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Influence of Parameters and Wear Analysis of Aluminium-Bronze ($CuAl_8Fe_3$) by Taguchi Method

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Abstract

Objective: The tribiological activity of aluminium bronze ($CuAl_8Fe_3$)has been explored using the pin-on-discmachine at various loads under dry sliding wear condition. **Method/Analysis**: The work piece had a size of 11.4mm in Diameter, 103 mm in length. In this paper, the wear rate has been evaluated at loads (1, 2 and 3 Kg) and Disc speed (500, 700, 900 rpm) at different time intervals. Taguchi method is applied to find out the powerfullness of parameters and optimization of influence of wear rate factors like speed, load and time on dry sliding wear. **Findings:**The results proves that the applied load was the major parameter among the controllable factors that cause the weight loss of aluminium bronze ($CuAl_8Fe_3$). For aluminium bronze ($CuAl_8Fe_3$), the load had the greatest effect on the wear. The sliding speed had a minimum effect. The best combination of the testing parameters could be determined. A good agreement is found between the forecasted and actual weight loss. **Application/Improvement:** The most influencing parameters involved tribiological industries are speed, load, time and indirectly sliding velocity were considered throughout the theoretical investigation.

Keywords: Aluminium Bronze**,** Orthogonal Array, Pin-on-Disc, Taguchi Methods, Wear Rate

1. Introduction

Aluminium Bronze ($CuAl_8Fe_3$) has received substantial attention due in piping systems,structural components, machine parts, corrosion resistant vessels, sea water piping, condensertubes, tube sheets, welded pipe, seamless tubing and pipe, chutes for abrassive grains,heat exchanger tubes, mining shoves, tanks, condeser head plates.

The Annual of the National Academy of Sciences, the U.S. Mint assayer alluminum –bronze alloy for the production of coins. Modern methods and alloy improvements, provide aluminum–bronze ingots/coins with no tarnish problems[1]. Mr. Pierre Henri Gaston Durville of France has a patent (us1007548A) involving the making of aluminium bronze alloy via the addition of the proper amounts of manganese for reducing the aluminium oxides occuring during the making of alloy. He recommonded the addition of 0.5% to 5% of manganese to the aluminium –copper alloy[2]. The material has excellent corrosion resistance in most of the environments and good hot-working properties. The most commonly used wrought forms are plate, sheet and rod.[3-5]

Wear is the topmost encountered trouble leading to frequent replacement of components,especially abrasion[3,6]. Abrasive wear occures when hard particles get through physically a softer surface and uproot material in the form of elongated chips.

The aim of the study was to investigate the dry sliding wear of stir cast Aluminium Bronze ($CuAl_8Fe_3$) using pin on disc machine.[7] It is framed for process optimization and **disclosure** of optimal alignment of the parameters for given response. The experiment is planned in this a way to estimate simultaneously two or more factors which posses their ability to affect the resultant average or variability of perticular product or operational characterisitcs.[8]

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The effect of various process parameters and their interaction on abrasive behaviour of the Aluninium Bronze ($CuAl_8Fe_3$)has been studied under Taguchi method.

2. Scheme of Investigation

With a view to support the desirable performance measures and minimize undesirable performance measures, the investigation was done in the following sequence:

1. Preparation of sample material and manufacturing the sample.
2. Recognize the important wear process parameters.
3. Determine the range of the selected process parameters.
4. Define the orthogonal array (OA; design of matrix).
5. Execute the experiments as per the selected OA.
6. Record the performance measures (i.e. Applied Load, Disc Speed, Time)
7. Find the optimum condition for performance measures and recognize the significant factors.
8. Perform the confirmation test.

2.1 Preparation of Sample Material and Manufacturing the Sample

The work piece material employed in this study was Aluminum Bronze. Chemical composition of Aluminum Bronzeisshown in Table1.

Stir casting is appliedas it is a method of composite material fabrication in which a dispersed phase (reinforcement) is mixed with matrix metal (both should be in liquid state) by means of mechanical stirring.[9] its advantages lie in its Simplicity, adaptability and usefullness for mass production. It permits a conventional metal processing path to be used and hence reduces the final cost of product. It allows very large size components to be fabricated.

Table 1. Material Composition

Composition	Cu	Al	Fe
Range	88.5-92.00	6.00-8.00	2.00-3.500

In this process three pure materials like aluminium, copper, iron rods are weighed accurately on weighing machine according to percentage composition requirement. The aluminium- bronze alloy is produced by casting process as shown in Figure 1.

Figure 1. Stir Casting set up.

The process consists of making the metal in grain or powder form. Separate metals in proportion are required is as follows:-

Copper-91%, Aluminium-8%, Ferrous-1%.

XRF is used to decide the basic composition of materials. XRF spectroscopy is ansuperb technology for qualitative and quantitative analysis of material composition[10].

Testing report shows that material contains 90.73% of copper and remaining is percentage of aluminium and iron.

2.2 Recognize the Important Wear Process Parameters

On account of the literature, it was concluded that the most important influencing parameters (load, speed, time) which has more influence on the wear rate of the aluminium bronze alloy.

2.3 Determine the Range of the Selected Process Parameters 2.3

A wide range ofexperiments were conducted by changing one of the process parameters and keeping the other parameters constant. The approximate range of applied load, sliding speed, time was explored by inspecting the wear produced in the work piece[11,12]. Theoperating range of the identified parameters selected under the present study is indicated in Table 2.

Table 2. Working range of the operating parameters and their levels[15]

Symbol	Wear Parameter	Unit	Level 1	Level 2	Level 3
A	Load	kg	1	2	3
B	Speed	rpm	500	700	900
C	Time	min	3	6	9

2.4 Define the Orthogonal Array (OA; Design of Matrix)[13]

L9 (3^4) OA is considered for the specific study. Based on the preliminary experimentation, there is no inter relation between the selected factors. Hence interaction is not considered for the study in this paper. Three trails of each experiment wereperformed to average of these values so that minimize the pure experimental error. The selected OA is presented in Table 3.

Table 3. Layout of OA using an L9 (3^4) OA[20]

Sr. no.	Wear parameter		
	A Load	B Speed	C Time
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The DoE approach is used to aquire data in systematic way applying Tagochi method[2]. It is used for optimisation of effect of different control factors on S/N ratio. Signal to Noise ratio and coefficient of friction is used to find out the wear demeanorr of aluminum -bronze composite[13].-e experimentsignifies three major wear testing conditions includingsliding distance, time and applied load. The Sinal/Noise ratio for wear rate "smaller the better" characteristic is selected for Tagochi method.

2.5 Execute the Experiments as per the Selected OA[14]

The sample material with 11.4 mm in Diameter, 103 mm in length was used. Thetests were conducted as per the layout shown in Table 3.

Testswere conducted for duration of 3 min., 6min, 9min. Prior to machining, the test sampleswere cleaned and polished. Wear samples were prepared in the shape of pin. Tests on sample have been conducted in the Pin-on-disc type Friction and Wear monitor (DUCOM) with data acquisition system which was used to evaluate the wear behaviour of the composite.[13] The block diagram of pin on disc apparatus shown in Figure 2.

Figure 2. Pin on disc set up.

2.6 Record the Performance Measures (i.e. Applied Load, Disc Time)

The wearratemeasures were evaluated by the work piece weight loss (WWL) under a period of machining time in minutes, i.e., slidingspeed and load[15]. The average experimental results ofwear rate, and their corresponding S/N ratios using are presented in Table 4.

Table 4. Average experimental results wear rates and their corresponding S/N ratios

Level	Load	Speed	Time
1	-7.721	-14.752	-17.495
2	-16.967	-15.129	-14.343
3	-20.058	-14.866	-12.909

2.7 Find the Optimum Combination of Wear Parameters and Identify the Influencing Factors

In Taguchi method, the impacts of wear parameters on sample areanalised under optimal condition. It is used to findappropriate combination ofwear parameters to minimize wear rate[14].

The experimental results of load, timeand sliding velocity were further changed into a S/N ratio. The particular characteristic thatlower value signifies betterworking performance, such asminimum wear, is called "smaller the better"[14].

The mean Signal/Noise ratio for every machining parameter at each level was calculated by averaging the Signal/Noise ratios for the experiments at the same level for that particular parameter. Table 5 shows Signal/ Noiseresponse table for wear rate and Figure 3 shows the

Table 5. Response Table for Signal to Noise Ratios

Sr. no.	Wear Rate	SNRA1
1	2.7922×10^{-6}	-8.9189
2	2.4930×10^{-6}	-7.9344
3	2.0680×10^{-6}	-6.3110
4	6.9800×10^{-6}	-16.8771
5	4.9860×10^{-6}	-13.9550
6	10.0800×10^{-6}	-20.0692
7	8.3760×10^{-6}	-18.4607
8	14.9580×10^{-6}	-23.4975

The optimization of factors using Taguchi method permits assessment of the effects of individual parameters independent of the other parameters[16,17] ANOVA was implimented to find out the significance of main factors and the F-test was used to determine the process parameter significantly effect on the responses[18]. Usually, the change of the wear parameter has significant effect on the response when F ratio is large. Table shows the results of ANOVA for the wear rate[14,19].

2.8 Perform the Confirmation Test

Optimum levels of design parameters were used for prediction and confirmation of the performance measures improvement[21]. For validations of the optimum results, experiments were conducted as per the optimum conditions and machining performance measures were evaluated and the results are presented in Table 6. It is observed that, experimental values are closer to the optimum values.

Table 6. Validation of the optimum results[11]

Performance measure	Optimum condition	Optimum Theoretical value	Actual mental value
wear rate	A1B1C3	1.894×10^{-6}	1.0862×10^{-6}

3. Conclusion

Effect of parameters on wear rate measures based on the S/N ratio and ANOVA analysis. As shown in Table 7 and Figure 3, factors at level A1 (load 1 kg), B1 (sliding speed, 500 rpm), and C3(time, 9 min) givesminimum wear rate. Factor B (sliding speed) is having least remarkable effect on wear. The contribution of each parameter (applied load, then time, and then sliding speed) is shown in Table 7.

Table 7. Results of the ANOVA for wear rate

Source	DoF	SoS	Mean Square	F-value	P-value	%Contribution
A	2	98.54	4927	6.81	0.029	69.44
B	2	31	1.5	0.07	0.937	2.18
C	2	29.2	14.6	0.78	0.508	20.57
Error	2	1106				7.79
Total	8	141.9				100

In this paper, the effect of the process parameters and optimizedcombination was studied by using Taguchi method. From ANOVA, load is more significant than time. Whereas time is more significant than sliding velocity. Besides, sliding velocity is less significant for all performance characteristics considered.

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