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Comparison of Wear Properties of AISI D3 and O1 Steel with the Same Hardness

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Abstract
Die wear is an undesired and unpredictable failure and downtime reason in metal forming operations. It directly affects the part formability and surface quality, and causes production loss, cost increase and delays. In sheet metal stamping, the wear of deforming dies continues to be a great concern to the automotive industry as a result of increasing die maintenance cost and scrap rate. The demand to reduce the use of lubricants and increase tool life in sheet metal stamping has resulted in increased research on the suitable combination of die materials. During production, the higher forming forces, higher wear; galling and premature die surface failures, and eventually insufficient product quality, interrupted production, and unexpected cost increases. Hence, in order to prolong the die-life, reduce down-time, and increase production rate and profitability; manufacturers are looking into alternative die materials, coatings, lubricants and their compatible combinations that would increase the die-life/ performance at reasonable cost levels. There are so many options and combinations of die materials and coatings that it is rather time-consuming to select a proper, if not optimal, pair of die material and coating for a given application. The various types of tool or die steels are there which are used in industries like sheet metal industry and press working. The wear of tools or dies is a common problem in these industries. Hence the present study aims to investigate the wear performance of AISI D3 die steel against mild steel under dry sliding conditions. Sliding parameters such as sliding speed, sliding time and normal load are taken.

1. Introduction

Cold work steel dies are important tools used in sheet metal stamping. During the operation, the higher forming forces, higher wear, galling and premature die surface failures, and eventually insufficient product quality, interrupted production, and unexpected cost increases. Hence, in order to prolong the die-life, reduce down-time, and increase production rate and profitability; manufacturers are looking into alternative die materials, coatings, lubricants and their compatible combinations that would increase the die-life/performance at reasonable cost levels. There are so many options and combinations of die materials and coatings that it is rather time-consuming to select a proper, if not optimal, pair of die material and coating for a given application.

2.Experimental procedure and test materials

In the present study, wear and friction monitor- TR 201 has been used for wear study of pins of AISI D3 steel. The Ducom wear and friction monitor TR 201 Series has become the industry standard in wear and friction analysis. The TR 201 Series tribometer is specifically designed for fundamental wear and friction characterization. This instrument consists of a rotating disk against which a test pin is pressed with a known force. A provision for measurement of compound wear and frictional force is provided.

Table 1 Technical specification of Wear and Friction monitor TR-201

PARAMETER	Minimum	Maximum
Pin Diameter (mm)	4	8
Disc Size (mm)	0	100
Wear Track Diameter (mm)	50	80
Disc speed (r.p.m)	100	1000
Normal Load (N)	10	100

Table 2 Chemical composition of Steels, % weight

Grade	C	Mn	P	S	Si	Cr	V	W	Mo
D3	2.135	0.275	0.025	0.014	0.506	11.463	0.047	0.034	0.02
O1	0.92	1.29	0.03	0.03	0.65	0.79	0.3	0.56	----

Table 3 Chemical Composition of mild steel, % weight

Element	C	Mn	P	S	Si	V	Cr	Moly	Fe
Percentage	0.102	0.456	0.028	0.016	0.192	0.011	0.048	0.053	rest is Fe

Table 4 Parameters and their levels

Factor	Level			
Load (N)	50	50	50	50
Speed (m/s)	1.16	1.67	2.2	2.56
Time (min)	10	10	10	10

3. Results and Discussions

The complete results of 16 experiments were carried out for further analysis. The influence of each parameter was carried out with the help of various plots. Different types of wear processes also revealed out with the help of SEM observations. Several parameters were developed to quantify the wear performances of materials. Table 5 shows the specific wear rate and weight loss of AISI D3 at different speeds. The smaller values of specific wear rates means high wear performance.

Table 5 Experimental Results **(**At a Load and time of 50N and 10 Min respectively**)**

Speed *(m/s)*	Material			
	AISI D3		AISI O1	
	Weight lose *(g)*	Specific wear *(mm^3/Nm)*	Weight lose *(g)*	Specific wear *(mm^3/Nm)*
1.15	0.0936	3.62E-04	0.2301	8.62E-04
1.67	0.0508	1.35E-04	0.0279	1.15E-04
2.2	0.1013	2.05E-04	0.0445	1.80E-04
2.56	0.1354	2.35E-04	0.0922	4.69E-05

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Fig. 1(a): Friction behaviour of AISI D3

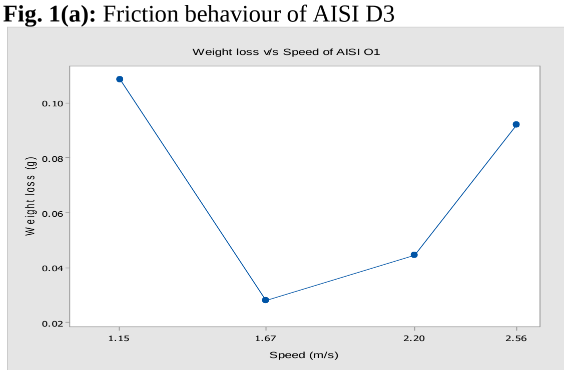

Fig.1(b): Friction behaviour of AISI O1

3. Wear behavior of AISI D3 and O1 steel

Figure 2 shows the Scanning Electron micrograph of worn out surfaces of AISI D3. As observed, when the speed was 1.15 m/s the transfer layers of compacted wear debris can be observed over the surface. These layers reach a critical thickness before being detached from the surface resulting in higher weight loss. The sign of both abrasive and adhesive wear are there on the surface. As the speed is increased, the worn surface appears very smooth and sign of abrasive wear are there and no layer has been formed due to material transfer. Now as the speed is increased to a higher level the transfer layers are formed due to high heat generation and the wear behavior is adhesive. As the layers Fig. shows the Scanning Electron micrograph of worn out surfaces of AISI O1 steel. The SEM micrograph of AISI O1 steel at a speed of 1.15 m/s shows almost same results as AISI H11. In this the layers of transferred metal are formed along the wear track and are detached after reaching a critical thickness. So the weight loss is more at such speed. Here the normal load has affected the wear rate more than sliding speed. Also the wear debris can be observed on the surface. The sign of both abrasive and adhesive wear are there on the surface. As observed, at a speed of 1.67 m/s the surface is smooth and wear behavior is abrasive. As the speed is increased, high heat is generated due to high temperature which results in formation of oxide scales. The formation of oxide layer on the surface inhibits the wear.

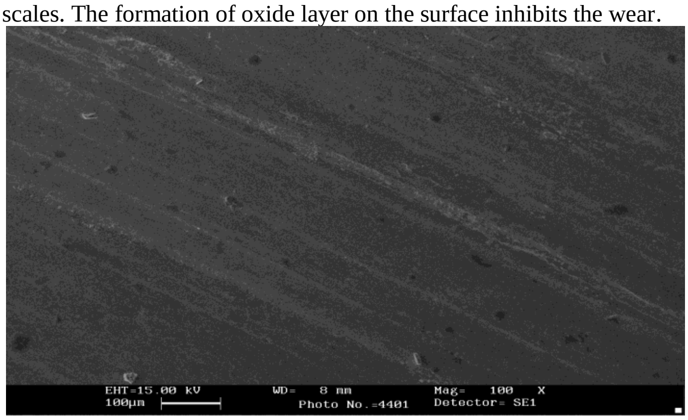

Fig. 2 (a): SEM Micrograph of worn surface of AISI D3 steel pin at speed 1.15 m/s

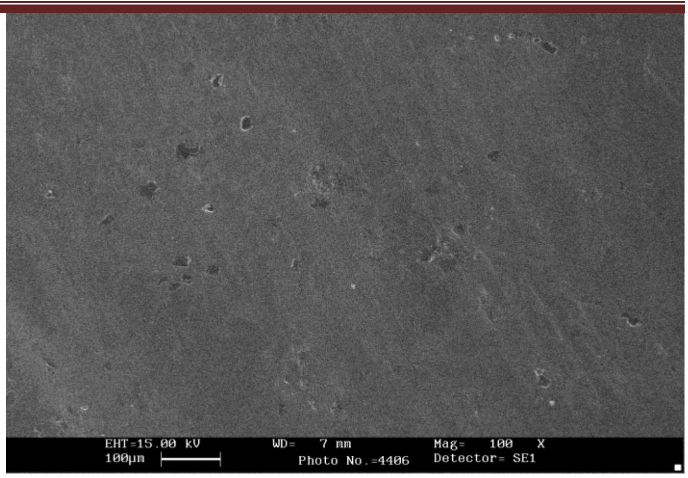

Fig. 2 (b) SEM Micrograph of worn surface of AISI D3 steel pin at speed 1.67 m/s

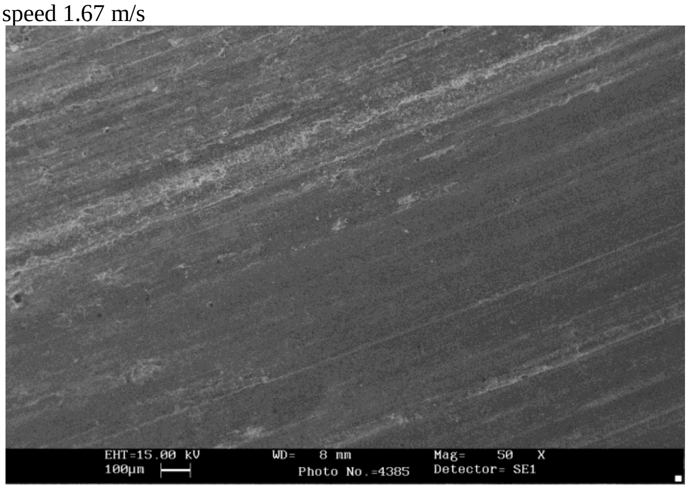

Fig. 2(c): SEM Micrograph of worn surface of AISI D3 steel pin at speed 2.56 m/s

4.Conclusions

The relationship between weight loss (wear volume) and sliding speed has been developed. The experimental results show that at a speed of 1.67 m/s, the weight loss is minimum. As the speed is increased the weight loss increases. This is due to the generation of high frictional heats due to formation of high temperature. The rise of surface temperature softens the substrate of the rubbing materials; these enhance the rate of delamination. Different wear mechanisms were observed depending upon the current values of speed. Abrasion, adhesion, galling and surface ploughing are the dominating wear processes, observed in the study through SEM investigations.

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