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Study of Wear Characteristics of AISI H11 Steel

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Abstracts

In metal casting and forming industries, the wear of dies continues to be a great concern to the automotive industry due to increasing die maintenance cost and scrap rate. The demand to reduce the use of lubricants and increase tool life in pressure die casting has resulted in increased research on the sliding contact between the tool and the metal. Hence it has been recognized that the deforming conditions, such as - normal load, sliding speed, sliding time etc. affect the performance of the operation to a greater extent [3]. The objective of the present work is to assess the effect of the sliding parameters on the wear of AISI H11 steel. It is used as the die material in many hot working processes and other press working industries. The experiments have been conducted on PIN ON DISK (TR-20LE-PHM-400). The wear experiments were performed on pins made of AISI H11 steel and disks made of Aluminium 6082. Design of experiment with three independent factors (normal load, sliding speed, sliding time) has been used to develop relationships for predicting weight loss of pins caused by rubbing action[2]. The weight loss of pins has been measured within 10-4 g precision.

Keywords: Die materials, die wear, contact pressure, sliding distance, die wear test.

Introduction

Among the property requirements of hot working dies, the following can be considered to be the most important: hot strength, thermal stability, ability to resist abrasion (wear resistance) by the work piece scales formed at the high temperatures of working. Chromium hardened and tempered largely fulfil these requirements and hence are the first choice for the dies in the pressure die casting industries. The sliding parameters such as normal load, sliding speed, sliding distance or sliding time etc., play a vital role in controlling the wear of the die material[5].

The wear is the progressive loss or removal of material from a surface. It has important technological and economical significance because it changes the shape of the tool and die interfaces and hence that of the work-piece. Thus it affects the process, size & quality of the parts produced. General engineering materials have limitations in achieving optimum levels of strength, stiffness, density, toughness and wear resistance. To overcome these shortcomings, discontinuously reinforced aluminium metal matrix composites are gaining importance due to their high specific strength, high stiffness, low density and good wear resistance, they have the potential to replace their monolithic counterparts primarily in automotive, aerospace and energy applications[1]. The Aluminium 6082 alloy has the highest strength and ductility of the aluminium alloys with excellent machinability and good bearing and wear properties[6].

Experimental procedure and test materials

In the present study, pin on disk tribometer (TR-20LE-PHM-400) has been used for the study of pins of H11 steel. The Ducom pin on disk Tribometer (TR-20LE-PHM-400) Series has become the industry standard in wear and friction analysis. The TR 20LE Series tribometer is specifically designed for fundamental wear and friction characterization[3]. This instrument consists of a rotating disk against which a test pin is pressed with a known force. A provision for testing at elevated temperature is also provided. The pin-on-disk wear tester makes use of a high torque drive motor to rotate a flat sample under a loaded wear pin. The wear pin creates a circular wear track of the required diameter by offsetting the pin relative to the sample's centre of rotation. Different wear track diameters allow a number of tests to be performed on one sample. The same linear speed can be used for all tests by adjusting the rotational speed for each diameter. The load can be varied by adjusting the amount of dead weight hung at the end of the loading beam[8]. An additional arrangement to change the temperature during experiments also exists. The samples are positioned on the sample table. Values for the following parameters are then selected via computer control.

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Fig. 1 PIN ON DISK (TR-20LE-PHM-400) (Industrial Engineering lab, GNDEC, Ludhiana.)

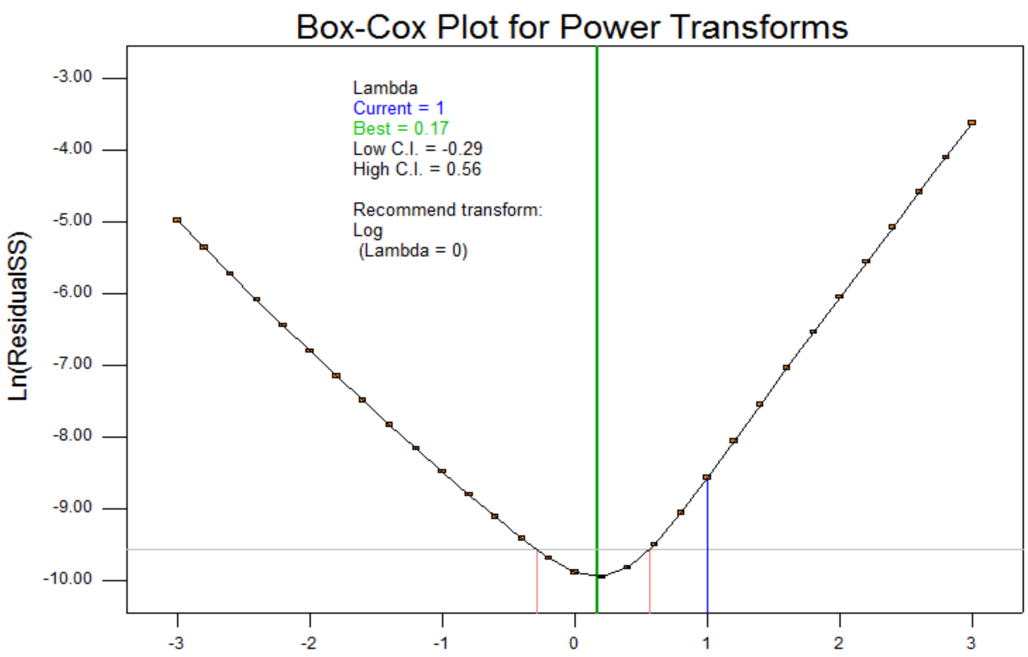
Fig. 2 Pin specimen made of H11 stee(beforewear) ***Fig 3 Pin specimen made of H11 steel (after wear)***

Table 1 Parameters and their levels according to response surface methodology

Factors	Symbol	Type	Levels	Low Level	High Level
Speed (N)	A	Numeric	1.75	1.00	2.50
Load (m/sec.)	B	Numeric	40.00	20.00	60.00
Time (min.)	C	Numeric	9.00	4.00	14.00

Result and discussion

The complete results of the 20 experiments performed as per the experimental plan were input into the Design Expert 8.0.4.1 software for further analysis. In this paper the mathematical models for showing relationship between dependent parameter (weight loss) and independent parameters (normal load, sliding speed, sliding time), ANOVA for response surface quadratic model. This paper presents the influence of all the parameters on weight loss and optimization of parameters for minimum weight loss. Optimization has been carried out by studying various plots, contour plots and 3D surface graphs. Various plots like Box-Cox plots for power transforms, normal plot of residuals, plot of residuals v/s predicted response and plot of predicted v/s actual response have also been studied.



The figure 3 shows the Box-Cox transformation for the residuals. The Box-Cox provides a family of transformations to normalize the data which are not normally distributed by identifying an appropriate exponent (Lambda =λ). The Lambda value indicates the power to which all data should be raised. Box and Cox originally envisioned this transformation as a panacea for simultaneously correcting normality, linearity and homogeneity (Mayers& Montgomery, 2002).

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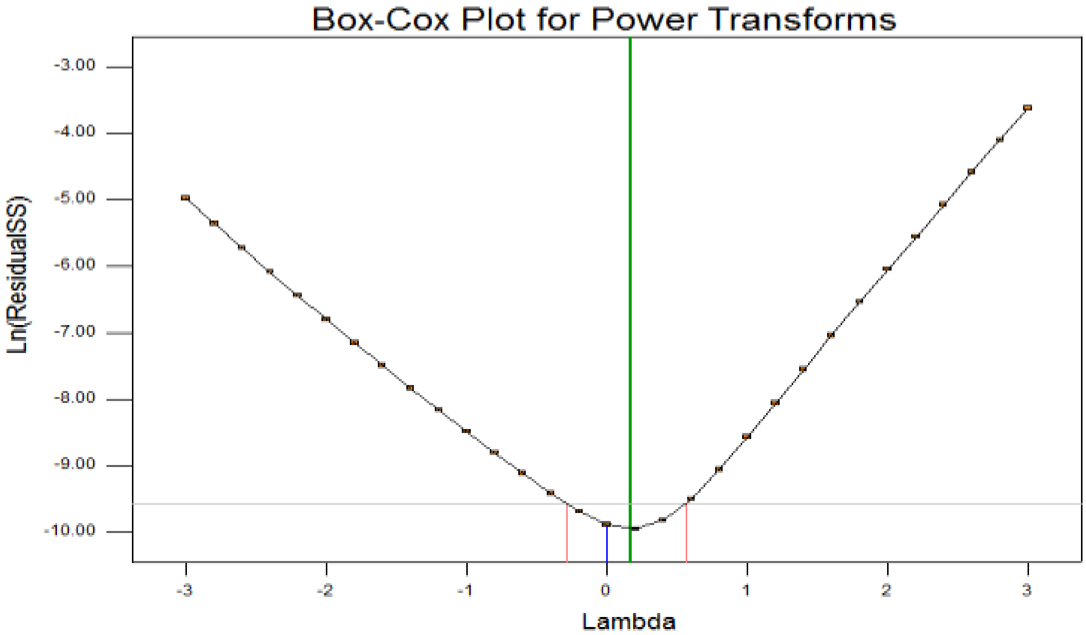
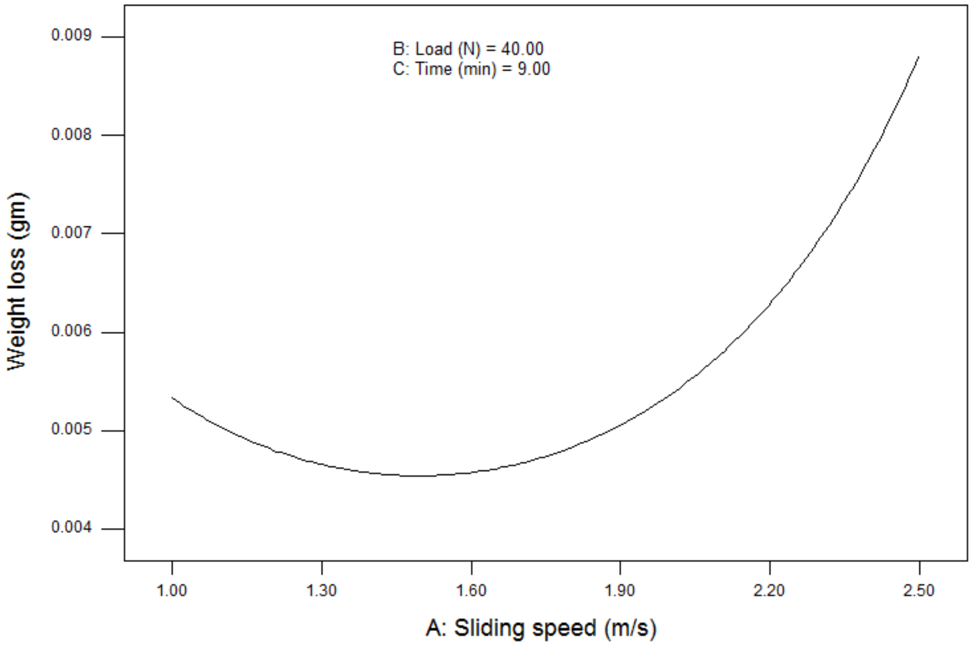


Fig. 4 shows Box-Cox plot after natural log transformation. Figure indicates the current value of lambda is close to best recommended value of lambda which demonstrates that residuals follow the assumptions of ANOVA.

Effect of sliding speed on weight loss

Influence of sliding speed on weight loss at constant load of 40 N and time 9 min is shown in fig. The effect of sliding speed on weight loss is quite random and usually depends upon the current normal load as well as the materials of rubbing pairs. The result shows that the effect of sliding speed on weight loss is scattered within the range of testing parameters. The weight loss decreases as the sliding speed increases upto 1.4 m/s. After that weight loss increases continuously as sliding speed increases. The weight loss reaches at a minimum level at sliding speed 1.5 m/s. When the normal load is increased to some levels, the increase in sliding speed cause the rate of generation of frictional heat to increase, and so raises the surface temperature. The rise of surface temperature softens the substrate of the rubbing materials; these enhance the rate of delamination.



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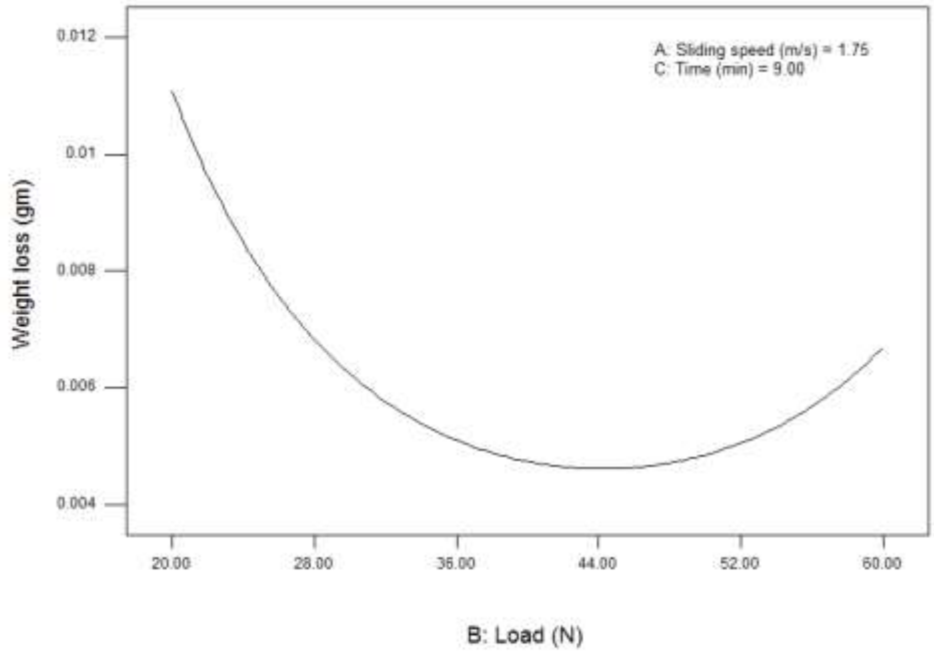
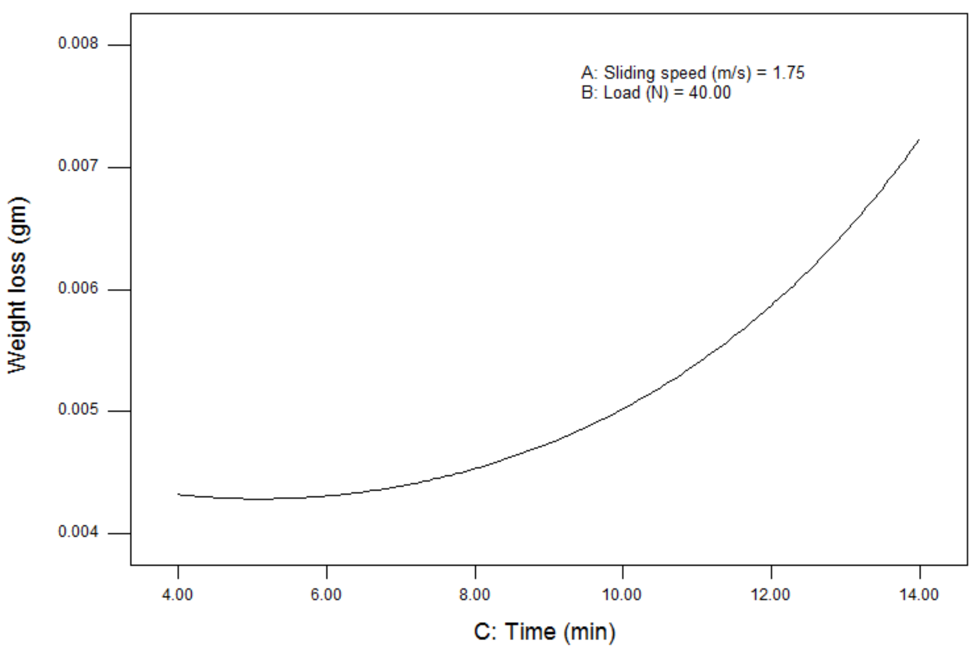
Effect of load on weight loss

Influence of normal load on weight loss at constant speed of 1.75 m/s and time 9 min is shown in fig.6 The result shows that the effect of normal load on weight loss is scattered within the range of testing parameters. The weight loss decreases as the normal load increases from 20 N. The weight loss reaches at a minimum level when the load is 44 N. However when the load further increases the weight loss also increases until it reaches to 60 N.



Effect of sliding time on weight loss

Influence of sliding time on weight loss at constant load of 50 N and speed of 1.67 m/s is shown in fig. 7 It is clear from the plot that as the sliding time increases from 4 min to 12 min, the value of weight loss continuously increases.



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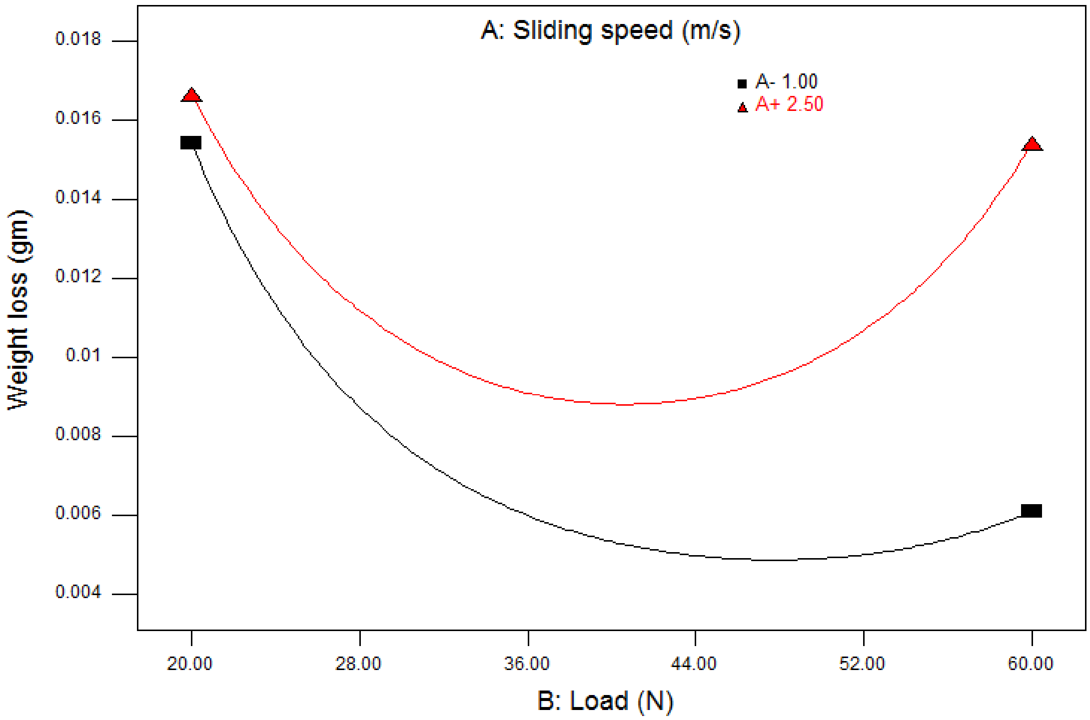
Interaction effect of normal load and sliding speed

Influence of interaction between load and speed on the average weight loss at constant sliding time of 9 min is shown in fig 8. From the interaction plot it is clear that as the load increases the weight loss decreases after a certain value of load again weight loss increase with increase in load. From the plot it has also been revealed that weight loss is higher at high value of sliding speed for all the values of load. Hence it is explicable from the result that if the sliding speed is kept constant but the load varies, there is a critical load over which the wear rate of the stationary pin increases to a much higher value. The rapid increase in wear rate is caused by the massive volume in the pin undergoing plastic deformation. The plastic deformation may be caused by a decrease in flow stress at high bulk temperatures.



The 3D surface graphs for weight loss is shown in fig. 5.10 and the curves have curvilinear profile in accordance to the quadratic model fitted.

Optimization of sliding conditions

In the present study, the aim is to obtain the optimal values of sliding parameters in order to minimize the value of weight loss of the steel pins. The constraints used during the optimization process are summarized in Table 5.3.The optimal solutions are reported in Table 5.4.

Table 2 Constraints for optimization of sliding conditions

Condition	Units	Goal	Lower limit	Upper limit
Sliding speed (A)	m/s	Is in range	1	2.5
Load (B)	N	Is in range	20	60
Time (C)	min	Is in range	4	14
Weight loss	gm	Minimize	0.0032	0.0436

Table 3 Optimization results

Solution No.	Sliding speed (m/s)	Load (N)	Time (min)	Wt. Loss (gm)	Desirability	Remarks
1	1.53	51.56	4.00	0.00352	0.991307	Selected
2	1.55	51.23	4.00	0.00355	0.991284	
3	1.50	51.94	4.00	0.00356	0.99126	

Conclusion

The important conclusions drawn from the present work are summarized as follows:

The relationship between weight loss and applied load, sliding speed, sliding time has been developed. The predicted results are in good agreement with the measured ones. These relationships are applicable within the ranges of tested parameters. All the three independent parameters (load, speed, time) seem to be the significant sliding parameters. The results of ANOVA and the confirmation runs verify that the developed mathematical model for weight loss (wear volume) show excellent fit and provide predicted values of weight loss that are close to the experimental values, with a 95 percent confidence level. The optimum result of weight loss has been observed to be 0.00352 gm, corresponding to normal load = 51.56N, sliding speed = 1.53 m/s, sliding time = 4 min.

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