International Journal of Mechanical and Industrial Technology ISSN 2348-7593 (Online)
Vol. 3, Issue 1, pp: (242-247), Month: April 2015 - September 2015, Available at: www.researchpublish.com

Tribo Analysis of Hot Forging Tool Steels

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***Abstract*: Wear is the progressive damage, involving material loss, which occurs on the surface of a component as a result of its motion relative to the adjacent working parts; it is the almost inevitable companion of friction. Most tribological pairs are supplied with a lubricant as much to avoid the excessive wear and damage which would be present if the two surfaces were allowed to rub together in dry condition. The aim of this contribution is to assess the wear mechanisms of hot forging tool steels at various test temperature and also at different load conditions. The tribological tests are performed on a high temperature pin-on-disc tribometer in the laboratory. Experiments are carried out for varying load conditions & different test temperatures ranging 50ºC to 450ºC and wear mechanisms are investigated by this method.**

***Keywords*: Tribology, Wear, Weibull distribution, Reliability analysis.**

I. INTRODUCTION

During the hot metal forming process, the forging tools are submitted to thermal and mechanical cyclic stresses. Under such working conditions, tools are usually damaged through complex and interactive mechanisms under cyclic loading like abrasive, adhesive and spalling wear. The main factors influencing die life are thermal fatigue, plastic deformation and wear etc. Amongst these, wear is the dominating failure mechanism for forging dies, being responsible for approximately 70% of failures. The aim of this contribution is to assess some wear mechanisms of different hot forging tool steels at various test temperature and under varying load conditions.

II. TRIBOLOGICAL STUDIES

The understanding of the tribological behaviour in hot forging dies is crucial to develop new tool steels and tool steel coating systems. Direct examination of industrial tools may provide information about the acting damaging mechanisms but this is tedious, time consuming and may not feasible in some industrial applications (mainly due to size of tools and their high cost that do not permit the use of destructive analysing techniques).Thus a lab scale test that reproduces the tribological behaviour of tools during hot working process will help to evaluate the applicability of different tool steels.

A. *Pin-on-disc tribometer:*

The tribological studies were carried out using a DUCOM pin on disc tribometer, which consists of a pin on disc, loading panel and controller. The sample machined as a pin is attached to the pin holder mechanism of the machine. The wear disc is a EN 31 steel disc, hardened to 60HRC. For rotation of the disc to take place, time period of revolution is set up initially in the control panel. The equipment is designed to apply loads up to 200N & speeds starting from 200 to 2000 rpm, provision is made only to conduct tests under dry and heated conditions.

Fig.1: Pin on disc tribometer

This apparatus facilities study of friction and wear characteristic in sliding contacts under different test conditions, sliding occurs between the stationary pin and a rotating disc .The normal load, rotational speed & wear track diameter can be varied to suit test conditions. Tangential frictional force and wear are monitored with electronic sensors and recorded on PC.These parameters are available as functions of load and speed.The specifications of the instrument are given in the table.

Table1: Specifications of the pin-on-disc tribometer

Parameter	Unit	Minimum	Maximum
Disc speed	RPM	200	2000
Pin diameter	mm	4	12
Pin length	mm	20	60
Wear track diameter	mm	50	100
Normal load	N	5	200
Frictional force	N	0	200
temperature	°C	0	600

B. *Materials:*

The pin samples are made up of AISI L6, AISI H11and AISI O1 hot forging tool steel specimens. Whereas the disc is a EN 31 steel disc, hardened to 60HRC. The hardness values and chemical composition of the tool steel specimens are reported in Table 3.

Table 2: Hardness values of the material

Material	Hardness
AISI O 1	52HRC
AISI L 6	58HRC
AISI H 11	54HRC

Table 3: The chemical composition (wt %) of AISI O 1, AISI L 6 AND AISI H 11

Element	AISI O 1	AISI L 6	AISI H 11
C	0.85-1.00	0.65-0.75	0.30-0.40
Mn	1.00-1.40	0.20-0.80	0.20-0.50
Si	0.50	0.50	0.80-1.2
W	0.40-0.60	-	-
Mo	-	0.50	1.10-1.75
Cr	0.40-0.60	0.60-1.20	4.75-5.50
V	0.30	0.30	0.80-1.20
Co	-	-	-
Ni	0.30	1.25-2.00	0.30

Fig.2: Test specimens of AISI L6, AISI H11 and AISI O1.

C. *Test procedure:*

Before doing the experiment, all test specimens and specimen holders were cleaned in petroleum spirit and were then rinsed with hexane solution. Initially, tribological tests are carried out without chamber heating in dry condition (no lubrication).In heating condition; chamber is first heated up to a given constant temperature and kept at temperature during the test. For conducting each test three different specimen samples are used. To evaluate the influence of load on wear behaviour, different tool samples are tested under varying load condition (constant track diameter and sliding speed) without any lubricants. The applied load varies from 10N to 20N .To assess the effect of the disc temperature on wear damage, the normal load (60 N) ,track diameter and the linear sliding speed are kept constant. Temperature varied from 50ºC to 450ºC.Test duration is five minutes in all the cases.

III. WEAR RESULTS

The wear results obtained during the test can be presented in terms of wear volume. But commonly represented in terms of specific wear rate (K) which is calculated as follows:

$$\text{Specific wear rate} = \frac{\text{Volume of wear}}{\text{Applied load} \times \text{Sliding distance}}$$

Here wear volume is in mm3, applied load in N and sliding distance is in mm.
Sliding distance is calculated as,

$$\text{Sliding distance} = \frac{\pi \times D \times N \times T}{60000}$$

Here D is the diameter of wear track in mm, N is the disc speed in rpm and T is the test duration in second.

A. *Variation in specific wear rate under varying load:*

Fig.4 shows the variation of average value of specific wear rate (K) of each die material with load in ambient temperature. Initially, all the three samples show an identical nature such that specific wear rate increases with increase in the load. This trend is more on AISI O1 and then followed by AISI H11 and AISI L6. When the load increases above 20 N, specific wear rate values decreases gradually in all the three cases as shown in the fig. This is mainly due to the formation of wear debris in the disc, which prevents the fresh contact between them and wears rate decreases. But the further increase in the load above 40 N causes an increase in the specific wear rate, which is more on in the cause of AISI O1 and then followed by AISI H11 and AISI L6.This is due to, with increase in load, the previously formed wear debris are flush off and wear rate increases. In the case of AISI L6 , the variation of specific wear rate value shows a gradual increase when the load is increase from 50N to 60N.

During chamber heating, the variation of average value of specific wear rate with temperature is shown in the figure. With increase in temperature average value of specific wear rate increases in all the three cases. But this trend is less in the case of AISI L6.The graphs of the other two specimens (AISI H11, AISI O1) shows a gradual increase. In all these cases the specific wear rate value is highest for AISI O1 followed by AISI H11.

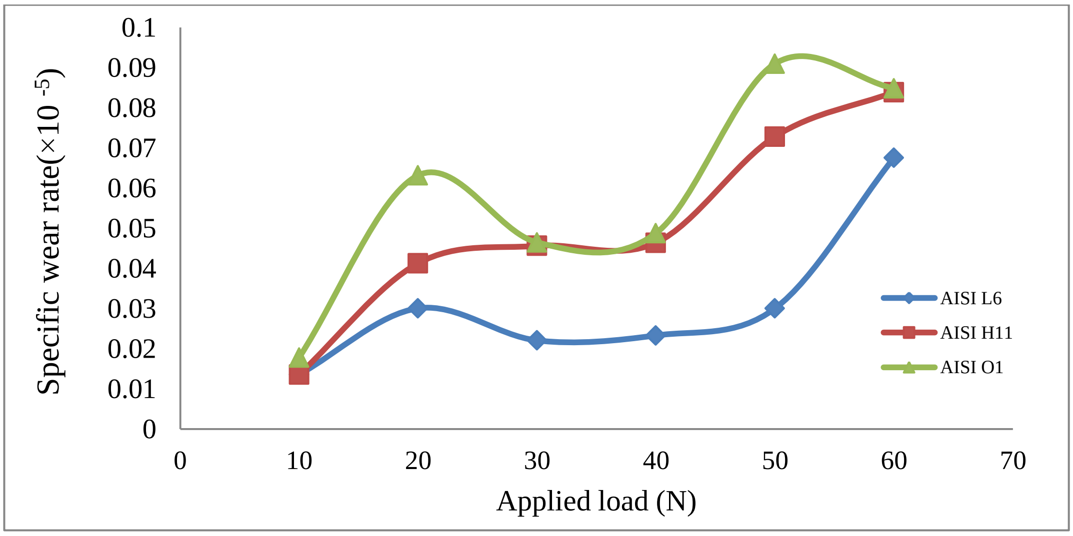

Fig.4: Variation in specific wear rate under varying load

Table 4: Average values of specific wear rate under varying temperature.

Temperature	Average value of Specific wear rate (10 -5)		
	AISI L6	AISI H11	AISI O1
30	0.0659574	0.088235	0.085440
150	0.0744242	0.1309	0.13581
300	0.0811474	0.15380	0.16804
450	0.0881750	0.16442	0.18929

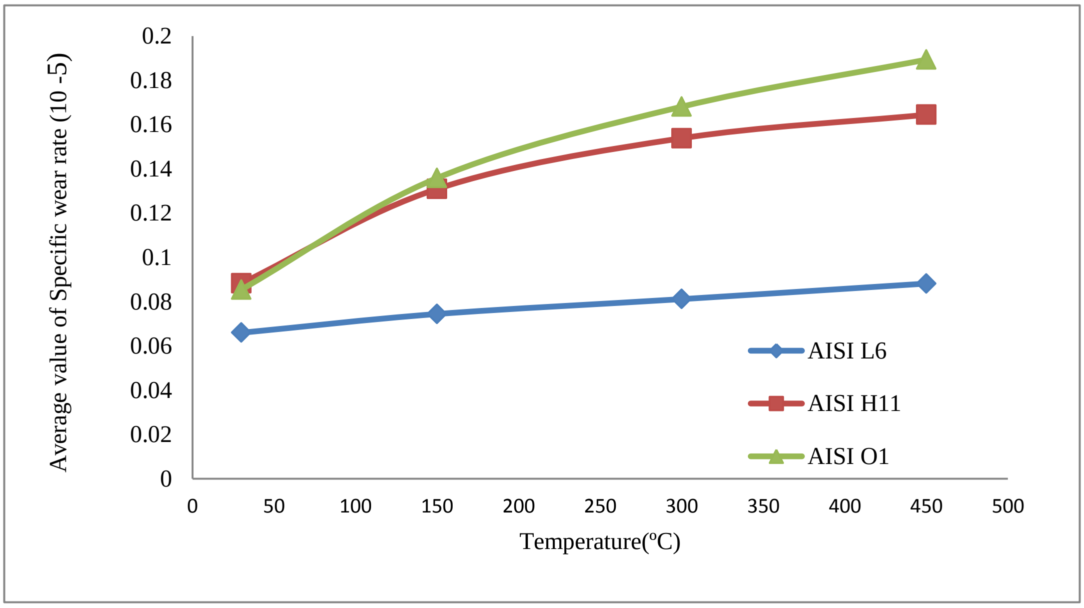

Fig.4: Variation in specific wear rate under varying temperature

IV. FRICTION RESULTS

The variation of maximum value of friction coefficient with temperature in each die material is shown in the fig.5.6. At room temperature, the value of friction coefficient is characteristic of a metal-metal contact. With increase in temperature, all the three material samples shows an increased value of friction coefficient up to a temperature of 300ºC.Above 300ºC, there is a slight decrease in the value of the friction coefficient in all the three cases. Maximum value of friction coefficient is observed in all the samples at a temperature of 300ºC, which is higher for AISI O1, then followed by AISI H11 and AISI L6.

Table 5: Average values of μ max under varying temperature.

Temperature	Average value of μ max		
	AISI L6	AISI H11	AISI O1
50	0.203	0.378	0.392
150	0.436	0.438	0.446
300	0.508	0.572	0.674
450	0.406	0.353	0.481

The tribological studies performed at elevated temperatures have shown that friction between the rotating disc and tool steel specimens are temperature dependent. However, a slight decrease was observed (not a strong one) possibly owing to formation and compaction of oxidized wear debris at elevated temperature.

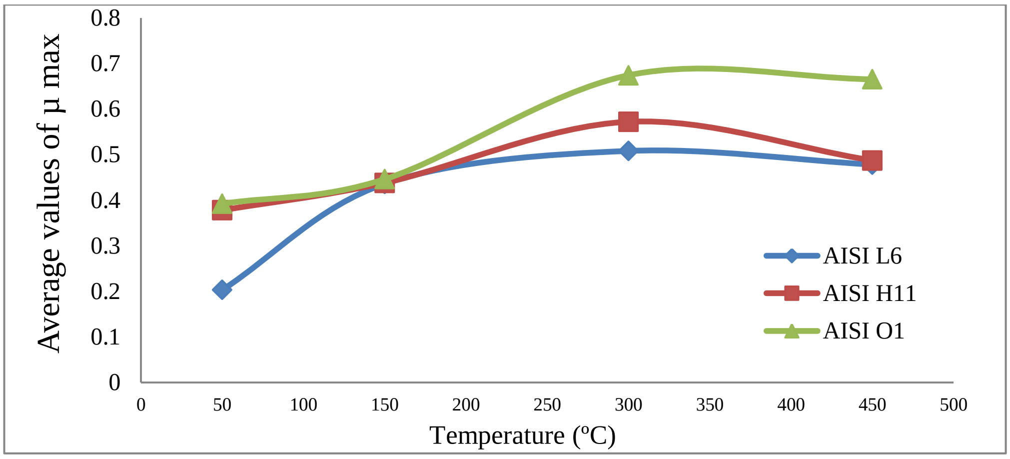

Fig.5: variation in average value of friction coefficient under varying test temperatures.

The friction curves of the one of the tool steel specimen (AISI L6) at different test temperatures are given below. The following curves explain how the friction coefficient varies with temperature in a particular test interval by fixing other parameters as constant

Fig.6: variation of friction coefficient with time at 450°C in AISI L6 (Sample1) specimen

Fig. 7: variation of friction coefficient with time at 450°C in AISI H11 (Sample1) specimen

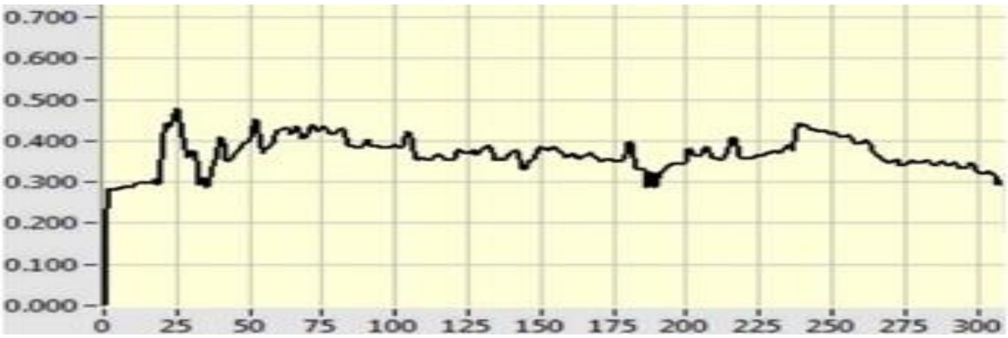

Fig.8: variation of friction coefficient with time at 450°C in AISI O 1 (Sample1) specimen

V. CONCLUSION

Experimental studies pertaining to the friction and wear behavior of different tool steels sliding against a rotating high hardened disc have been carried out at room temperature (varying loads) and at elevated temperature (450°C). These results indicate that the operating temperature and external load have significant influence on the tribological behavior of the tool steel during sliding against a rotating high hardened disc. The salient conclusions from this study are as follows.

1. At room temperature, under varying load conditions the wear characteristics (in terms of specific wear rate) of the tool steels AISI H11 and AISI O1 are different from tool steel AISI L6.With increase in the load, specific wear rate also increases up to 20 N, then again it decreases (this is mainly due to the formation of wear debris in the disc, which prevent the fresh contact between them and wear rate decreases) and further increase in load causes an increase in the value of specific wear rate (with increase in load, the previously formed wear debris are flush off and wear rate increases) in all the three tool steel materials. But the lowest value of specific wear rate is always shown by AISI L6 specimen.

2. During chamber heating, the variation of average value of specific wear rate with temperature is as with increase in temperature average value of specific wear rate increases in all the three cases. But which is less in the case of AISI L6.

3. At room temperature, the value of friction coefficient is characteristic of a metal-metal contact. With increase in temperature, all the three material samples shows an increased value of friction coefficient up to a temperature of 300ºC.Above 300ºC, there is a decrease in the value of the friction coefficient in all the three cases(due the formation of oxide wear debris). Maximum value of friction coefficient is observed in all the samples at a temperature of 300ºC, which is higher for AISI O1, then followed by AISI H11 and AISI L6.

4. At 400°C, the tribological properties are strongly influenced by the temperature. Friction at 400°C is about 0.4 for AISI L6 tool steel compared to 0.2 at room temperature. The hardness values of AISI L6 tool steel specimens have significant effect on the initial friction behaviour and also influence the final friction.

5. The wear mechanisms observed are predominantly adhesive at room temperature and a combination of abrasive and adhesive at higher temperature. Among all the tool steel specimens, AISI L6 resulted in lower friction and wear compared to the other tool steel variants at room temperature and at elevated temperatures.

6. The above results show that the excellent wear resistance of the AISI L6 tool steel specimen is attributed to its resistances to the plastic deformation and crack initiation.

REFERENCES

[1] Niels Bay, A Azushima, P Groche, I Ishibashi, M Merklein, M Morishita, T Nakamura, S Schmid, M YoshidA, 2010, Environmental tribo-systems for metal forming, CIRP Annals-Manufacturing Technology, 59-2, 760-780.

[2] E.R. Booser, 1997. Tribology Data Handbook, CRC Press, ISBN 0-8493-3904-9.

[3] K. Kato, Wear in relation to friction - a review, Wear 241 (2000) 151–157.

[4] B. Batora, K. Vasilko, Machined surfaces - technological heredity and functionality, 1st ed., GC Tech, Trencin, 2000.

[5] J. Chen, X. Xu, Tribological characteristics in high speed grinding of alumina with brazed diamond wheels, in: International Journal of Advanced Manufacturing Technology, 2014, vol. 71, pp. 1579-1585.

[6] Baker, T. N., How, H. C., 1997. Dry sliding wear behavior of saffil-reinforced AA6061 composites. Wear 210, 263-272.