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Investigation of Wear Behavior of 1060 and 1095 Steels using Regression Analysis

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ABSTRACT

The dry adhesive wear behavior of 1 060 and 1095 steels using pin on wheel wear test rig at room temperature under different wear conditions has been studied. The prepared specimens were normalized to m ake sure that all specimens are in the same conditions.

'The objective of this rese arch is to study the effect of operating parameters such a s rotating s peed , normal load and sliding time and their interaction on the wear behavior using regression analysis. Detailed data obtained was used to develop equations to describe the wear rate of steels. The wear losses of the specimens were expressed in term s of simultaneous contribution from the effects of rotating speed , normal load , sliding time and t heir interaction.

By applying the parameters such as rotating speed , normal load , and sliding time,observed a certain effects on the wear behavior of two types steel , the 1060 steel , sliding time is the m a in factor, followed by normal load and rotating speed . However ,for the 1095 steel , rotating s peed i s the main factor, followed by normal load and sliding time.

From results, it was concluded that the wear behavior of these steel s and the effects of this parameters on the wear depend on the physical and mechanical properties of this types of steels.

KEYWORDS: Wear behavior; Wear equations; Regression analysis; Dry sliding, 1060 and 1095 steel s; operating parameters.

فحص سلوك البلى للفولاذ 1060و1095 باستخدام تحليل الانحدار

الخلاصة

تم دراسة تصرفات البلى الالتصاقي الجاف لسبائك من الصلب الكربوني ذات محتوى كربون 0.60 % و 0.95 % باستخدام جهاز اختبار البلى المسمارعلى الدولاب وعند درجة حرارة الغرفة والانزلاق الجاف تحت ظروف بلى مختلفة . العينات المحضرة استخدمت بحالة المعادلة للتأكد بان جميع العينات بنفس الظروف . الهدف من البحث هو دراسة تأثير ظروف التشغيل مثل السرعة الدورانية والحمل المسلط وزمن الانزلاق وتأثيرها المتداخل

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على سلوك البلى باستخدام تحليل الانحدار <. النتائج التي تم الحصول عليها تم أستخدامها للحصول على معادلات رياضية لوصف معدل البلى للصلب . تم وصف معدل البلى من خلال التأثير المتداخل للسرعة الدورانية والحمل العمودي وزمن الانزلاق وتأثيرها المتداخل . من خلال تطبيق المتغيرات مثل تأثير السرعة الدورانية والحمل العمودي وزمن الانزلاق تم ملاحظة تأثيرات معينة على تصرفات البلى لكلا النوعين من الصلب الكربوني . ان اهم متغير للصلب 1060 هو زمن الانزلاق يليه الحمل العمودي ومن ثم السرعة الدورانية .أما الصلب 1095 فأن السرعة الدورانية هي العامل الرئيسي المؤثر ثم الحمل العمودي وزمن الانزلاق.

تم الاستنتاج من النتائج بأن سلوك البلى لهذه الانواع من الصلب وتأثيرها ظروف التشغيل على البلى تعتمد على الخصائص الفيزيائية والميكانيكية لهذه الانواع من الفولاذ.

INTRODUCTION

ALL wear analysis are very complex since there are many interdependent factor affecting the final removal of wear debris and formation of worn surface (1-2). It was \Nell established that .sometimes small changing in some variable totally change the wear rarer and wear mechanism (3). Therefore, it requires a technique that can predict the mechanism and wear rate under all parameters affecting the wear phenomena (4).A statistic analysis namely regression analysis based on modeling can analysis all the• variables in concern (5). Regression analysis i s focused on the effect of dependent variable and the related independent variables control the process. All information regarding the regression analysis can be found in the article of Prof. Sykes (6).

Wear is one of common failure mechanisms in machine parts. It has become an important subject in Tribology [7]. Steels are the most widely used and least expensive metallic on earth [8]. As well - known, the wear behavior of steel s can be influenced by many factors [9]. The factors which are studied rotating speed, normal load, and sliding time are the common factors. Many researches on wear behavior of steels have beendone and reported on the effect of these factors on wear [1O] . The effect of operating parameters and their interactions on wear behavior of steel s has not yet been studied. The aim of this paper was to investigate the effect of rotating speeds, applied loads, sliding time and their interactions on wear behavior of steels using regression analysis• in order to fully understand the effect of these factors on wear behaviour of materials. The wear tests were carried o u t using pin on w heel wear test rig at room temperature in dry sliding.

Materials and Experimental Procedures

Materials and preparations

The material s used in this paper were 1060, and 1095 steels. Their compositions andmechanical properties are given in Tables 1 and 2. The specimens prepared ascylindrical pins. The pins were 20mm in length and 6mm in diameter. All pins were treated as normalizing by heating to austenite temperature for 10 min then air cooled to room temperature. The aim of normalizing treatment was obtaining a homogeneous structure.

pin on Wheel

The wear tests were carried out u s m g pm on wheel wear test ri g in production engineering and metallurgy laboratories a t room temperature in dry sliding, as shown in Fig .l . The tool steel was used as the wheel material. W heel of 60mrn in diameter and 20mm in thickness, was fitted on shah that was driven by a n electrical motor. Loa d was applied by a dead weight on the pin holder. Three rotating speeds were fed from a n electrical motor and reduced by stepped pulley. Prior to the test, the pins were weighed using a balance with a precision of ±0.l mg. The wear amount of pins was defined as wear loss in (mg) with respect to the initial weight.

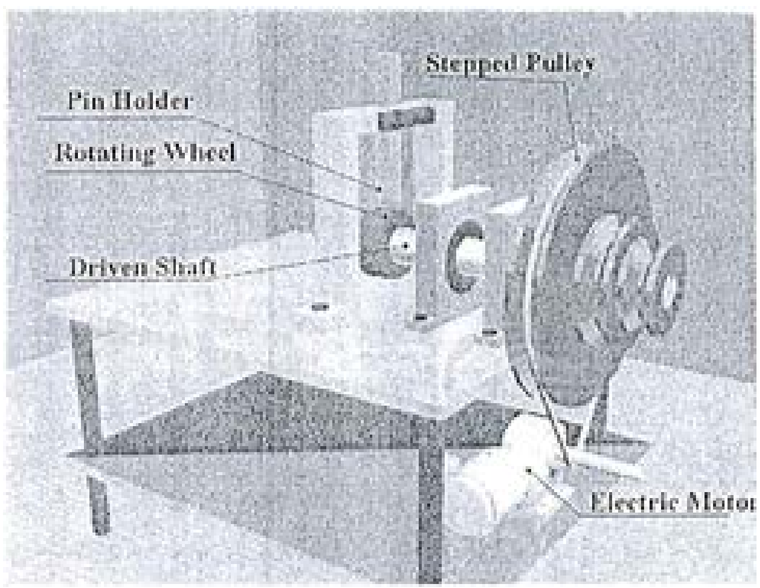

Figure (1). Schematic diagram of pin on wheel wear test rig.

Table(1). Composition of the steels used.

AISI	C%	Mn%	Si%	S%	P%
1060	0.6	0.4	0.25	0.03	0.03
1095	0.95	0.17	0.17	0.02	0.02

Table (2) Mechanical properties of the steels used.

Mechanical properties	AISI	
	1095	1060
Tensile stre n gth , MPa	1014	776
Y ield strength, MPa	500	421
Elongat ion %	9.5	18
Reduction in area %	13.5	372
Hardness (V. H)	293	229

Results and Discussion

Test Arrangement and Results

The effects of rotating speed (V, rpm), normal load (P , N), sliding time (t, min) and their interactions on the wear loss were investigated . The investigated parameters and their test level the range of normal load s was 50, 100, 150, and 200 N and the range of Speeds was 500, 850, and 1 200 rpm. Sliding times were differing in range of 30, 60 and 90 min as shown in Table 3. The test arrangement and results are listed in Table 4.

Table 3. Investigated para meters and their test levels.

test levels	rotating speed v ,(rpm)	Sliding time t , (min)	Normal loud P. (N)
Lower Level(-1)	500	30	50
Zero Level (0)	850	60	200
Higher level (+1)	1200	90	125

Regressive Equation between Mass Loss and its Affecting Parameters

A regression equation was established with the wear loss as the dependent variable and wit h a quadratic dependence on the three factors as independent variables. The significant coefficients of this equation were identified by regression analysis, using computer program Minitab 12 [11]. The coefficient describes the contribution of parameters to the amount of wear. The coefficients are estimated by minimizing the s um of the squared differences between y predicated and y observed. The absolute value of a coefficient, relative to its standard error, suggests the relative degree to which thecorresponding variable contributes to the &mount of wear.

A positive sig n for a give n coefficient suggests that higher contribution of the parameter increase the amount of wear, whereas a negative suggests that lower contribution provides higher wear amount. Variables are considered in order of their relative importance as indicated by tests studied based on the magnitude of the coefficient, relative to the standard error. Coefficients whose given tests have a small probability ($P < 0.05$) under the null hypothesis indicate significant contributions to the dependent variable.

Based on the output results in Tables 5 and 6, by using regress ion equations between wear loss y (mg) and each individual parameter as well as their interactions can be
obtained.
For 1060 steel, the regression equation y 1 (mg) was expresses as:

$$y_1 = 377- 67.7X_{11} + 73.3 X_{12} + 77.9 X_{13} + 9.86 X_{21} - 33.6 X_{23} \quad \text{. ….(1)}$$

And for 1095 steel , the regress ion equation y 1 (mg) was ex presses as:

$$y_2 = 248-111X_{11} + 68.2 X_{12} + 40.3 X_{13} - 51.6 X_{11} X_{12} + 37.4 X_{11} X_{13} \quad \text{….(2)}$$

Checking the Adequacy of the Developed Equations

The adequacy of fit estimated regression equations was tested by applying Analysis of Variance (ANOVA), as shown in Tables 5 and 6, using computer software SPSS 9 [1 2]. For significance level $\alpha = 0.05$, and based on p-value, it can be concluded that the developed equations of 1060 and 1 095 steels f it the experimental wear data adequacy.

Regression Analysis

The standard error (Se) to estimate i s one of a good indication of the fit in regression analysis method. If there are 68 % of the observations will falls within ± 1 Se, if there are 95% of the observations will fall s within ±2Se , and 99.7% of the observations will falls within ± 3 Se, then the regression equation s will be fit the experimental wear data [13]. The bellow results show good fit of the developed equations to the experimental wear data shown in table 7.

Calculated R^2 values (0.924) for]• 060 steel and (0.887) for 1095 steel as shown in Tables 5 and 6, it can be indicated that 92.4(% of the variation in the response (wear) was attributed the selected operating parameters, for 1 060 steel , and 88. 7% of the

variation in the response (wear) was attributed the selected operating parameters, for 1095 steel, during wear process.
The calculated adujsted-R2values (0.9 11) for 1060 steel and (0.8 68) for 1095 steel as shown in Tables 5 and 6, it can be indicated that the samples size and terms of the equations was satisfactory.

DISCUSSION

The regression coefficient can be taken as a measure of the role of parameter on the wear, the stronger the role of the parameter, the higher the coefficient. From the wear regress ion Equations, (1) and (2), it was see n that, during the wear process, the parameters such as rotating speed, normal load, and sliding time have certain effects on the wear behavior of two steels.

Among these parameters, sliding time is the main factor, followed by normal load and rotating speed for the wear of 1060 steel. However, rotating speed is the main factor, followed by normal load and sliding time for the wear of 1095 steel.

The relative role of operating parameters have been varied due to change in the physical and mechanical properties such as surface hardness, toughness, microstructure,… etc. resulted in the variations of the relative role of the parameters during the wear processes.

CONCLUSIONS

The main aim of this research was to investigate the effects of three operating parameters and their interactions on the wear of 1060 and 1095 steels, and to correlate the wear loss with these operating parametars.
In particular, the following observations and conclusions wear made:

1. A successful attempt has been made to describe the wear behavior of 1060 and 1095 steels using regression equations. The tegression equations between operating parameters and wear loss exhibit a good correlation with experimental measurements within the range of investigation.
2. Slibing time is the main parameter, followed by normal load, while rotating speed ptays less effect on the wear of 1060 steel then the other two parameters.
3. Rotating speed is the main parameter, followed by normal load, while sliding time plays less effect on the wear of 1095 steel then the other two parameters.
4. The individual operating parameters exerted a different on the two steels. The value of the relative degree of effect was dependent on the physical and mechanical properties of the materials.

Table(4). Test arrangement and results

Runs	**Rotating speed** ***V(rpm)***	**Sliding time** ***t(min)***	**Normal load *P(N)***	y_1**(mg)**	y_2**(mg)**
1	1200	30	5	141.3	20
2	1200	60	5	291	105.9
3	1200	90	5	295	162
4	1200	30	10	168.6	93.2
5	1200	60	10	319	122.2
6	1200	90	10	305	146.2
7	1200	30	15	244	53.9
8	1200	60	15	380	120
9	1200	90	15	383	153
10	1200	30	20	354	111.4
11	1200	60	20	494	130
12	1200	90	20	458	358.4
13	850	30	5	159.5	139.5
14	850	60	5	330	198.1
15	850	90	5	283	275.2
16	850	30	10	155	234.4
17	850	60	10	350	239.3
18	850	90	10	327	268.2
19	850	30	15	211	173.3
20	850	60	15	442	261.6
21	850	90	15	425	290.5
22	850	30	20	448	238.1
23	850	60	20	589	257.4
24	850	90	20	571	436
25	500	30	5	202	141.5
26	500	60	5	409	182.3
27	500	90	5	394	190
28	500	30	10	326	253.2
29	500	60	10	572	483.1
30	500	90	10	483	261.7
31	500	30	15	366	518.2
32	500	60	15	552	345.6
33	500	90	15	543	379.1
34	500	30	20	414	556.3
35	500	60	20	605	560
36	500	90	20	592	580.7

Table (5) Statistical of wear data of 1060 steel.

Analysis of Variance:						
Model	Sum of Squares		df	Mean Square	F	p
Regression	648571.186		5	129714.237	46.924	0.000
Residual	82930.131		30	2764.338		
Total	731501.316		35			
Coefficients :						
Model	**Un- standardized Coefficients**			**standardized Coefficients**	**T**	**P**
	Coefficient	Std. Error		Beta		
(Constant)	248.319	8.763		-	28.338	0.000
X_{11}	-111.479	10.732		-0.639	-10.387	0.000
X_{12}	68.168	7.838		0.535	8.697	0.000
X_{13}	40.333	10.732		0.231	3.758	0.001
X_{11} X_{12}	-51.558	9.599		-0.33	-5.371	0.000
X_{11} X_{13}	37.425	13.144		0.175	2.847	0.008
Model summary:						
R	R^2	Adjusted R^2		Std. Error of the Estimate (S_e)		
0.942	0.887	0.868		52.58		

Table 6 Statistical analysis of wear data of 1095 steel.

Analysis of Variance:						
Model	Sum of Squares	df	Mean Square		F	p
Regression	585931.815	5	117186.363		72.513	0.000
Residual	48482.031	30	1616.068			
Total	634413.846	35				
Coefficients :						
Model	**Unstandardized Coefficients**		**Standardized Coefficiens**		**t**	**p**
	Coefficient	Std. Error	Beta			
(Constant)	377.261	6.7	-		0.000	0.000
X_{11}	-67.713	8.206	-0.416		0.000	0.000
X_{12}	73.344	5.993	0.618		0.000	0.000
X_{13}	77.9	8.206	0.479		0.000	0.000
X_{21}	9.86	4.738	0.105		0.046	0.046
X_{23}	-33.5785	4.738	-0.358		0.000	0.000
R	**R^2**	**Adjusted R^2**	**Std. Error of theEstimate(S_e)**			
0.961	0.924	0.911	40.2			

Table (7). The relationship between standard error (S_e) and observations.

Steel 1060			Steel 1095		
±1 S_e	±2 Se	±3 Se	±1Se	±2 Se	±3 Se
70% of the observations fell in with this range	95% of the observations fell in with this range	100% of the observations fell in with this range	75% of the observations fell in with this range	97% of the observations fell in with this range	100% of the observations fell in with this range

NOMENCLATURE

Symbol	Description	Units
-1	Low level of parameter	
0	Zero level of parameter	
+1	High level of parameter	
P	Normal load	N
P	Probability for F- ratio test (p-value	
V	Rotating speed	rpm
X_{11}	First order of rotating speed	
X_{12}	First order of normal load	
X_{13}	First order of sliding time	
X_{21}	Second order of rotating speed	
X_{22}	Second order of normal load	
X_{23}	Second order of sliding time	
t	Sliding time	min
y_1	Wear loss of 1060 steel	mg
y_2	Wear loss of 1095 steel	mg
df	Degree of freedom	
α	Significance level	
R	Coefficient of multiple correlation	
R^2	Multiple coefficient of determination	

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