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Experimental Investigation and Optimization of Wear Properties of Aluminum Alloy LM30 Composite with Zircon Powder as Reinforcement

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Abstract – *This research paper focuses on experimental study of wear characteristics of hypereutectic aluminium alloy LM 30 with different weight percentage of Zirconium silicate powder of fine size and to optimize the results of wear. Composites of aluminum alloy are prepared with the help of stir casting process. The input parameters considered for this work are Load, Sliding distance and % Reinforcement. Load was taken as 15N, 25N and 35N, Sliding distance as 1000m, 1400m, 1800m and % reinforcement as 3 wt%, 6 wt% and 9 wt%. The results were optimized using Taguchi's DOE method and analysis was done with the help of ANOVA method. Pin-on disk machine is used for the wear experimentation*

Key Words: LM30, Zircon Powder, Wear, Stir Casting, DOE method, Pin-on disk machine.

1. INTRODUCTION

The world is developing rapidly and so the needs of composite materials for different applications. Also lots of research work is going on over improvement of tribological wear of materials. In composite materials category metal matrix composites are used widely. Especially aluminium alloys are used widely due to their low cost, good strength, wear resistance and corrosion properties. Also they have great strength to weight ratio. The slight change in the composition of the material by adding reinforcement changes the properties of material suitable for other applications. Aluminium alloy is the most commonly used composite as it is found on earth in abundant quantity and has very low density which is useful in many applications ranging from food processing industries to automobile and aerospace sector.

Aluminium alloy LM30 is as cast alloy which is used in the automobile sector for the applications like piston, alternative as piston ring, engine block, brakes, etc. Also LM30 shows different properties as it is hypereutectic alloy making it useful for applications where good wear resistance is required. Zircon powder is used to create the composite with different weight percentage in the LM30 base metal. Abrasion is one of the most important factors for the wear of material. The objective of this research is to study the effect of Zirconium silicate powder (fine size) on the properties of LM30 alloy. Also it has been observed that the coarser the structure of the material the lesser wear resistance it possesses and finer the structure of the material higher will be its wear resistance. In case of LM30 alloy primary silicon particles are present in large amount with coarse structure. So the objective of this study is to reduce the wear and optimize the result using Taguchi's Design of Experimentation method.

1.1 Literature Review

A. J. Clegg et. al. [1] Studied wear of hypereutectic aluminium alloy. By addition of sulphur and phosphorous an attempt has been made to refine the grain structure and to decrease the wear rate. From the results it was observed that structural modifications does not affect wear rate.

S. Das et. al. [2] studied the microstructure and wear characteristics of Al-Si alloy with the addition of graphite to make the composites tested under dry and wet lubrication. It has been showed that the LM 30 Material has optimum wear resistance due to different phases found in the material.

Sandeep Sharma et. al. [3] studied the effect of particle size on wear rate of LM30 alloy with sillimanite as reinforcement. The result showed that due to different particle sizes of sillimanite the wear resistance of the material increased by 55%. Load and Sliding distance were mainly having high impact over wear resistance.

Sourav Das et. al. [4] studied the braking performance of ADC12 and LM30 alloy using brake drum dynamometer test rig. For normal brake liners coefficient of friction was evaluated. In the result it has been found that LM30 alloy has better results and has advantages over ADC12 material.

Hani Aziz Ameen et. al. [5] studied the effect of load, sliding distance and sliding time on wear rate of different materials. And the result showed that the wear rate is mainly due to the adhesion and it is directly proportional to the sliding distance, load and time.

Pankaj Kumar et. al. [6] studied the abrasive wear of LM13 alloy with dual reinforcement of silicon carbide and titanium

carbide. The result showed that the combination of both the dual particles has greater influence over the wear resistance of the composite.

Suresh Kumar et. al. [7] studied the tribological properties of zircon and zirfloor mixed with LM13 alloy. The result showed that zircon mixed with LM13 alloy shows better wear resistance than the zirfloor mixed with the LM13 alloy composite.

2. Materials and Methods

2.1 Materials:

he material which was selected for this research work is LM30 aluminium alloy which is hypereutectic alloy. The alloys which contain percentage of silicon over 12.6% are known as hypereutectic alloys. They have large number of primary silicon particles present in it with coarse structure. Also Zircon powder was used as reinforcement which was of very fine size. Zircon powder has very high melting point and also it is very easily available in abundant quantity on earth and also has very low cost. The chemical composition of both the materials is as per given below.

Table -2.1: Chemical composition of LM30

Material	LM30 (in wt %)
Si	16.56
Fe	0.59
Mn	0.22
Cu	3.93
Mg	0.43
Ni	0.024
Zn	0.27
Ti	0.07
Al	Rest

Zirconium silicate powder selected is chemically inert material and it is stable at high temperatures also. It provides corrosion resistance and it is not soluble in water and diluted acids.

Table -2.2: Chemical composition of Zirconium Silicate

Material	Composition (In wt %)
ZrO_2	65.9
SiO_2	32

2.2 Preparation of samples

The composites of LM30 material with Zircon powder reinforcement were created using stir casting method. Stir casting is one of the most useful methods for the manufacturing of the composites as it helps in uniform distribution of the reinforcement powder in the molten metal. For preparing the samples firstly the Zircon powder with different weight percentages were preheated at 300 degree Celsius for 30 minutes. Pre-heating the powder helped in removing the moisture from it. Then the aluminium alloy LM30 metal was melt in the crucible at 750 degree Celsius for few minutes and then different weight percentages of the reinforcement were added in it to create four different composites of different grade. The molten mixture was firstly stirred by hand and then by mechanical stirrer for few minutes to distribute the reinforcement powder uniformly at 700 rpm. The final samples were made of the diameter 12 mm and 30 mm length by machining. The surface of the pins formed were cleaned using emery paper of grade 150 and cleaned with acetone for the further experimentation.

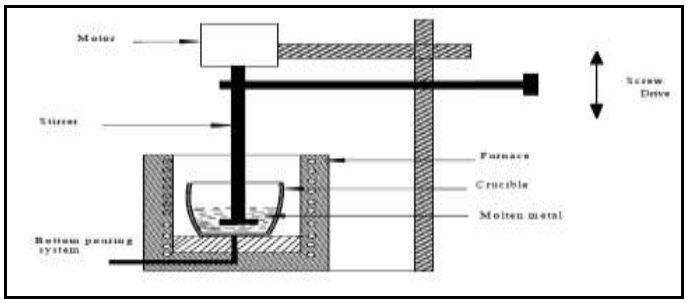

Figure -2.1: Stir casting process

3. Experimental Procedure

3.1 Taguchi Method of DOE

The design of experiment method chosen for this experimentation was of Taguchi. Taguchi method of DOE helps in minimizing the number of experiments which needed to perform. Three levels and three factors were selected for the experimentation and L9 orthogonal array was created using MINITAB 17 software. The factors selected are load, sliding distance and % reinforcement.

Table -3.1: Levels and Process Parameters

Factors/Levels	1	2	3
Load(in Newton)	15N	25N	35N
Sliding Distance(in meter)	1000m	1400m	1800m
% Reinforcement (in weight %)	3	6	9

The L9 orthogonal array for the above experiment is as given below. As per the array the experiments were performed on computerized pin-on disk machine and wear rate was calculated. To find out the wear rate smaller the better option was selected. Averages of the readings were taken for wear rate to avoid the errors. Analysis was done using ANOVA in Minitab 17 software.

Table -3.2: L9 orthogonal array for experimentation

Sr. No.	Load	Sliding Distance	% Reinforcement
1	15	1000	3
2	15	1400	6
3	15	1800	9
4	25	1000	6
5	25	1400	9
6	25	1800	3
7	35	1000	9
8	35	1400	3
9	35	1800	6

4. Results and Discussions

4.1 Hardness

Hardness test was conducted on the materials and it has been noticed that with the increase in the concentration of zircon powder the hardness increased for 3%, 6% and 9% to 90 BHN, 93 BHN and 96 BHN respectively.

4.2 Wear Rate

Experimentation work to find out wear rate was carried out on pin-on disk machine. According to Taguchi's L9 array experimentation was carried out. Average of the readings was taken to minimize the error. The result obtained are given below also the analysis was done using ANOVA method and Mains effect plots were obtained using MINITAB 17 software.

Table -4.1: Result for wear rate

Sr. No.	Load	Sliding Distance	% Reinforcement	Wear rate(in $mm^3/m*10^{-5}$)
1	15	1000	3	8.3208
2	15	1400	6	7.5001
3	15	1800	9	9.9192
4	25	1000	6	3.0769
5	25	1400	9	5.8608
6	25	1800	3	7.1632
7	35	1000	9	4.9188
8	35	1400	3	9.8676
9	35	1800	6	5.6398

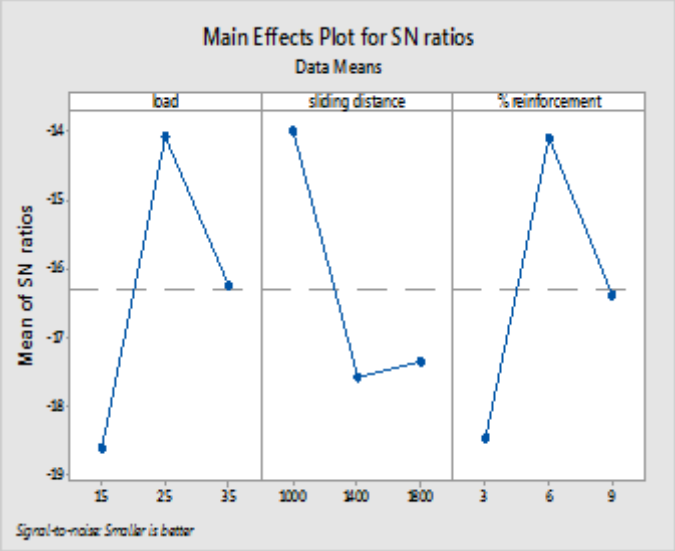

Figure -4.1: Main effects plot for S/N ratio

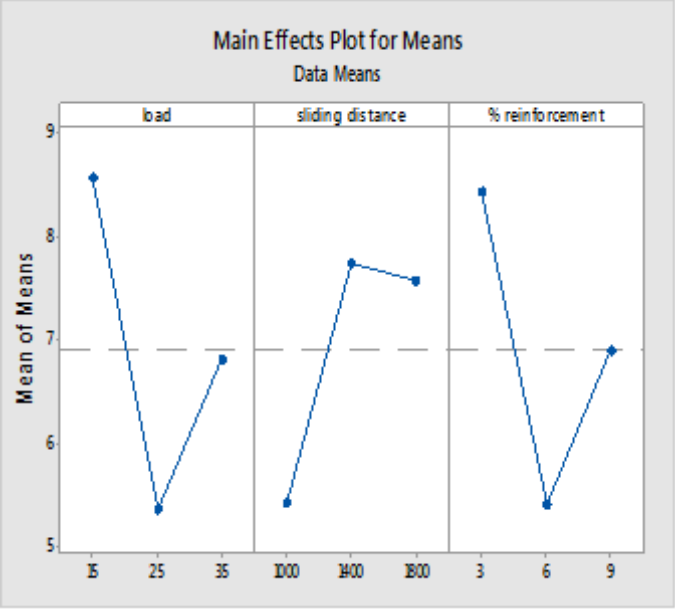

Figure -4.2: Main effects plot for Means

From the above figures it can be seen that for wear rate to be optimum, the conditions obtained are load 25N, Sliding Distance 1000m and Percentage Reinforcement 6%.

Table -4.2: Analysis of Variance

Factor	DF	SS	MS	F_{ratio}	% Contribution
Load	2	15.540	7.770	6.96	37.28
Sliding Distance	2	9.896	4.948	4.44	23.96
% Reinforcement	2	13.909	6.955	6.23	33.36
Error	2	2.231	1.116		
Total	8	41.576			

The regression equation for the wear rate obtained is as follows:

Wear Rate = 6.92-0.0883 load+0.0268 Sliding Distance-0.257 % Reinforcement.

5. CONCLUSIONS

In this study, effect of addition of zirconium silicate on wear resistance of LM30 alloy was investigated. And from the results obtained above following conclusions can be made

1. Stir casting can be used to create aluminium composites with proper distribution of reinforcements.
2. Wear resistance of the composite is better than the base alloy LM30 metal as the hardness of the composites increased significantly due to addition of zirconium silicate powder which refines the grain structure.
3. The most affecting parameters were firstly load 37.28%, secondly % reinforcement 33.36% and lastly sliding distance with contribution of 23.96%.
4. The optimum conditions obtained are load 25N, sliding distance 1000m and % reinforcement 6%.

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