with high-temperature pin-on-disc tribometer. For different Disc temperature 20°C, 200°C, 500°C, 700°C, 800°C, 950°C test were carried out. For the high temperature, it was observed that the decrease of the friction coefficient could reduce the thickness plastically deformed, but the loss of the mechanical properties leads to a strong plastic deformation of the tempered martensitic lathes. SEM and Energy Dispersive Spectrometry (EDS) investigations were revealed that wear is essentially due to abrasion, plastic deformation and fatigue.

5. Experimental Analysis

The present work is conducted with samples of D6 tool steel.D6 tool steel is also noted as T30405. 9.20mm diameter round bars are selected for this work. Specimens for wear test are made ready of height 30mm & diameter 9.20mm. For hardness test specimens are made ready of height 10mm & diameter 9.20mm. The chemical composition has analyzed by Optical Emission Spectrometer. Table no.1 shows the chemical composition of D6 tool steel.

Table -1: Chemical Composition of D6 Tool

Element		C	Mn	Si	S	P	Cr	Mo	W
Weight %	Actual	2.16	0.38	0.35	0.011	**0.015**	**12.02**	**nil**	**0.23**
	AISI Specification	2.00-2.35	0.60 Max	0.30 - 0.50	0.030 Max	0.030 Max	11.00-13.00	--	**1.00 max**

6. TREATMENTS

The material selected for this work is gone through various treatments

TEMPERING

Tempering is the process in which the hardened components are heated up to a temperature between 100°C to 700°C and holding at same temperature for specific period and cooling to room temperature, usually by air.

The function of tempering is,

1. To reduce the internal stresses urbanized due to volume changes taking place in the austenite to martensite transformation and due to rapid cooling of steels after hardening process
2. To trim down hardness, brittleness and to swell ductility and toughness,
3. To abolish retained austenite [12].

HARDENING

Table 2: Different Heat Treatments given to D6 tool Steel

Sr.No.	1	2	3	4	5	6	7	8	9	10
Nomenclature	HT	HTT	HTTT	HCT	HCTT	HCTTT	HCST	HTCST	HTTCST	HTTTCST
Particulars of Treatment	Hardening (1020°C for 1 Hr), Single Tempering (210°C for 2 Hr)	Hardening (1020°C for 1 Hr), Double Tempering (210°C for 2 Hr)	Hardening (1020°C for 1 Hr), Triple Tempering (210°C for 2 Hr)	Hardening (1020°C for 1 Hr), Cryotreated (-185°C for 36 Hr), Single Tempering (210°C for 2 Hr)	Hardening (1020°C for 1 Hr), Cryotreated (-185°C for 36 Hr), Double Tempering (210°C for 2 Hr)	Hardening (1020°C for 1 Hr), Cryotreated (-185°C for 36 Hr), Triple Tempering (210°C for 2 Hr)	Hardening (1020°C for 1 Hr), Cryotreated (-185°C for 36 Hr), Soft Tempering (100°C for 1 Hr)	Hardening (1020°C for 1 Hr), Single Tempering (210°C for 2 Hr), Cryotreated (-185°C for 36 Hr), Soft Tempering (100°C for 1 Hr)	Hardening (1020°C for 1 Hr), Double Tempering (210°C for 2Hr), Cryotreated (-185°C for 36 Hr), Soft Tempering (100°C for 1Hr)	Hardening (1020 °C for 1 Hr), Triple Tempering (210°C for 2 Hr), Cryotreated (-185°C for 36 Hr), Soft Tempering (100°C for 1 Hr)

HARDNESS MEASUREMENT

The hardness of different samples is shown in Table no.3

Table 3- Hardness of Specimens

Sr. No.	1	2	3	4	5	6	7	8	9	10
Sample	HT	HTT	HTTT	HCT	HCTT	HCTTT	HCST	HTCST	HTTCST	HTTTCST
Hardness (HRC)	59.8	60.4	60.6	62.8	62.2	61.4	60.1	60.7	60.3	60.1
Hardness (VHN)	693	707	712	770	753	732	700	715	705	700

Experimental Setup

Fig. 1 Experimental Setup of Pin-on-disc Tribometer

Specifications of Pin on Disc Tribometer

Make	Ducom Ltd, Bangalore.
Pin Size	3 to 12 mm diagonal
Disc Size	160 mm dia. X 8 mm thick
Wear Track Diameter (Mean)	10 mm to 140 mm
Sliding Speed Range	0.26 m/sec. to 10 m/sec.
Disc Rotation Speed	100-2000 RPM
Normal Load	200 N Maximum
Friction Force	0-200 N, digital readout, recorder output
Wear Measurement Range	4 mm, digital readout, and recorder output
Power	230 V, 15A, 1 Phase, 50 Hz

Wear rates (WR) have been estimated by volumetric method from the recorded cumulative height loss of the specimens with respect to sliding distance in the steady-state wear regime considering mean of at least two test results under identical conditions.

Table 4- Wear Test Details

Sr. No.	1	3
Normal Load FN (Kg, N)	3.1,30.41	5.1,50.03
Pressure P (MPa)	0.4575MPa	0.7526 MPa
Velocity V (m/s)	1.5	1.5

Table 5- Rotating Disc Speed in rpm

Sr.	**No.**	1	2	3	4
Sliding Velocity Disc	**V(m/s)**	1.5			
Wear Track Diameter	**D(m)**	0.06	0.08	0.1	0.116
Disc Speed	**N(rpm)**	477.5	358.1	286.5	246.9

Results and Discussion

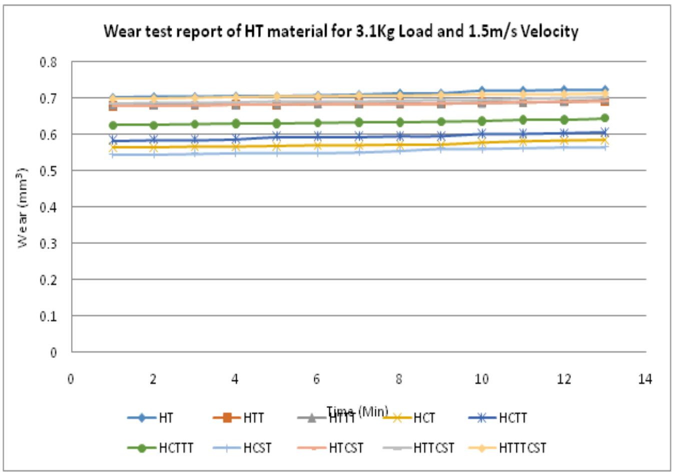

Fig. 1 Wear of D6 tool steel for different heat treatment - Velocity 1.5m/s and load 3.1Kg

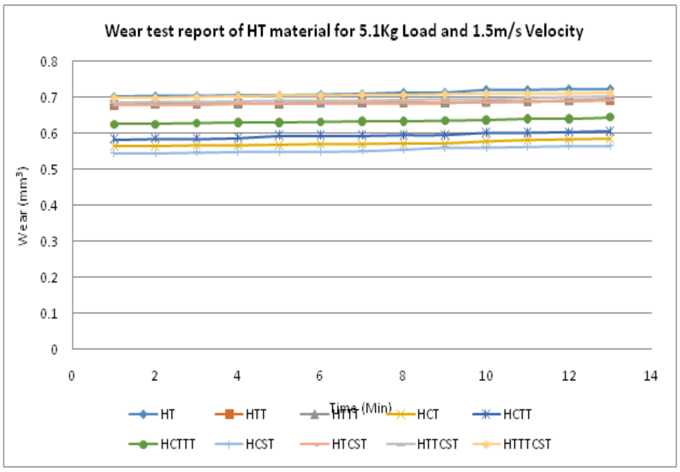

Fig. 2 Wear of D6 tool steel for different heat treatment - Velocity 1.5m/s and load 5.1Kg

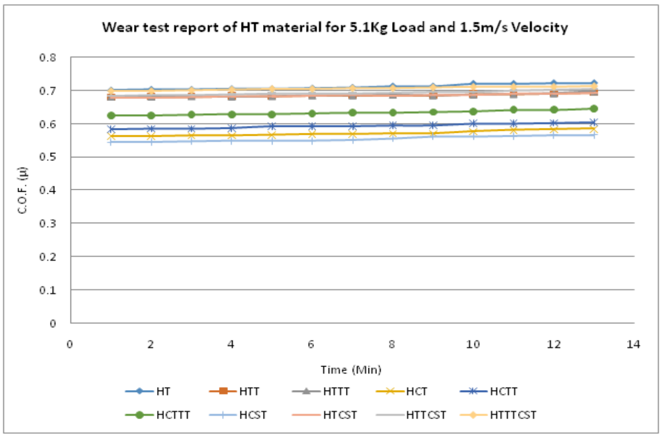

Fig. 3 Coefficient of Friction of D6 tool steel for different heat treatment - Velocity 1.5m/s and load 5.1Kg

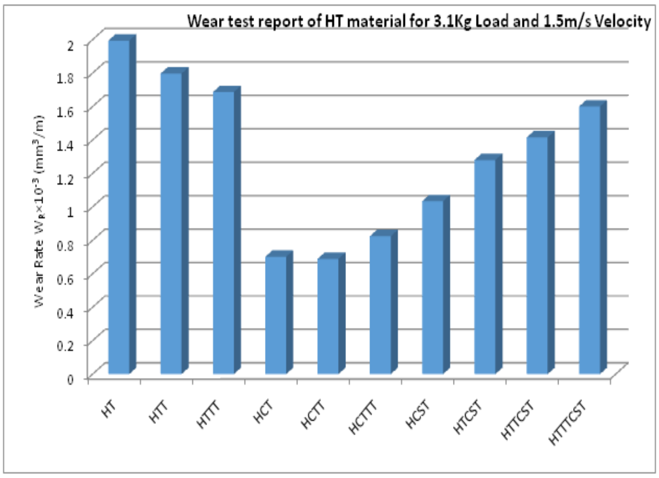

Fig. 4 Wear Rate of D6 tool steel for different heat treatment - Velocity 1.5m/s and load 3.1Kg

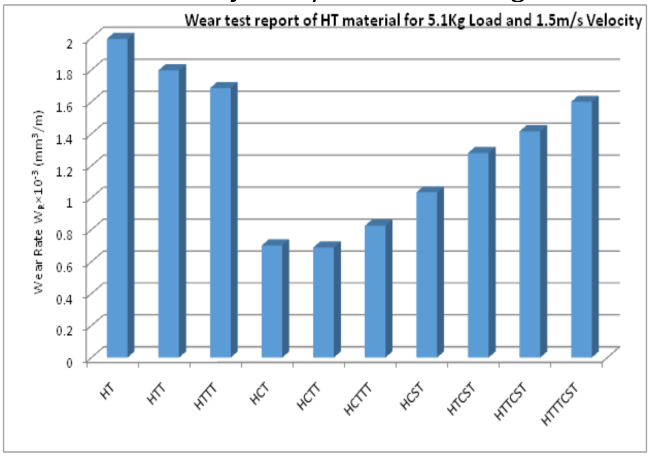

Fig. 5 Wear Rate of D6 tool steel for different heat treatment - Velocity 1.5m/s and load 5.1Kg

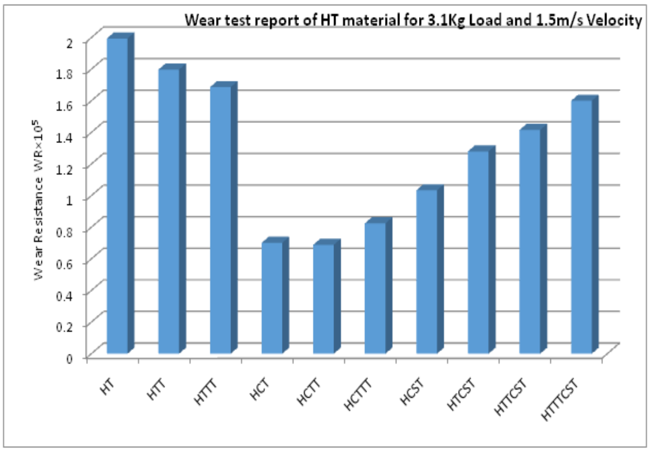

Fig. 6 Wear Resistance of D6 tool steel for different heat treatment - velocity 1.5m/s and load 3.1Kg

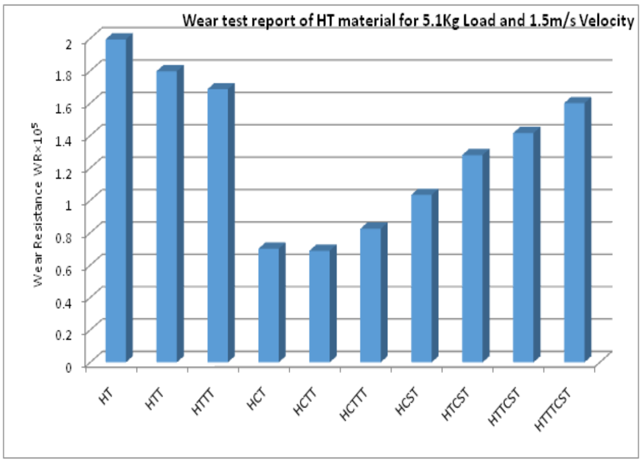

Fig. 7 Wear Resistance of D6 tool steel for different heat treatment - velocity 1.5m/s and load 5.1Kg

7. CONCLUSIONS

The current work done is based on the consequence of CT on friction and wears behaviour of D6 tool steel from experimental results.

As the Normal load increases the wear volume and wear rate (WR) increases and coefficient of friction decreases

From the results at the higher velocities the coefficient of friction is to be fluctuating and wear rate is enhanced

It is observed that there is improvement in the wear resistance in HCT, which is 140% to 248% that of the HT. The improvement in WR decreases with increasing normal load the material properties i.e. wear resistance, coefficient of friction, wear rate and Wear volume depends upon the combination of heat treatments.

The lowest wear volume, coefficient of friction and wear rate is observed in HCT among different heat treatments. As a outcome of the minor retained austenite, the cryogenic treatment improves the wear resistance and the hardness of the D6 tool steel.

REFERENCES

[1] L. Bourithis, G.D. Papadimitriou, J. Sideris; "Comparison of wear properties of tool steels AISI D2 and O1 with the same hardness"; Tribology International 39 (2006), pp 479-489.

[2] M. H. Staia, Y. Perez-Delgado, C. Sanchez, A. Castro, E. Le Bourhis, E.S. Puchi-Cabrera; "Hardness properties and high-temperature wear behavior of nitrided AISI D2 tool steel, prior and after PAPVD coating"; Wear 267 (2009), pp 1452-1461.

[3] A. Molinari, M. Pellizzari, S. Gialanella, G. Staffelini, K. H. Stiansy; "Effect of deep cryogenic treatment on the mechanical properties of tool steels"; Journal of Materials Processing Technology 118 (2001), pp 350-355.

[4] N. B. Dhokey, S. Nirbhavne; "Dry sliding wear of cryotreated multiple tempered D-3 tool steel"; Materials Processing Technology 209 (2009), pp 1484-1490.

[5] D. Das, A.K. Dutta, K.K. Ray; "Correlation of microstructure with wear behavior of deep cryogenically treated AISI D2 steel", Wear 267 (2009), pp 1371-1380.

[6] Cord Henrik Surberg, Paul Stratton, Klaus Lingenhole; "The effect of some heat treatment parameters on the dimensional stability of AISI D2"; Cryogenics 48 (2008), pp 42-47.

[7] D. Das, A.K. Dutta, K.K. Ray; "Optimization of the duration of cryogenic processing to maximize wear resistance of AISI D2 steel"; Cryogenics 49 (2009), pp 176-184.

[8] A. Akhbarizadeh, A. Shafyei, M.A. Golozar; "Effects of cryogenic treatment on wear behavior of D6 tool steel"; Materials and Design 30(2009), pp 3259–3264.

[9] N. Saklakoglu, I.E. Saklakoglu, V. Ceyhun, O. R. Monteiro, I.G. Brown; "Sliding wear behaviour of Zr-ion-implanted D3 tool steel"; Tribology International 40(2007), Analysis of Friction And Wear Behaviour of D2 Tool Steel 84 pp 794–799.

[10] O. Barrau, C. Boher, R. Gras, F. Rezai-Aria; "Analysis of the friction and wear behavior of hot work tool steel for forging"; Wear 255 (2003), pp 1444-1454.

[11] G. Roberts, G. Krauss, R. Kennedy; "Tool Steel", Fifth Edition, ASM International, Latrobe, Pennsylvania, 1980, pp. 1-28 & 203-218.

[12] V. D. Kodgire, S. V. Kodgire; "Material Science and Metallurgy for Engineers", Twenty Sixth Edition, Everest Publishing House, 2010, pp. 308-416.