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Wear Analysis of Aluminium - Zinc Alloys under Dry Lubrication

Gaurav L. Deshpande[1]*, S. A. Sonawane[2], K. V. Nemade[3]

[1]PG Student, Government College of Engineering, Aurangabad, India

[2]Assistant Professor, Government College of Engineering, Aurangabad, India

[3]Assistant Secretary, MSBTE, India

Abstract – In this study, the effect of applied load, sliding time and sliding velocity on the wear and frictional behaviour of Aluminium Zinc and its three alloys is studied. These alloys consist of Cu, Mn, and Si, containing Al-Zn-Cu-Mn-Si (0-5%). Experiments were carried out by using a single pin type on disc machine with design of experiment based on taguchi approach and L9 array. The specific pressure applied i.e. applied load is the most significant parameter followed by the sliding velocity. Material Al-Zn-Cu-Mn-Si (2.5%) gives the best friction performance and can be considered as a good tribo material from friction point view.

Keywords— Wear, Friction, Alloys, Aluminium-Zinc, ANOVA.

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INTRODUCTION

Wear is one of the main causes of the material wastage, is an important problem related with industrial components. Friction is the natural phenomenon of resistance to motion between moving surfaces.

Zinc based alloys have been proven to be a good bearing material. However, copper based zinc alloy suffer from the low ductility and dimensional instability problems. To eliminate these problems zinc was replaced with aluminium and this resulted in stability of the alloy. As a result of these investigations Al-Zn-Cu-Si alloy have been developed. The wear resistance, tensile strength, hardness of this alloy was much higher than traditional bearing bronze. This can be hence be tested for their tribological applications.

The ZA alloys are mainly classified in terms of their higher aluminium content. The numerical digits (8, 12, 27, 40) represent their approximate weight percentage of aluminium. In this study, Al-Zn nonferrous alloy prepared as a higher performance engineering material which is used in industry due to its properties like light weight, high wear resistance, low coefficient of friction, high heat transfer, advantages for same application as that of conventional material this application tries to fulfil by this study.

OBJECTIVE OF STUDY

Here the load, sliding velocity, and time these three parameters have been varied for different experiments in order to examine the effect of different alloying element of Cu, Mn, Si , Al- Zn are studied.

The wear mechanism is dependent on following factors-

1. The load on contacting area
2. The Sliding velocity
3. The duration of the sliding
4. The working conditions namely, dry or lubricated
5. Metallurgical structure such as grain structure, hardness.

Here the first three parameters have been for material A, material B, material C. Dry working conditions at ambient temperatures have been used and other parameters have been considered constant. The objective will be to generate new performance data which will be useful for the design engineer.

LITERATURE SURVEY

Tamel savaskan, Ali Pas Hekimoglo, observed that the hardness of the alloys increased consciously with increasing copper content up to 5% and tensile strength also increased with the increasing copper content up to 2%, but beyond this level strength decreased as the copper content increased further [6].

Ahmet Turk, Mehmet Durman, Sabri Kayali found that addition of Manganese over the entire range of concentrations has a successful effect on the alloy hardness. Also, ultimate tensile and 0.2% yield strength of the samples did not change significantly with Manganese addition up to 0.045 weight percentage but decreased gradually with a further increase in Manganese content. On the other hand the creep resistance of the alloy increased with Manganese content up to 0.53% weight .[7]

Miroslav Babic, Slobodan Mitrovic, Branislav Jeremic observed the heat treatment resulted in reduction in the tensile strength, hardness and increase in elongation. Both friction and wear characteristics of the heat treated alloy improved over the as cast alloy [8].

Zeki azakh, Temel Savaskan observed that the heat treatment increased the tensile strength and hardness of the alloy. However the friction coefficient increased with the increasing speed after showing a small decrease with it and the temperature of the wear sample increased with both pressure and sliding speed. However the increase in the wear loss with the sliding speed became exponential at pressures above 4 MPa [9].

B. K. Prasad analysed the coMParison of the zinc based alloy of the cast iron on wear performance in similar working conditions with the increasing sliding speed and load, the wear rate of the samples increased [10].

Temel Savkan, Zeki Azakli observed the zinc based alloy in both heat treated and as cast conditions showed higher wear resistance than SAE 65 bronze, especially at the pressures beyond 4 MPa. It was also found that the quench ageing treatment increased the tensile strength and hardness of Zn - 40 Al - 2 Cu-2Si alloy considerably, but only a small improvement was obtained in wear resistance of the alloy after this heat treatment [11].

TAGUCHI DESIGN METHOD

Taguchi method of design was developed by Dr. Genichi Taguchi during the Second World War. During the Second World War due to the scarcity of the resources the need for optimization was at peak. The Taguchi method believes that every problem has easy solutions and that every problem can have linear solutions. The Taguchi method provides set of experiments arranged in arrays such as L9, L18, etc., that provides same solution that would have got using all the permutations and combinations in the levels and input parameters of the experiment. The three levels of parameters were taken as shown in the table 2.

Table 2 Assigning Of Levels to the Variables as Applicable To Pin on Disc Machine

Level	Low	Medium	High
Load (Kg)	3	6	9
liding Velocity (RPM)	200	300	400
Sliding Time (min)	30	60	90

The actual vales calculated for the parameters are shown in the table 3.

Table 3 Assigning Of Levels to the Variable as Applicable Practically

Level	Low	Medium	High
Pressure (MPa)	0.374	0.749	1.124
Sliding Velocity(m/s)	1.047	1.570	2.094
Sliding Time (min)	30	60	90

The Taguchi method is applied in following 4 steps,

1. Search for the quality characteristics and design input parameters
2. Design and conduct the experiment
3. Define the output parameters and calculate the same
4. For confirmation of the optimal solution check using the confirmation test.

A. Signal-to-Noise Ratio:

There are 3 Signal-to-Noise ratios of common interest for optimization

(I) Smaller-The-Better: n = -10 Log10 [mean of sum of squares of measured data]

(II) Larger-The-Better: n = -10 Log10 [mean of sum squares of reciprocal of measured data]

(III) Nominal-The-Best: n = 10 Log10 [(square of mean)/ Variance]

B. Work Material and Equipment

For the Experimentation the test material was turned in the form of Pin with Diameter of 10 mm and Length 25 mm. Test Parameters used with test Rig are shown in following table 3.Fig 1 and Fig 2 shows the actual photograph of the pin and disc machine and the pin used in the experiment

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Fig 1. Pin on Disc Machine

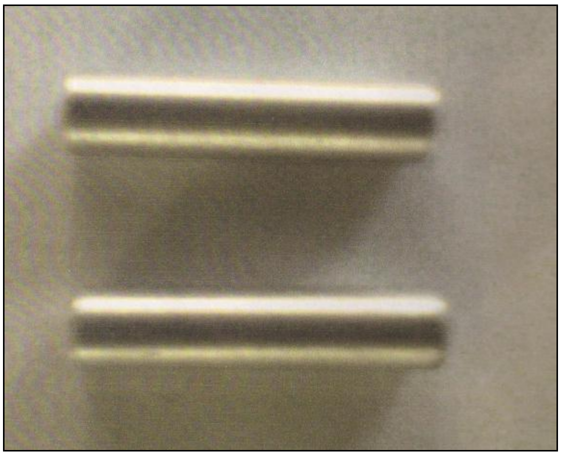

Fig2. Pin Used In Experiment

The three materials namely A, B, C with the chemical composition are used for the experiment as shown in the table 1.

Table 1 Assigning Codes For Three Al-Zn Alloy

Material	Chemical Composition in Wt%
A	Al-25Zn-2.5Cu-0.4Mn-0Si
B	Al-25Zn-2.5Cu-0.4Mn-2.5Si
C	Al-25Zn-2.5Cu-0.4Mn-5Si

The Design of the standard L9 Orthogonal array is shown in the table 4.

Table 4 Design Matrix for Taguchi Experimentation

Trail No	Applied Load (MPa)	Velocity (m/s)	Time (min)
1	0.375	1.047	30
2	0.375	1.57	60
3	0.375	2.094	90
4	0.749	1.047	60
5	0.749	1.57	90
6	0.749	2.094	30
7	1.124	1.047	90
8	1.124	1.57	30
9	1.124	2.094	60

Analysis of S/N ratio: The desirable value for the output characteristics is referred by the term signal in taguchi method whereas the undesirable value is referred as noise. (Standard Deviation) for the output characteristics. To measure the quality characteristic deviating from the desired S/N ratio is used. In S/N ratio S is calculated as S= -10 log (M.S.D.) where, M.S.D. is the mean square deviation for the output characteristic. The M.S.D. for higher-the –better quality characteristic can be expressed

$$MSD = \frac{1}{R}\sum_{j=1}^{R}(y_j - y_o)^2$$

Where R = Number of repetitions

The experiments were performed on the three different materials and the resultant wear was calculated. The results for Materials A, B, C are shown in the table 5, table 6, table 7 respectively.

Table 5 Experimental Data for Material A

Trail No	Applied Load (MPa)	Velocity (m/s)	Time (min)	Wear (micron)
1	0.375	1.047	30	91.383
2	0.375	1.57	60	480.617
3	0.375	2.094	90	760.212
4	0.749	1.047	60	289.175
5	0.749	1.57	90	716.76
6	0.749	2.094	30	266.497
7	1.124	1.047	90	712.253
8	1.124	1.57	30	369.465
9	1.124	2.094	60	602.131

Table 6 Experimental Data for Material B

Trail No	Applied Load (MPa)	Velocity (m/s)	Time (min)	Wear (micron)
1	0.375	1.047	30	82.64
2	0.375	1.57	60	360.19
3	0.375	2.094	90	550.4
4	0.749	1.047	60	87.624
5	0.749	1.57	90	670.428
6	0.749	2.094	30	257.531
7	1.124	1.047	90	422.047
8	1.124	1.57	30	268.582
9	1.124	2.094	60	591.000

Table 7 Experimental Data for Material C

Trail No	Applied Load (MPa)	Velocity (m/s)	Time (min)	Wear (micron)
1	0.375	1.047	30	94.601
2	0.375	1.57	60	662.36
3	0.375	2.094	90	781.057
4	0.749	1.047	60	341.244
5	0.749	1.57	90	730.452
6	0.749	2.094	30	325.253
7	1.124	1.047	90	756.094
8	1.124	1.57	30	391.831
9	1.124	2.094	60	641.23

ANOVA

Using the analysis of variance (ANOVA) technique, the adequacy of the models is tested. This is statistical tool for testing null hypothesis for experimentation design, where all the variables of the experiment are studied simultaneously so as to check the performance and contribution of the individual input parameter on the optimality of the solution. ANOVA is used to quickly analyse the variances occurred in the experiment with the help of fisher test. This analysis was performed for a level of significance of 5%, i.e. the level of confidence 95%. Manual ANOVA for AZ alloy. The calculations are formulated in the table 8.

One can observe from the ANOVA analysis that the value of P is less than 0.05 in all three parametric sources.

Table 8 Manual Anova

Factors	Df	SS	MSS	F ratio
P	2	32944.71	16472.35	Pool
V	2	57320.95	28660	1.74
T	2	357849.66	178924.80	10.86
Residual	2	447664.42		
Total	8	448115.32		

RESULTS AND DISCUSSION

The results obtained from the experimentation have been expressed in the form of tribo- graphs shown in the fig 3, fig. 4, fig. 5.

A. Results Related to Wear

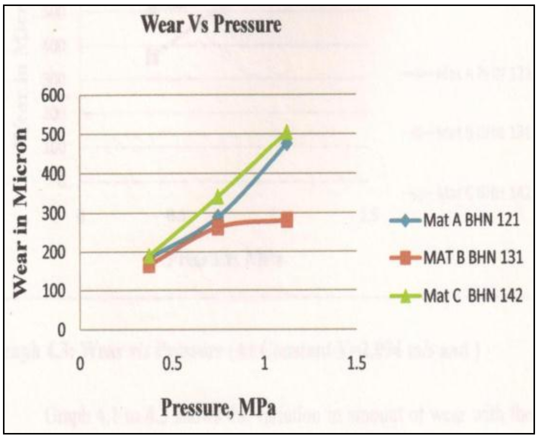

Fig.3 Wear Vs Pressure at constant velocity 1.047 m/s

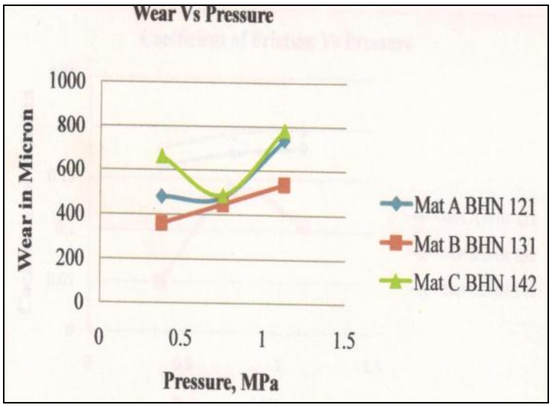

Fig 4. Wear vs Pressure at constant velocity 1.57 m/s

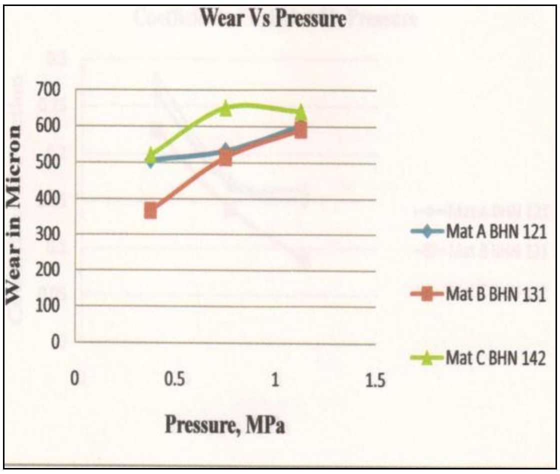

Fig 5. Wear Vs Pressure at constant velocity 2.094 m/s

B. Results Related to Friction

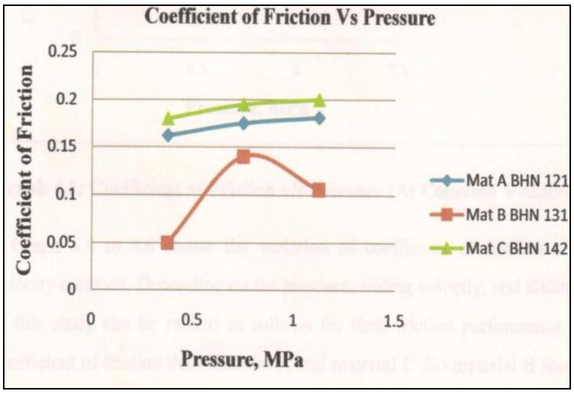

Fig.6 Coefficient of friction Vs Pressure at constant velocity 1.047 m/s.

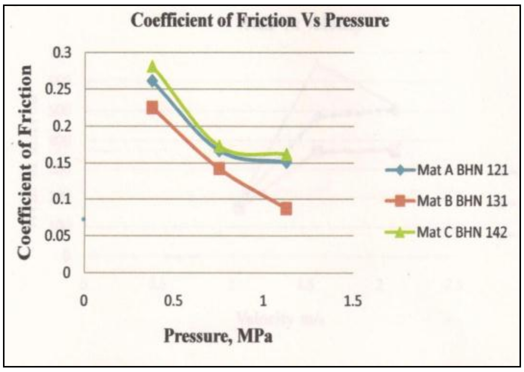

Fig 7. Coefficient of friction Vs Pressure at constant velocity 1.57 m/s.

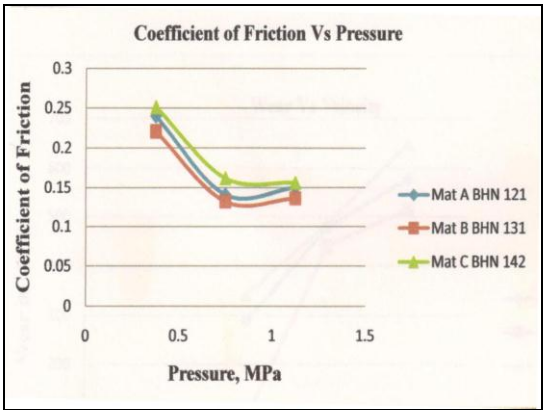

Fig 8. Coefficient of friction Vs Pressure at constant velocity 2.094 m/s.

From the results of the experimentation and the calculation of the coefficient of friction the results are plotted in the graph fig 6, Fig 7, Fig 8.

C. Results Related to Wear

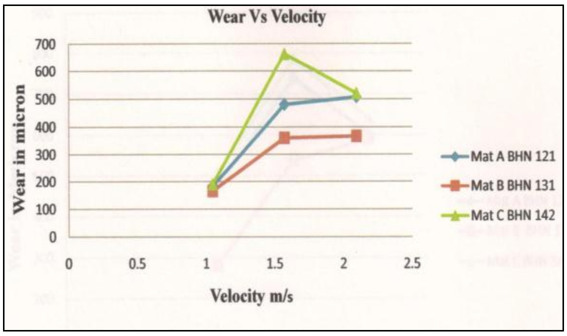

Fig.9 Wear Vs Velocity at constant Pressure of 0.375MPa.

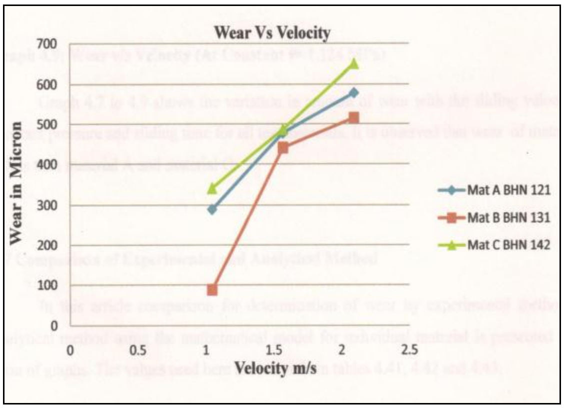

Fig 10. Wear Vs Velocity at constant Pressure of 0.749 MPa.

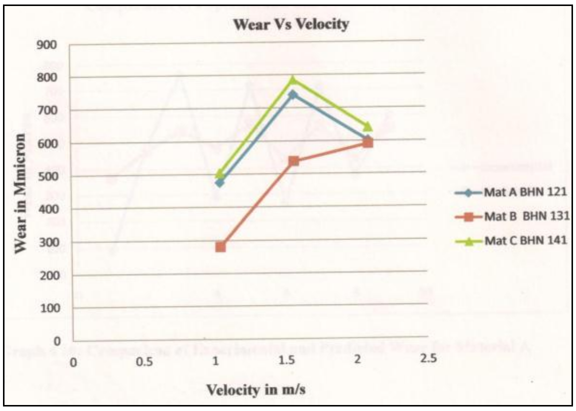

Fig 11. Wear Vs Velocity at constant Pressure of 1.124 MPa.

The Fig 9, Fig 10, Fig 11 show the variation in the amount of wear with the sliding velocity, at constant pressure and sliding time for all test materials. It is observed that wear of material B is less than material A and material C.

CONCLUSIONS

The Experiments were conducted by varying different parameters such as the pressure, sliding velocity, and sliding time. The materials used were contained silicon 0%, material contained 2.5% silicon, and the material containing 5% silicon. Based on the investigation following conclusions were drawn-

1. The hardness, compressive and tensile strengths of Al-2.5Zn-2Cu-0.4Mn based alloys increased with increasing silicon content, but the trend reversed for one with more than 2.5%Si. Amongst the as cast alloys, the highest wear resistance was obtained with the 2.5% Si alloy.

2. The highest wear resistance was obtained with the 25Zn-2Cu-0.4Mn-2.5Si alloy.

3. The lowest coefficient of friction was obtained with the 25Zn-2Cu-0.4Mn-2.5Si alloy.

4. The wear resistance of Al-25Zn-2Cu-0.4Mn-2.5Si alloy is less.

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Corresponding Author

Gaurav L. Deshpande*

PG Student Government College of Engineering, Aurangabad, India

E-Mail – gaurav.deshpande93@gmail.com