International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-7 Issue-4s, November 2018

Investigation on Dry Sliding Wear Behaviour of Self-Lubricating Metal Matrix Composites Reinforced with Fly ash and Solid Lubricant

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***Abstract** – The present study is focussed to explore the dominant factors on metal removal of self-lubricating composite materials through rotating disc. The proposed composite material is reinforced with fly ash and Boron Nitride. As referred with ASM standard AA2218 alloy is suitable for tribological applications. Composites samples are processed by liquid metal stir casting route. AA2218 matrix alloy was reinforced with Five, Ten and Fifteen weight percentage of fly ash as hard reinforcement particles and five percentages. Levels of Boron Nitride as the second stage fortification particles in the composite material. Ninety percentage of hardness value has been correlated with tensile strength of the composite material. The hardness of the amalgamated specimens are experimented, test results shows that BHN values are significantly higher than the structural material. Dry sliding wear behavior of test samples are experiment with pin-on-disc apparatus. Affecting parameters of load on pin, weight level of support content and sliding speed on amount of wear was tested. Formation of trials through DOE approach utilizing Taguchi technique was embraced to break down the exploratory outcomes. Because of Taguchi investigation, mix of most appropriate qualities is accounted for. Motion to-commotion proportion and examination of change (ANOVA) is been utilized to explore the impact of process parameters on wear rate.*

***Keywords** – Wear, Hardness, ASM, Design of Experiment & Analysis of Variance.*

I. INTRODUCTION

Traditional solid materials have limits in accomplishing great blend of elasticity, hardness, thickness and wear opposition. To beat these weaknesses and to take care of the persistently expanding demand of cutting edge innovation, in recent times amalgamated metals are encouraging materials of current attention.

Particle reinforced hybrid composite contains with low density and a low cost reinforcement is an increasing demand for automotive and aero space industries. Components with low density material has ultimately reduces the weight of the component. Less weight of component results with improved performance of the vehicle.

Manuscript published on 30 November 2018.
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Engineering machineries are equipped with journal bearings. Frequent problem in journal bearing is lubrication. Improper lubrication leads to reduce the overall efficiency of the equipment[2]. Babbitt, red brass and gun metal are used as a journal bearing materials; by replacing this conventional material with newer material is the promising technique to reduce the wear failure. Improved mechanical properties can be achieved through composite materials. Introducing hard particles in matrix alloy gives better wear resistance to the composites. Incorporating solid lubricants with matrix alloy offers self lubrication effect to the composites[3]. Tensile strength of composites affects with higher weight percentage of solid lubricants. Along with the distinctive broken scatterings utilized, fly powder is a standout amongst the cheapest and low thickness fortification accessible in expansive amounts as strong waste[4]. Fly fiery remains is the result amid the ignition of coal in warm power plants.

II. PLAN OF EXPERIMENTS

A. *Material Selection*

In this investigation AA2218 alloy is chosen as a matrix material and it's the superior chemical composition. The metal alloy was strengthened with three wt. %, six wt. % and nine wt%. Fly ash and unchanged five wt % of BN particles are added. The concerned chemical compounds to synthesize the hybrid composite through liquid scientific discipline route[5]. Ash and BN particles with a variety of fifty-three to seventy-five micro meter were used. Fly ash particulates posses arduous in nature can improve the resistance to indentation, Tensile strength and rigidity of the proposed material. Boron Nitride provides wonderful lubricating effect of the proposed material. A modest add of Magnesium (one weight percentage) is supplemented to confirm the wetability of reinforcement particles with base alloy[6].

B. *Specimen Preparation*

To develop the material with estimated weight percentage of constituent materials are processed by liquid metallurgy method. The planned metal is manufactured by adding AA2218 metal with different weight proportions of fly ash (Three, Six, and Nine percentage) and a invariable weight proportion of solid lubricant (Five percentage)[7]. So as to achieve improved adhesiveness among the matrix and particles, one weight percentage of Magnesium as wetting material is added[8]. The experimental procedure has been summarized in the form of a flow chart in Figure I.

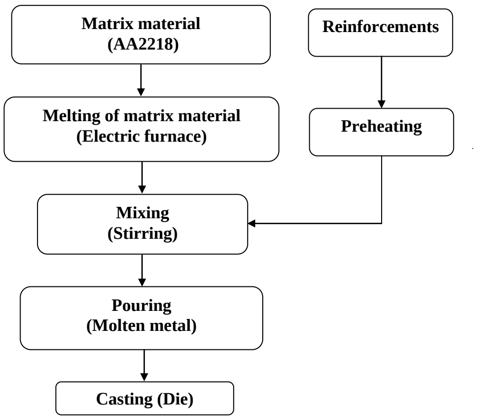

Fig. I. Steps involved in stir-cast method.

C. *Analysis of Mechanical Properties*

Brinnel hardness test trials were taken on conformity of ASTM E10 standard[9]. Hardness results of the materials are compared with matrix alloy in Fig. II. It was found that increase in fly ash results to increase in hardness of hybrid reinforced materials. Hardness of reinforced material is significantly higher than the matrix alloy[10].

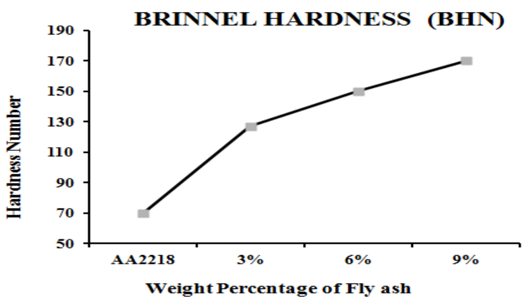

Fig. II. BHN value.

D. *Design of Experiment using Taguchi Principle*

The test method was defined by focusing on three parameters and three proportions dependent on the optimization technique which was developed by Taguchi[5]. Three autonomous factors are included for the examination as compressive load on pin, sliding rate of rotating disc & weight level of fly ash powder. Dimensions of the factors are decided for examination is tabulated in Table: I

Table I: Test variables

Levels of control parameters	**I**	**II**	**III**
Load (N) - A	9.810	19.61	29.42
Speed (m/sec) - B	2.0	3.0	4.0
Fly ash (weight percentage) - C	3.0	6.0	9.0

III. RESULT AND DISCUSSIONS

A. *Wear Analysis*

In the proposed examination, L-27 symmetrical exhibit is selected and it was tabulated with twenty seven lines and thirteen segments. The determination of the symmetrical cluster depends relying on the prerequisite that the degrees of opportunity for the symmetrical exhibit ought to be more remarkable or equivalent to total level of the parameters. Every factor with the comparing collaborations was appointed to the segment characterized by Taguchi technique. Principal section is separate to compressive load on pin (L), the next segment to distance travelled by disc with respect to time (S), ash slag is assigned for fifth segment (F), and rest of the segments were separate to their co operations. The reaction factors to be inspected for wear rate. Rubbing of pin over the rotating disc without lubrication effect of the proposed metals was tried with Pin on Disk mechanical assembly and the outcomes were deciphered in Table II.

Table II: Process variables with results

Weight Kg	**Sliding Speed of disc m/s**	**Fly ash wt%**	**Wear of pin *10^-6 mm^3/m**
1	2	3	0.937
1	2	6	0.7855
1	2	9	0.6322
1	3	3	0.7808
1	3	6	0.6284
1	3	9	0.4741
1	4	3	0.7808
1	4	6	0.4713
1	**4**	**9**	**0.3161**
2	2	3	1.561
2	2	6	1.256
2	2	9	0.9483
2	3	3	1.249
2	3	6	1.099
2	3	9	0.7903
2	4	3	0.937
2	4	6	0.6284
2	4	9	0.4741
3	2	3	2.03
3	2	6	1.571
3	2	9	0.9483
3	3	3	1.405
3	3	6	1.099
3	3	9	0.9483
3	4	3	1.249
3	4	6	0.9426

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3	4	9	0.7903

B. Signal to Noise Ratio examination

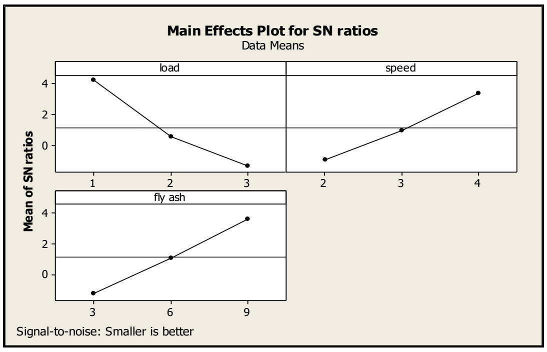
Impact of the dominant process variables, for example, weight loss of pin, rotating speed of disc and contribution of ash particle volume on wear has been assessed utilizing Signal to Noise proportion reaction analysis[11]. The dominant factor with most grounded impact was constrained with the dissimilarity among the greatest - least estimation of the mean of Signal to Noise variations. The Signal to Noise reaction examination exhibited in Table: III. It records that among every one of the variables, compressive load on the pin was the most persuasive and huge limitation pursued by rotating speed of disc followed by ash proportion. Figure II demonstrates the mean of Signal to Noise proportions for metal removal and the Figure III delineates with principle impacts scheme for mean metal removal rate. In the examination of this outcome, tends to derived the variables mix of 9.81 N as load on pin, Four m/s as rotating speed of disc and nine weight percentage of ash provides comparatively better metal loss for a scope of variables tried.

Table III: Table for Signal to Noise Ratios - Smaller the Better (metal loss*10^-6 (mm^3/m)

Levels	Weight N	Sliding Velocity m/sec	Fly ash wt. %
1	0.6451	1.1855	1.2144
2	0.9937	0.9415	0.9424
3	1.2204	0.7322	0.7024
Delta	0.5753	0.4533	0.5120
Grade	First	Third	Second

Table IV: Results of ANOVA for Wear Rate

Basis of variance	Sequence SS	Adjacent Means	Adjacent SS	Prababilty value	Fishers test	P (percentage)
L	1.48124	0.6856	1.48119	0	54.471	**36.9**
F	1.1702	0.590486	1.179	0	38.6283	29.8
S	0.92202	0.463227	0.92209	0	29.017	24.7
L x S	0.118	0.029408	0.118	0.2	3.04912	6.1
L x F	0.071	0.0178	0.071	0.3	2.242	0.0029
S x F	0.06782	0.016948	0.067793	0.31	2.17759	0.002
Errors	0.1151	0.0143	0.1141			2.49
Sum of all	4.101					**100**



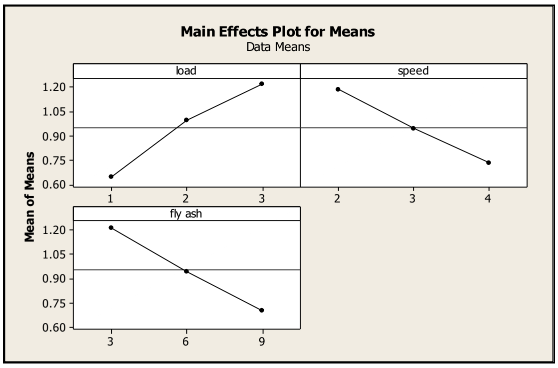


Fig. III: Main effect scheme for metal loss by wear

C. Level of Contribution by ANOVA

Analysis of variance is associated to characterize the plan variables essentially affecting the outcome. Table IV displays the consequences of the proposed analysis of variance technique for metal loss of pin by dry sliding. The final part of the Tabulation four demonstrates level of commitment (P %) for every variable in the response, presenting the impact level on outcome. This tends to seen in the outcomes acquired in tabulation four, the heap was the most critical parameter having the most astounding factual impact (Thirty seven percentage) on wear of pin slides over the rotating disc pursued by ash fiery remains (Thirty one percentage) and sliding rate of pin (Twenty five percentage).

D. Multiple Linear Regression Models

A numerous direct deterioration model is created by MINITAB 15* factual programming. The developed model provides the connection with autonomous and reaction parameters by proper condition.

Relapse condition for wear rate is,

Volume loss of pin material = 1.569 + 0.2879 load on pin in N - 0.08529 ash percentage - 0.22690 sliding velocity in m/s

The framed mathematical model has been used to identify the volume loss of the pin material[12]. Invariable terms presents in the numerical relation are considered as negligible.

E. Verification Test

So as to approve the Regression equation, affirmation experiments are directed.

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Levels of the variables are unique in relation to those utilized for examination. The distinctive levels of the factors has been decided to the affirmation experiment is arranged in the Table V; comparing the outcome of dry sliding wear experiments are recorded in Table VI.

Table V: Parameter for the Verification Test

Exp	Load (or) Weight N	Sliding velocity meter/sec	Ash contented (Weight)
1.	1.450	2.50	3%
2.	2.249	3.00	6%
3.	2.749	3.49	9%

Comparison of pin on disc experimentation result and regression model results reveals that error percentage not more than that of 5%. Strength of regression model is 95%

Table VI: Comparison of Experimental Results with Predicted Results through Regression equation

Exp	Experimental volume loss of pin (mm^3 / m) * 10^-6	Predicted or Calculated volume loss (mm^3 / m) *10^ -6	Error of the Equation
1.	0.9420	0.986	4.25
2.	0.8920	0.9092	1.90
3.	0.673	0.6898	1.49

IV. CONCLUSIONS

- Signal to Noise ratio reaction analysis confirms to load or weight was the large amount of governing constraint controls the dry sliding wears of hybrid self lubricating metal matrix composites materials.
- Force on the pin was the most important constraint having the main numerical control of thirty two percentage of wear rate of metal matrix composites, go after by fly ash content is thirty percentage and sliding speed gets twenty five percentage.
- A multiple linear regression numerical equation was framed through MINITAB 15* and it offer results with less than five error percentage.

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