EFFECT OF TITANIA ON AL-CU-MG ALLOY ON DRY SLIDING WEAR BEHAVIOR USING – TAGUCHI TECHNIQUE.

Puneeth Tahkur

Dept. of Industrial engineering and Management. Siddhartha University, Tumkur India

ABSTRACT

In the present study, Al-Cu-Mg alloy reinforced with 4 Wt % of Titania was prepared using stir casting method. This investigation is carried out to understand tribological properties of as cast Aluminium alloy and 4wt% Titania reinforced metal matrix composite. Dry sliding wear test was conducted to understand the tribological behaviors of samples. In the present study, the experiments were conducted as per the Taguchi design of experiment. The wear parameters chosen for the experiment were: Sliding speed, Load and sliding distance. Each parameter was assigned three levels. The experiment consists of 27 tests according to L_{27} *orthogonal array. The analysis of variance was used to investigate the significant factors that affect the dry sliding wear and to know the effect of Titania on Aluminum alloy. The result shows that Titania particles reinforced composite exhibited reduced wear rate than the unreinforced alloy.*

Key words: Titania; Taguchi Technique; ANOVA: Significant factors.

1.0 INTRODUCTION

Metal matrix composites (MMCs) are engineering materials that refer to a metal based materials reinforced with particulates, whisker or fiber which can produce considerable alteration in the physical and mechanical properties of the base alloy. Metal matrix composites have proved to be an important class of materials with the potential to replace a number of conventional materials being used in automotive, aerospace, defense and leisure industries where the demand for lightweight and higher strength components is increasing [1]. Aluminum matrix composites (AMCs) are the promising materials in high technology fields owing to their excellent specific mechanical properties. The key benefits of Aluminum matrix composites in transportation sector are lower fuel consumption, less noise and lower airbone emissions [2].

Ceramic whisker, fibers and particulate reinforced AMCs have been used as a tribo material. For e.g., piston and cylinder liners in automotive engines are typical applications [3]. MMCs generally posses superior wear resistance compared with unreinforced Aluminum alloy. A lot of research on the dry sliding wear behavior of MMCs have been reported [4-6] and also reviewed [7-9]. Tribological behavior of materials depends on many factors such as properties of material combinations, experimental condition and type of wear tester. Figure 1 shows the Ishikawa cause –effect diagram of Tribological behavior of materials.

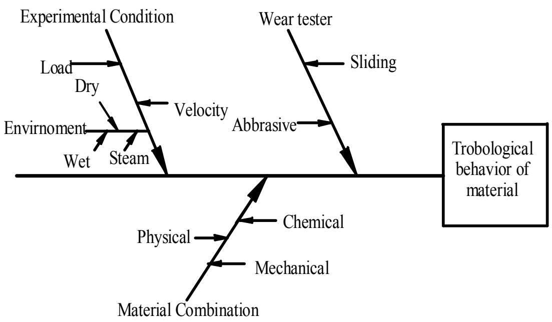


Figure 1. Ishikawa cause –effect diagram

T .Miyajima et al. [3] carried out dry sliding wear tests using pin-on-disc wear tester where the pins were of 0.45% carbon steel and disc were made of Aluminum alloy composites reinforced with SiC-whisker , Al2O3-fibers and SiC particles. The result analysis shows that, the wear rate of MMCs decreased with increasing volume fraction of reinforcing material. Basavarajappa et al., [4] investigated the dry sliding wear behavior of Aluminum alloy reinforced with SiC particles and reported that the wear rate of the MMCs reduces with increasing reinforcement content. Shipway et al. [6] produced TiC reinforced AMCs using novel casting technique. The sliding wear behavior of the extruded composites has been studied as a function of load and volume fraction. The result reveals that, particle addition of TiC has reduced the wear rates of the composites. Ranganath et al. [10] studied the dry sliding wear of garnet reinforced Zinc-AMCs and reported that wear resistance of the

MMCs increases as the content of the Garnet increases. S.K. Acharya et al. [11] investigated the wear behavior of Al / red mud composites and reported that coefficient of friction decreases as the load increases. Presence of red mud particles improves the hardness and wear resistance of the composites.

Esteban Fernandez et al. [12] used a statistical method, the factorial experimental design to investigate the effects of reinforcement, load and abrasive grain size of Ni based coating alloy. The summary of the result is grain size exerted the greatest effect on abrasive wear, followed by reinforcement. The load applied had a much lower effect and the environment was found to have minor effect. Leisk et al, [13] adopted Statistical-approach to optimize the heat – treatment of Alumina reinforced AMCs. The heat treatment was carried out according to orthogonal array. The interpretation is that the highest yield strength and ultimate tensile strength are obtained for the optimal solutionzing time (6h) and aging temperature (160^{o} C) for the both the 10 and 20 % alumina composites respectively. Hari singh et al, [14] used a design of experiment - Taguchi method to know the optimal setting of turning parameters that yield the optimal tool wear. The results indicated that selected process parameters affect significantly the tool wear characteristics of Tic coated carbide tool.
This study is carried out to know the effect of Titania on dry sliding wear behavior of the Al alloy. The ANOVA was employed to find the significant factor, which affects the dry sliding wear of Aluminum alloy and Al alloy composite.

1.1 Taguchi methodology

Taguchi methodology has the incredible power of total qualcost optimization of products and processes with minimum costs, effort and time. Dr. Genichi Taguchi has two basic beliefs that are fundamental to his statistical method. The first is that a reduction in variation of a product or process represents a lower loss to society. His second belief is that proper development strategies can reduce variation [15]. The purpose of running experiments, therefore should be reduced and control the variation in a product or process. This technique is a powerful tool for acquiring the data in a controlled way and to analyze the influence of process variable over some specific variable which is unknown function of these process variables. The overall aim of this technique is to make the products that are robust with respect to influencing parameters.

2.0 EXPERIMENTAL PROCEDURE

2.1 Materials

Aluminum2618 alloy that contains Copper and Magnesium as major constituent was used as matrix material. Titania of laboratory grade was used as a reinforcing material. 2 wt % Titania reinforced Al alloy composite was produced using stir-casting technique, which was used by researcher [16]. Both Aluminum alloy and composite specimen were subjected to T-6 heat treatment standards.

2.2. Selection of Orthogonal array

In the present study, the experiments were conducted as per the Standard orthogonal array. The wear parameters chosen for the experiment were: Sliding speed in m/s, Load in N and sliding distance in m. Each parameter was assigned three levels, which are tabulated in table 1. The experiment consists of 27 tests according to L_{27} orthogonal array shown in Table2. The first column was assigned to sliding speed, second column was assigned to load and the fifth column was assigned to sliding distance. The remaining columns were assigned to their interactions. The response to be studied is the wear rate in grams with the objective of smaller is the better.

Table1. Process parameters with their different levels.

Factors	**Code**	**Units**	**Level 1**	**Level 2**	**Level 3**
Sliding speed	S	m/S	1.256	2.090	3.056
Load in	L	N	19.6	29.4	39.2
Sliding Distance	D	m	500	1000	1500

Table.2 Orthogonal array L_{27} matrix

L_{27} test run	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	2	2	2	2	2	2	2	2	2
3	1	1	1	1	3	3	3	3	3	3	3	3	3
4	1	2	2	2	1	1	1	2	2	2	3	3	3
5	1	2	2	2	2	2	2	3	3	3	1	1	1
6	1	2	2	2	3	3	3	1	1	1	2	2	2
7	1	3	3	3	1	1	1	3	3	3	2	2	2
8	1	3	3	3	2	2	2	1	1	1	3	3	3
9	1	3	3	3	3	3	3	2	2	2	1	1	1
10	2	1	2	3	1	2	3	1	2	3	1	2	3
11	2	1	2	3	2	3	1	2	3	1	2	3	1
12	2	1	2	3	3	1	2	3	1	2	3	1	2
13	2	2	3	1	1	2	3	2	3	1	3	1	2
14	2	2	3	1	2	3	1	3	1	2	1	2	3
15	2	2	3	1	3	1	2	1	2	3	2	3	1
16	2	3	1	2	1	2	3	3	2	1	2	3	1
17	2	3	1	2	2	3	1	1	2	3	3	1	2
18	2	3	1	2	3	1	2	2	3	1	1	2	3

19	3	1	3	2	1	3	2	1	3	2	1	3	2
20	3	1	3	2	2	1	3	2	1	3	2	1	3
21	3	1	3	2	3	2	1	3	2	1	3	2	1
22	3	2	1	3	1	3	2	2	1	3	3	2	1
23	3	2	1	3	2	1	3	3	2	1	1	3	2
24	3	2	1	3	3	2	1	1	3	2	2	1	3
25	3	3	2	1	1	3	2	3	2	1	2	1	3
26	3	3	2	1	2	1	3	1	3	2	3	2	1
27	3	3	2	1	3	2	1	2	1	3	1	3	2

2.3 Experimental set –up

In order characterize the dry - sliding wear behaviour of the specimens, wear tests were performed using a Pin-on-disc machine, which was similar to the machine described by c.s. Ramesh [17]. Circular pins of diameter 8 mm and height 30 mm was used as a test specimen. The initial weight of the specimen was measured using an electronic weighing machine which as a resolution of 0.001 gram. The test specimen was gripped in the wear testing machine to avoid rolling during the test. The wear test was conducted as per the orthogonal array of Taguchi as shown in table 3. The wear rate of the specimen was studied as a function of the sliding velocity, applied load and sliding distance. Wear test were conducted as per procedure reported in the paper. [18] At the end of each experiment, the specimen was removed from the testing set-up, cleaned with acetone dried and weighed to determine the weight loss due to dry sliding wear. The difference in the weight measured before and after test gives the wear rate in grams. Each experiment was repeated twice and mean response values were tabulated in table 3.

Table3. Orthogonal array of Taguchi for Wear test & test results.

Test	Sliding speed	Load (N)	Sliding Distance	Wear rate of	Wear of Composite

	(m/s)		(m)	Al alloy (Gram)	material (Gram)
1	1.256	19.6	500	0.006	0.004
2	1.256	19.6	1000	0.009	0.007
3	1.256	19.6	1500	0.014	0.011
4	1.256	29.4	500	0.007	0.006
5	1.256	29.4	1000	0.009	0.008
6	1.256	29.4	1500	0.016	0.015
7	1.256	39.2	500	0.010	0.008
8	1.256	39.2	1000	0.013	0.010
9	1.256	39.2	1500	0.017	0.015
10	2.090	19.6	500	0.006	0.005
11	2.090	19.6	1000	0.012	0.009
12	2.090	19.6	1500	0.015	0.013
13	2.090	29.4	500	0.006	0.007
14	2.090	29.4	1000	0.015	0.012
15	2.090	29.4	1500	0.015	0.016
16	2.090	39.2	500	0.012	0.010
17	2.090	39.2	1000	0.015	0.013
18	2.090	39.2	1500	0.016	0.014
19	3.056	19.6	500	0.007	0.006
20	3.056	19.6	1000	0.009	0.008
21	3.056	19.6	1500	0.011	0.010
22	3.056	29.4	500	0.008	0.007
23	3.056	29.4	1000	0.010	0.008

24	3.056	29.4	1500	0.008	0.007
25	3.056	39.2	500	0.011	0.009
26	3.056	39.2	1000	0.014	0.012
27	3.056	39.2	1500	0.012	0.010

Table4. S/N ratio for Al alloy and composite Material.

Run	**S/N Ratio (db) of Al alloy (x -1)**	**S/N Ratio (db) of Composite (x -1)**
1	44.4370	47.9588
2	40.9151	43.0980
3	37.0774	39.1721
4	43.0980	44.4370
5	40.9151	41.9382
6	35.9176	36.4782
7	40.0000	41.9382
8	37.7211	40.0000
9	35.3910	36.4782
10	44.4370	46.0206
11	38.4164	40.9151
12	36.4782	37.7211
13	44.4370	43.0980
14	36.4782	38.4164

15	36.4782	35.9176
16	38.4164	40.0000
17	36.4782	37.7211
18	35.9176	37.0774
19	43.0980	44.4370
20	40.9151	41.9382
21	39.1721	40.0000
22	41.9382	43.0980
23	40.0000	41.9382
24	41.9382	43.0980
25	39.1721	40.9151
26	37.0774	38.4164
27	38.4164	40.0000

3.0 RESULT DISCUSSION

The selected quality characteristic, sliding wear is a 'lower is better' type and signal to noise ratio (S/N ratio) for 'lower is better' type of response was used as given below.

$$\eta = -10log_{10}\left\{\frac{1}{n}\sum_{i=1}^{n} y_i^2\right\} \qquad \text{----------- (1)}$$

Where n = number of tests in a trial.

For the present study n = 2.

The S/N ratio was computed using equation (1) for each of the 27 trial and the values are reported in table 4.

Figure 3 and 5 shows the mean effect of process parameters on the wear quality characteristics for both Aluminum alloy and composite material. The average mean wear of Aluminum alloy is 0.0112 grams, where as for the composite material it is 0.0096 grams. This shows that wear resistance of Aluminum alloy increases by adding Titania.

The average values of S/N ratios of three parameters at three levels for both Aluminum alloy and composite material are plotted in Figure 2 and 4. It is evident from the figure that, Wear quality characteristic is lowest when the process parameters is at, 3rd level of parameter S, 1st level of parameter L and 1st level of parameter D. The analysis of means also suggested the same level of parameters for lowest dry sliding wear.

3.1 Analysis of variance.

The analysis of variance (ANOVA) establishes the relative significance of factors in terms of their percentage contribution to the response. ANOVA is also needed for estimating the error variance for the effects and variance of the prediction error. Based on ANOVA the optimal combinations of the process parameters are predicted. The analysis is carried out for the significance of 5 % (95% confidential level). The table4 and 5 shows analysis of variance for Aluminum alloy and AMCs. From the results of ANOVA, it is found that distance factor has major influence on sliding wear characteristic (P = 46.72% for Aluminum alloy and P = 48.829 % for composite material. The second significant factor is Load which as P = 22.21 % for Aluminum alloy and P = 18.687 % for composite material. The interaction between S * D which as moderate effect, on the sliding wear characteristics for both Aluminum alloy and composite.

Table 4. ANOVA test for S/N Ratio for Al alloy.

Factors	**DOF**	**SS**	**Adj SS**	**V**	**F**	**P**	**% Contribution**
Sliding speed (S) M /Sec.	2	11.240	11.240	5.620	3.69	0.073	4.59

Load(L) N	2	48.300	48.300	24.150	15.44	0.002	22.21
Distance(D) M	2	99.887	99.887	49.943	31.93	0.000	46.72
S*L	4	9.539	9.539	2.385	1.52	0.283	3.78
S*D	4	26.688	26.688	6.672	4.27	0.039	11.93
L*D	4	1.958	1.958	0.489	0.31	0.862	0.18
Error	8	12.514	12.514	1.564			10.59
Total	26	210.426	210.426				100

Table 5. ANOVA test for S/N Ratio for composite material.

Factors	**DOF**	**SS**	**Adj SS**	**V**	**F**	**P**	**% Contribution**
Sliding speed (S) M /Sec.	2	18.755	18.755	9.378	12.03	0.004	7.432
Load (L) N	2	45.977	45.977	22.989	29.50	0.000	18.687
Distance (D) M	2	118.879	118.879	59.440	76.28	0.000	48.829
S*L	4	12.662	12.662	3.165	4.06	0.044	4.913
S*D	4	29.758	29.758	7.440	9.55	0.004	11.981
L*D	4	9.594	9.594	2.398	3.08	0.082	3.64
Error	8	6.234	6.234	0.779			4.518
Total	26	241.860	241.860				100

4.0 CONCLUSION:

Following conclusions were drawn from the present investigation.

1. Titania particle reinforced composite exhibited reduced wear rate than the unreinforced alloy specimen.
2. Sliding wear rate for both Al alloy and composite were found to be lowest, when the parameters were set at the following levels. i. Sliding velocity: 3.056 M/Sec ii. Load: 19.6 N iii. Distance: 500 M for both Aluminum alloy and composite material.
3. The process contribution of each parameters to the lowest sliding wear of the both as cast and AMCs are as follows

Process parameters	**Aluminum alloy specimen**	**Composite specimen**
Sliding Velocity in m/s	4.59	7.432
Load in N.	22.21	18.687
Sliding distance in m.	46.72	48.829

4. The interaction between sliding speed X distance is more significant both in Aluminum and Composite material.

Figure2. Signal to noise ratio for Al Alloy material.

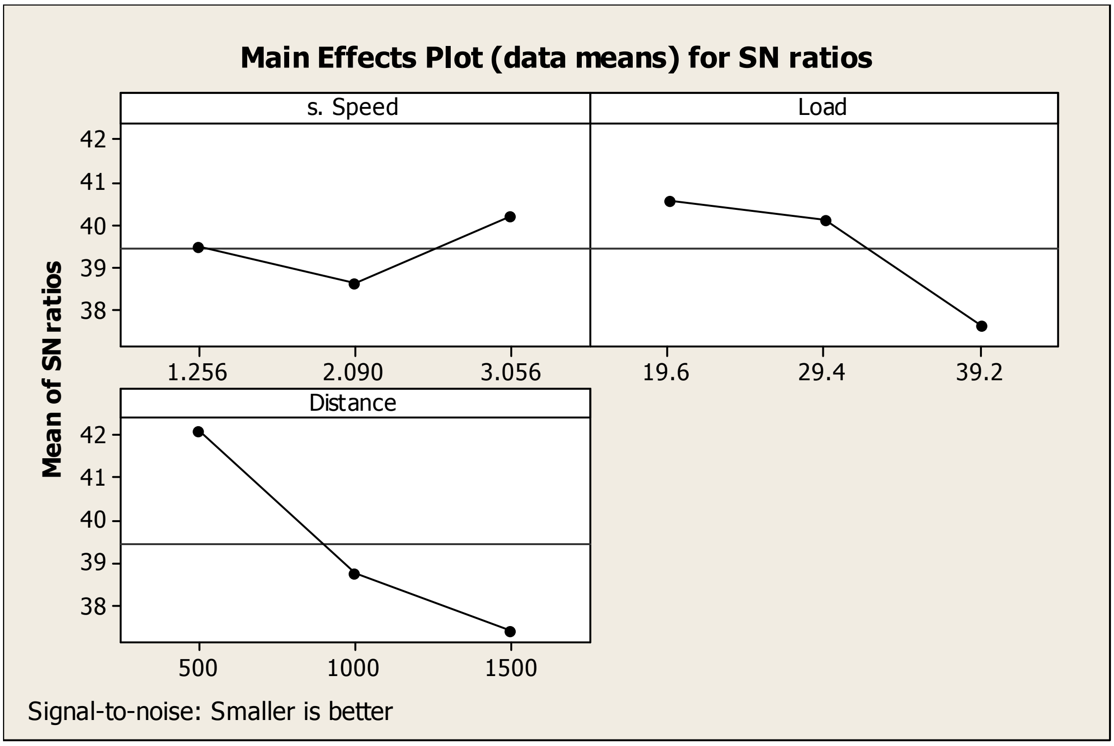


Figure3. Analysis of means for Al Alloy material.

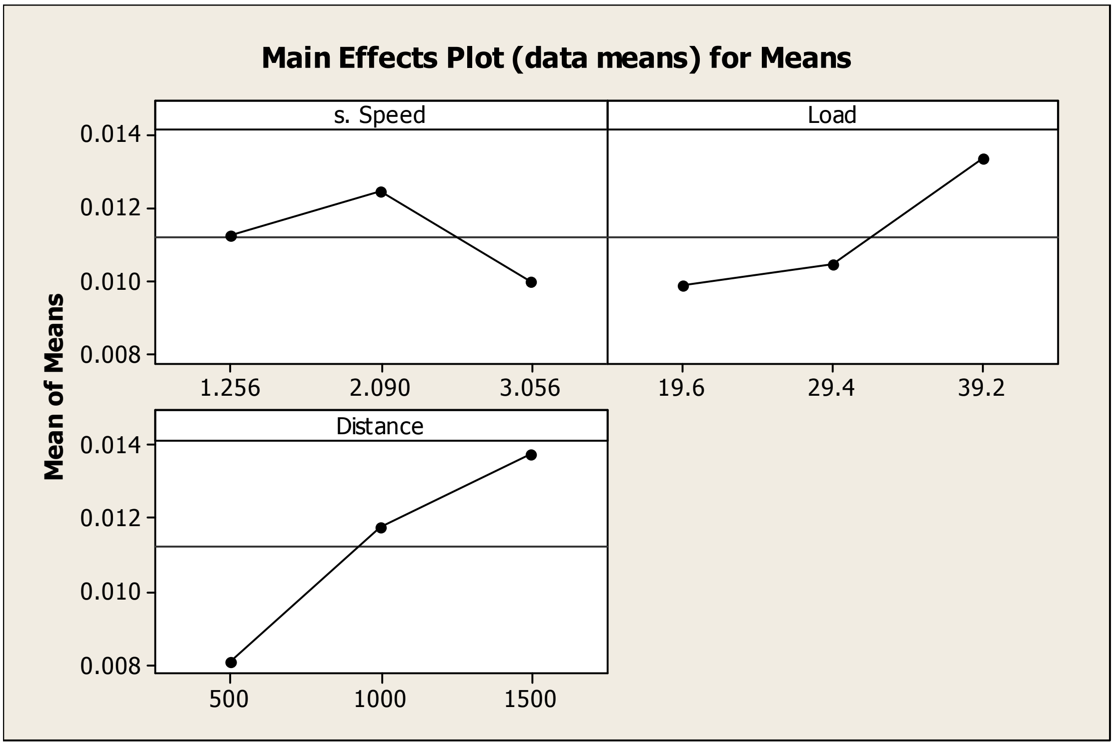


Figure4. Signal to noise ratio for Composite material.

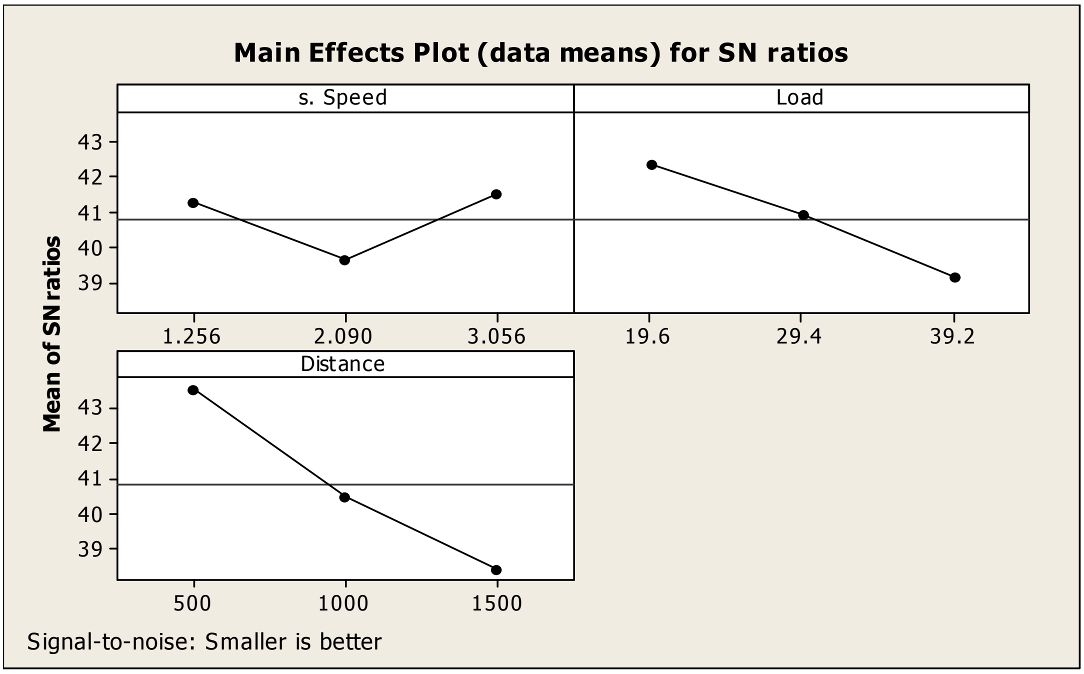
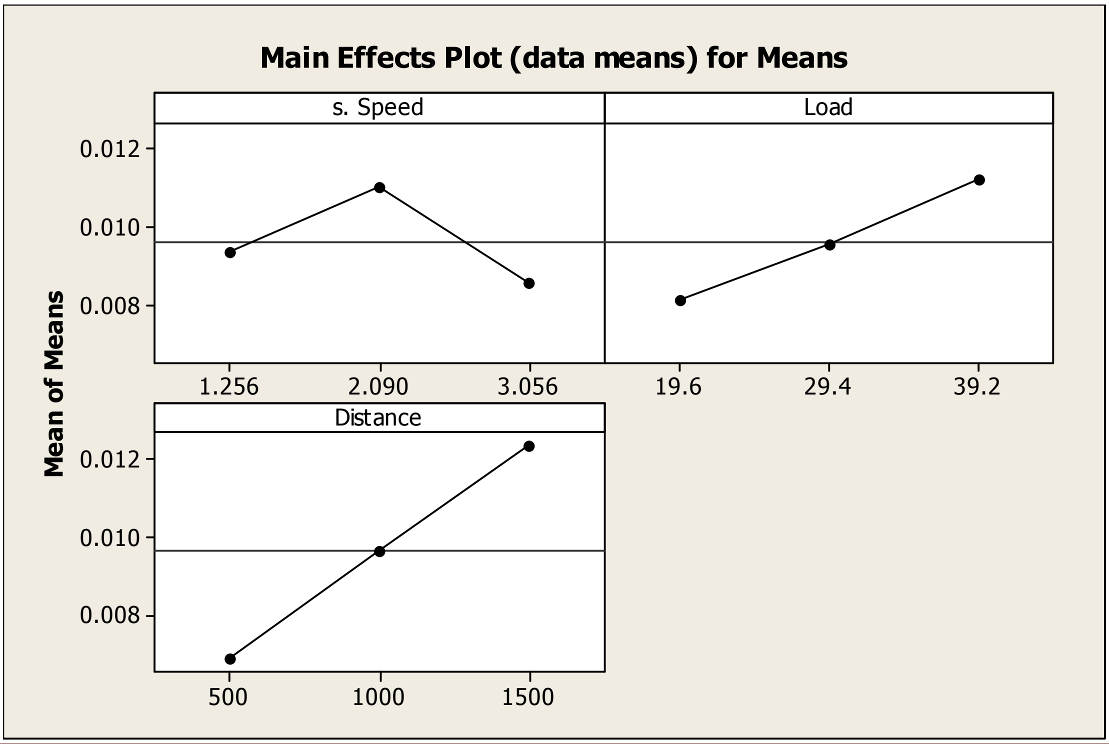


Figure5. Analysis of Means for composite material



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