A Study on Optimization of Reinforcements Al_2O_3 and Tur Husk on Mechanical and Tribological Properties of AA7068 MMC's by Taguchi Technique

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***Abstract*: Two phases namely a matrix and a reinforcement phase constitute composite materials. Most of studies shows that the material used for components should possess better mechanical and tribological properties. In this paper the investigation on influence of reinforced particles Al_2O_3 and Tur husk on mechanical and tribological properties of aluminium alloy (AA7068) composites which is developed by stir casting technique. The samples are prepared by casting method and are fabricated by varying weight percentage of the reinforced particles as 5%,10%, 15% and Al2O3 kept constant as 5%, samples are heated at 650°c,700°c and 750°c with different stirring time 5,10 and 15 minutes. The Taguchi L9 Orthogonal Array is applied to find the optimum level from the results it is proved that the pouring temperature played a vital role in increasing the tensile strength and in reducing the hardness and wear. From the results it is also noted that the % weight of Tur husk is helped to increase the wear of the material. AA7068 is now being used in auto sport gear box actuators and wheel components, connecting rods and automotive industries.**

***Keywords*: Stir casting, Aluminium 7068, Al_2O_3, Tur husk, Taguchi optimization technique, ANOVA.**

1. Introduction

Stir casting is a liquid state method for the fabrication of composite materials, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. Stir Casting is the simplest and the most cost effective method of liquid state fabrication.

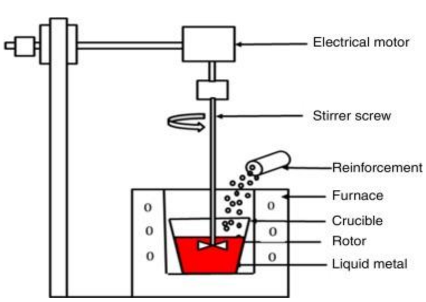


Fig. 1. Stir casting process

In this process of stir casting, particles come together to form a collected mass which can only be dissolved by continuous and rigorous stirring of molten mixture at high temperature. This method is one of the low cost process out of available manufacturing techniques for AMCs, with advantage of low cost; it also offers a wide range of material and bonding of metal matrix. The addition of ceramic particles is done with continuous stirring.

A. *Metal Matrix Composites*

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound. Metal Matrix Composites are significantly contributing towards important role in engineering applications and are in the forefront of significant research in present day due to their scientific and technical advantages. Particle or discontinuously reinforced MMCs are relatively inexpensive and are found to possess specific properties compared to fiber reinforced MMCs. While metal matrix composites enjoy other advantages over polymer matrix composites such as better abrasion resistance, creep resistance, resistance to degradation by fluids, dimensional stability, and non-flammability, they are limited in application due to their much higher weight and cost of production. The main matrix materials employed in MMCs are aluminium, titanium, magnesium, and copper. The main reinforcements employed are silicon carbide and alumina. MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix.

B. *Taguchi's Optimization Technique*

Taguchi's concept is based on the effective application of engineering approach rather than advanced statistical analysis. It focused on both upstream and shop-floor quality engineering concept. Upstream methods effectively reduce the cost and variability by use of small-scale experiments, and used robust designs for large scale production and market aspect. Shop-floor techniques facilitate economical, real time methods for monitoring and maintaining quality aspects in production. The further upstream a quality method is applied, the greater leverages it produces on the improvement, and the more it reduces the cost and time. The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide. Taguchi proposes an off-line strategy for quality improvement as an alternative to an attempt to inspect quality into a product on the production line. He observes that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three-stage process: system design, parameter design and tolerance design. His approach gives a new experimental strategy in which a new developed form of design of experiment is used. In other words, the Taguchi approach is a form of DOE with some new and special application approach. This technique is helpful to study effect of various process parameters (variables) on the desired quality and productivity in a most economical manner. By analyzing the effect of various process parameters on the results, the best factor combination taken. Taguchi designs of experiments using specially designed tables known as “orthogonal array”. With the help of these experiments table the design of experiments become the use of these tables makes the design of experiments very easy and consistent and it requires only few number of experimental trials to study the entire system. In this manner the whole experimental work can be made economical. The experimental outcomes are then transformed into a S/N ratio. Taguchi suggest the use of the S/N ratio to investigate the quality characteristics deviating from the standard values. Usually, there are three type of classification of the quality characteristic in the study of the S/N ratio, i.e. the-lower-the better, the higher-the-better, and the nominal-the-better.

The S/N ratio for each category of process parameters is computed based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimum level of the process parameters is the level with the greatest S/N ratio, so in this manner the optimal combination of the process parameters can be predicted.

1) Types of S/N ratio [14]

- *Larger- the- better:* $S/N = -10 \log 10(1/n \Sigma 1/yi^2)$

Where, i=1 to n, n = no. of replications applied to the problems where maximization of quality characteristics of interest is needed.

- *Smaller- the- better:* $S/N = -10 \log 10(1/n \Sigma yi^2)$

It is used where minimization of the characteristics is intended.

2. Literature survey

From the literature survey it is found that many researchers done research on effect on mechanical properties of Aluminium alloy by varying the reinforcements like SiC, Al_2O_3, Mg and so on. And some of them are summarised below.

[1] Prasanna gubbi, B. S. Motagi, *a study on mechanical and tribological properties of aluminium 7068 mmc’s reinforced with silicon carbide (sic) and tur husk*, *(2017*). In this paper five samples were prepared by using stir casting. First sample is Al7068, second sample consist of Al7068 with 2% sic and 8%tur husk, third sample consist of Al7068 with 4% sic and 6% tur husk the fourth sample consist of Al7068 with 6% sic and 4% tur husk and the fifth sample is of Al7068 with 8%sic and 2%tur husk. It was found that tensile strength and impact is increased when sic and tur husk is added to Al7068. Wear is decreased when sic and tur husk is added to Al7068.

[2] Shaikh sharjeel zeeshan, Sunil J Mangshetty, *a study on mechanical and tribological properties of aluminum-7068 alloy reinforced with sic and* Al_2O_3*, (2018),* the %wt of reinforcement are varied to study the difference in aluminum property. Following are the samples are first sample is Al7068 with 2% sic and 8% Al_2O_3, second sample consist of Al7068 with 4% sic and 6% Al_2O_3, third sample consist of Al7068 with 6% sic and 4% Al_2O_3, and the fourth sample is of Al7068 with 8%sic and 2% Al_2O_3. The materials are obtained by stir casting technique. The casted composite specimens were machined as per standards. The aim is to study the mechanical and tribological properties of Al-7068 alloy reinforced with sic and Al_2O_3 composite with various weight fractions were prepared by stir casting method.

[3] Zahid hussain mansoor, Sunil J. Mangshetty, *a study on hardness and tribological properties of aluminum-7068 alloy based metal matrix composite reinforced with titanium carbide (tic) particles, (2018),* experiments were conducted by varying weight fraction of tic (0%, 3%, 6%, 9% and 12%). Wear characteristics of al-tic composites have been investigated under dry sliding. Dry siding wear tests have been carried out using pin-on-disk wear tester at different loads (2 kg & 3 kg) and different speeds (200rpm, 400rpm, 600rpm). The tests were carried out making possible combination of load and speed with each weight fraction of tic. The results indicate that on addition of tic reinforcement in al-7068 alloy has improved the wear performance. The effect of load indicates that as load increases the wear increases and while speed increases the wear performances decreases. The hardness of the composite materials was measured using brinell hardness tester and found that as weight fraction increases the hardness of the composite increases.

[4] Md. sadiq ali, B. S. Motgi, *a study on mechanical and tribological properties of al6063 mmc reinforced with nano sic, fly ash and red mud, (2015),* the main aim involved in the present work is focused on study of mechanical and tribological properties of al6063 alloy composite having varying weight percentages of 3% - 2% - 2% of nano sized silicon carbide, fly ash and red mud. The result indicated that the developed method is quite successful and there is an increase in the value

of tensile strength, hardness with increase in weight percentage of sic. Metal matrix composites reinforced by nano-particles are very promising materials, suitable for a large number of applications.

[5] Prerana Evangeline, B. S. Motgi, studied, *experimental investigations on mechanical properties of al 6061, sic, flyash and redmud reinforced metal matrix composites, (2014),* in the present investigation Al6061 alloy composites having varying weight percentages of (3% - 6%) silicon carbide, fly ash and red mud were fabricated by liquid metallurgical (stir casting) method. The casted composite specimens were machined as per bs: 18: 1962 test standards. The specimens were tested to know the mechanical properties such as tensile test, impact (charpy) test and wear test. The result reveals higher tensile strength, impact strength and wears resistance in al6061-sic-flyash samples when compared to al6061-sic-redmud samples.

[6] Praful kumar, Sunil J. Mangshetty, *a study to optimize the casting process parameters of Al-6063 alloy using taguchi technique, (2016),* the primary objective is to use taguchi method for predicting the better parameters that give the highest tensile strength and hardness to the castings, and then preparing casting sample at these parameters and comparing them with the randomly used ones. The experimental and analytical results showed that the taguchi method was successful in predicting the parameters that give the highest properties and the pouring temperature was the most influential parameter on the tensile strength and hardness results of castings.

[7] Vijay Kumar S. Maga, B. S. Motagi, *a study on mechanical properties of aluminium alloy (lm6) reinforced with fly ash, redmud and silicon carbide, (2014),* in this present study a modest attempt has been made to develop aluminium based mmcs with reinforcing material with an objective to develop a conventional low cast method of producing mmcs and to obtain homogeneous dispersion of reinforced material. To achieve this objective stir casting technique has been adopted. Aluminium alloy (lm6) and sic, fly ash, red mud has been chosen as matrix and reinforcing material respectively. Experiment has been conducted by varying weight fraction of sic, fly ash, redmud. The result shown that the increase in addition of fly ash is giving better result when compared with redmud.

[8] Vinitha, B. S. Motgi, investigated *evaluation of mechanical properties of al 7075 alloy, flyash, sic and red mud reinforced metal matrix composites, (2014),* the main aim involved in the present work is focused on study of mechanical properties of Al7075 alloy composite having varying weight percentages of 3% - 6% of silicon carbide, fly ash and red mud were fabricated by liquid metallurgy (stir casting) method. The casted composite specimens were machined as per bs: 18: 1962 test standards. The result obtained reveals that tensile strength, impact strength and wear resistance is higher in Al7075-sic-redmud samples when compared to Al7075-sic-flyash samples.

[9] Mohammed Zafar Ali, B. S Motgi, *a study on mechanical and tribological properties of aluminium 7075 mmc's reinforced with nano silicon carbide (sic), tur husk and e-glass fiber, (2017),* the Al-7075 composites were fabricated by liquid metallurgy (stir cast) method by varying different percentages. The composite specimens were machined as per astm test standards. It has been observed that addition of nano sic, tur husk and e-glass fiber significantly improves ultimate tensile strength along with compressive strength and hardness properties as compared with that of unreinforced matrix. The reinforcement is varied in 3 sets each set comprises of 3 specimens. Nano sic is kept constant [1% in 1st set, 2% in 2nd set and 3% in 3rd set], tur husk and glass fiber are varied in 1% and 2% in all specimens. The casted composite specimens were machined as per astm standards. The mechanical properties like ultimate tensile strength, impact strength and wear behavior of the test specimens were investigated.

[10] Amarnath, B. S. Motgi, *a study on synthesis and characterization of Al 7075 reinforced with nano sic and red mud, (2016),* the main mechanical properties studied were the tensile strength, ductility impact strength & wear strength. Unreinforced al7075 samples were also tested for the same properties. In our study we varied the reinforcing material in smaller quantity to avoid the mixing problem. And from the results what we got shows the addition of reinforcing materials like red mud and nano sic improves tensile strength, impact strength and reduces % elongation.

[11] Syed Affan Ahmed, B. S. Motgi, *a study on mechanical and tribological properties of al lM6 mmcs reinforced with nano sic, fly ash and red mud, (2015),* the objective of this experimental investigation is to produce two different metal matrix composite (mmcs) specimens using al lm6 as a base material which reinforced with silicon carbide, fly ash, red mud whose grain size is in nano size i.e sic-80 nano meter (nm), fly ash-100000 nm or 100 microns (μm), redmud-120000 nm or 120 μm and then studying its mechanical and tribological properties such as tensile strength, impact strength, hardness and wear behavior of produced test specimen. Experiment is conducted by varying weight fraction of sic, fly ash, red mud and then testing its tensile strength, impact strength, hardness, wear behavior. The result reveal that the optimum tensile strength of the hybrid composite is obtained constant as the weight percentage of red mud varies from (2% to 4%) and also results in higher tensile strength. The result also shows that increased in addition of fly ash improve the impact strength and also improve wear resistance.

[12] Youhizama, B. S Motgi, *Evaluation of mechanical properties of Al6063 MMC's reinforced with nano sic,tur husk and e-glass fiber, (2017),* the present study deals with the investigation of mechanical properties of aluminium alloy (Al6063) based hybrid metal matrix composite reinforced with nano silicon carbide, glass fiber and tur husk. The sample specimens were made by varying the percentage of reinforcement with respect to aluminium alloy through stir casting technique. The reinforcement is varied in 3 sets each set comprises of 3 specimens. Nano sic is kept constant [1% in 1st

set, 2% in 2nd set and 3% in 3rd set], tur husk and glass fiber are varied in 1% and 2% in all specimens. The casted composite specimens were machined as per astm standards. The mechanical properties like ultimate tensile strength, impact strength and wear behavior of the test specimens were investigated.

[13] P. Naresh, Syed Altaf Hussain, B. Durga Prasad, *a review on wear analysis of aluminium based metal matrix composites (2018)*, this paper research about the al-7068&tic with different weight percentages that focus on wear analysis of this metal matrix composites. Originality/ value: by surveying the different research articles of wear analysis on metal matrix composites the gap will be identified in al-7068 & tic with different weight percentages, wear analysis by using the pin-on-disc apparatus with central composite design in minitab-17.

[14] Prashant Mulge, Sunil Mangashetty, *A Study to Optimize the Casting Process Parameters of Al-365/LM25 Alloy using Taguchi Technique,* the optimization of casting process parameters (Pouring temperature, [poring speed and cooling time) was optimized by Taguchi method and the authors had revealed that the optimum level of process parameters to obtain good mechanical properties for the sand casting of Aluminium 365/LM25 are 800^0C pouring temperature, 10 seconds Pouring time And 9 minutes cooling time for tensile strength and 8000C pouring temperature, 10 second pouring time and 3 minutes cooling time for hardness. From the pareto analysis it was evident that the Pouring temperature is a major contributing factor for improving tensile strength and hardness.

[15] J. Lakshmipathy, S. Rajesh kannan, B, K. Manisekar, s. Vinoth Kumar, *effect of reinforcement and tribological behaviour of aa 7068 hybrid composites manufactured through powder metallurgy techniques (2016)*, the hybridization of the two reinforcements enhanced the wear resistance of the composites, especially under high applied load, sliding distance and sliding speeds. Due to this, the hybrid aluminium composites can be considered as an outstanding material where high strength and wear-resistant components are of major importance, predominantly in the aerospace and automotive engineering sectors. The morphology of the wear debris and the worn out surfaces were analyzed to understand the wear mechanisms.

3. Objective of the work

- The casting samples are prepared as per Taguchi L9 orthogonal array.
- The samples are prepared by varying the weight % of Tur husk by 5,10 and 15, keeping the weight of Al_2O_3 constant as 5% and varying the pouring temperatures by 650,700 and 750.
- The samples are machined as per (ASTM SA370) standard.
- Testing of samples for Tensile strength, hardness values and for wear values.
- Applying the Taguchi optimization technique.

4. Experimental setup

A. Preparation of Casting Samples

- Using electric muffle furnace, the tur husk is burnt completely to powder form for about 6-7 hours at 700^0C.
- Induction furnace is used to melt the Al 7068.
- Stir casting process is used to mix all the reinforcements correctly.
- A metal die is used to pour the molten material in it.
- The samples are prepared as per the table 3.

Fig. 2. Induction furnace

Fig. 3. Induction furnace

Fig. 4. Tur husk powder

Fig. 5. Al_2O_3 powder

Fig. 6. Tensile tester

Fig. 7. Brinell Hardness Tester

Fig. 8. Wear Tester

B. Preparation of Specimens

1) For Tensile test (ASTM SA370)

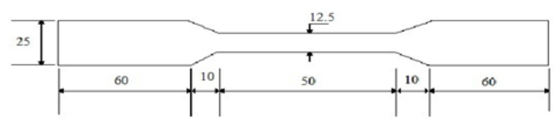


Fig. 9. Tensile test specimen (All dimensions are in mm)

Fig. 10. Tensile Samples before testing

Fig. 11. Tensile Samples after testing

The tensile test is carried out for all specimens respectively. The maximum capacity of U.T.M (universal testing machine) is 400 KN. The UTM is used to obtain the tensile property of the specimen. The dimension of Specimen is 50 mm gauge length and 12.5 mm diameter and 20 mm diameter on both end for holding purpose.

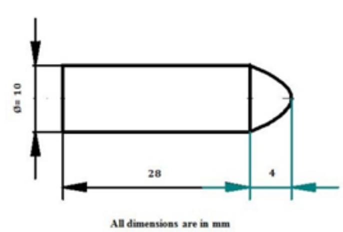
2) For Hardness test

Hardness test is conducted for each specimen using a load of 250 N and a steel ball indenter of diameter 5 mm.

Fig. 12. Hardness Samples before testing

Fig. 13. Hardness Samples after testing

3) For wear test



Dry sliding wear tests for different number of specimens is conducted by using a pin-on-disc machine (Model: Wear & Friction Monitor TR-201 CL DST- FIRST). The pin is held against the counterforce of a rotating disc with wear track diameter 60 mm & the pin is loaded against the disc through a dead weight loading system.

Fig. 14. Wear sample for testing

5. Steps involved in Taguchi method

A. Design of Experimental (DOE) [14]

The steps applied for Taguchi optimization in this study are as follows.

- Select Taguchi orthogonal array
- Conduct Experiments
- Tensile test results, Hardness results & wear values
- Analyze results; (Signal to noise ratio)
- Predict optimum performance
- Confirmation experiment

Degree of Freedom (DOF) = number of levels -1,
For each factor,
DOF equal to:
For (% weight of Tur husk) DOF = 3 – 1 = 2
For (Stirring time) DOF = 3 – 1 = 2
For (Pouring temperature) DOF = 3 – 1 = 2

Table 1
L_9 Orthogonal array [14]

Exp. No.	A	B	C
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

Table 2
Control factors and levels

Factors	Control Factor	Level 1	Level 2	Level 3
A	Weight of Tur husk	5%	10%	15%
B	Stirring time	5min	10min	15min
C	Pouring temperature	650^0 C	700^0 C	750^0 C

Table 3
Control factors value for Sample preparation

Sample No	% weight of reinforcements (A)	Stirring time (min) (B)	Pouring temperature (C^0) (C)
1	5% Th +5%Al_2O_3+90%Al	5	650
2	5% Th +5%Al_2O_3+90%Al	10	700
3	5% Th +5%Al_2O_3+90%Al	15	750
4	10% Th +5%Al_2O_3+85%Al	5	700
5	10% Th +5%Al_2O_3+85%Al	10	750
6	10% Th +5%Al_2O_3+85%Al	15	650
7	15% Th +5%Al_2O_3+80%Al	5	750
8	15% Th +5%Al_2O_3+80%Al	10	650
9	15% Th +5%Al_2O_3+80%Al	15	700

*Th=Tur husk, Al_2O_3=Aluminium Oxide, Al=Aluminium

B. Analysis of the S/N Ratio

Taguchi method uses the (signal – to – noise (S/N) ratio, because it minimizes quality characteristic variation due to uncontrollable parameter. The Tensile strength and Hardness are the objective functions so that "the larger-the-better" S/N ratio is chosen. The S/N ratio used for this type of response is

The S/N ratio for the larger-the-better is:

$$S/N_{LTB} = -10 \log [\text{MSD}] \qquad [14]$$

$$\text{MSD} = \frac{1}{n}\sum_{i=1}^{n=1} \frac{1}{y_i^2} \qquad (1)$$

And for Wear the objective function so that "the smaller the better" S/N ratio used for this type of response is,

The S/N ratio for the smaller-the-better is:

$$S/N_{STB} = -10 \log [\text{MSD}] \qquad [14]$$

$$\text{MSD} = \frac{1}{n}\sum_{i=1}^{n=1} y_i^2 \qquad (2)$$

where: n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row.

C. Analysis of variance (ANOVA)

Analysis of Variance (ANOVA) is a computational technique to quantitatively estimate the relative contribution, which each controlled parameter makes to the overall measured response and expressing it as a percentage. ANOVA uses the S/N ratio responses for these calculations.

Table 4
Pareto ANOVA for three level factors [14]

Factors	A	B	C	E	Total
Sum at factor level	$\sum A_1$	$\sum B_1$	$\sum C_1$	$\sum E_1$	T
	$\sum A_2$	$\sum B_2$	$\sum C_2$	$\sum E_2$	
	$\sum A_3$	$\sum B_3$	$\sum C_3$	$\sum E_3$	
Sum of squares of difference	S_A	S_B	S_C	S_E	S_T
Degree of freedom	2	2	2	2	8
Contribution ratio (X 100)	$\frac{S_A}{S_T}$	$\frac{S_B}{S_T}$	$\frac{S_C}{S_T}$	$\frac{S_E}{S_T}$	100

$T=\sum A_1+\sum A_2+\sum A_3$

$S_A= (\sum A_1-\sum A_2)^2+ (\sum A_1-\sum A_3)^2+ (\sum A_2-\sum A_3)^2$

$S_B= (\sum B_1-\sum B_2)^2+ (\sum B_1-\sum B_3)^2+ (\sum B_2-\sum B_3)^2$

$S_C= (\sum C_1-\sum C_2)^2+ (\sum C_1-\sum C_3)^2+ (\sum C_2-\sum C_3)^2$

$S_E= (\sum E_1-\sum E_2)^2+ (\sum E_1-\sum E_3)^2+ (\sum E_2-\sum E_3)^2$

$S_T= S_A+ S_B+ S_C+ S_E$

6. Results and Discussions

Table 5
Experimental Observations

Sample No.	A	B	C	Tensile strength (N/mm^2)	Hardness Number (BHN)	Wear value (µm)
1	5	5	650	96.745	121	364
2	5	10	700	169.601	80.4	701
3	5	15	750	149.953	76.3	824
4	10	5	700	179.474	79.5	1444
5	10	10	750	146.194	72.4	494
6	10	15	650	114.734	71.7	1133
7	15	5	750	134.996	73.2	1426
8	15	10	650	144.720	75.5	1355
9	15	15	700	149.209	72.4	1144

A. S/N ratio values

Table 6
S/N ratio for Tensile strength, Hardness & Wear

Sample No	A	B	C	E	S/N ratio for (Tensile strength)	S/N ratio for (Hardness BHN)	S/N ratio for Wear
1	1	1	1	1	39.714	41.655	-51.222
2	1	2	2	2	44.589	38.107	-56.914
3	1	3	3	3	43.519	37.670	-58.318
4	2	1	2	3	45.080	38.007	-63.191
5	2	2	3	1	43.299	37.196	-53.874
6	2	3	1	2	41.197	37.110	-61.084
7	3	1	3	3	42.606	37.290	-63.082
8	3	2	1	1	43.205	37.559	-62.638
9	3	3	2	2	43.477	37.196	-61.168

A=% wt of Tur husk, B=stirring time, C=pouring temperature, E= Error

1) For tensile strength

$$S/N_{LTB} = -10 \log [\text{MSD}]$$

$$\text{MSD} = \frac{1}{n}\sum_{i=1}^{n=1} \frac{1}{y_i^2}$$

$$\text{MSD} = \frac{1}{(96.745)^2}$$

$$\text{MSD} = 1.068 \times 10^{-4}$$

$$S/N_{LTB} = -10 \log [\text{MSD}]$$

$$= -10 \log [1.068 \times 10^{-4}]$$

$$S/N_{LTB} = 39.714$$

2) For hardness

$$S/N_{LTB} = -10 \log [\text{MSD}]$$

$$\text{MSD} = \frac{1}{n}\sum_{i=1}^{n=1} \frac{1}{y_i^2}$$

$$\text{MSD} = \frac{1}{(121)^2}$$

$$\text{MSD} = 6083 \times 10^{-5}$$

$$S/N_{LTB} = -10 \log [\text{MSD}]$$

$$= -10 \log [6.83 \times 10^{-5}]$$

$$S/N_{LTB} = 41.655$$

3) For wear

$$S/N_{STB} = -10 \log [\text{MSD}]$$

$$\text{MSD} = \frac{1}{n}\sum_{i=1}^{n=1} y_i^2$$

$$\text{MSD} = 364^2$$

$$\text{MSD} = 132496$$

$$S/N_{STB} = -10 \log [132496]$$

$$S/N_{STB} = -51.222$$

Calculations are similar for sample 2 to sample 9 for all the tests.

B. Pareto ANOVA

1) Pareto ANOVA for tensile strength

Table 7
Pareto ANOVA for Tensile strength

Factors	A	B	C	E	Total
Sum at factor level	127.822	127.400	124.116	126.218	386.686
	129.576	131.093	133.146	129.263	
	129.288	128.193	129.424	131.205	
Sum of squares of difference	5.307	22.676	123.568	37.913	189.464
Degree of freedom	2	2	2	2	8
Contribution ratio	2.80%	11.968%	65.219%	20.010%	100%
Optimum level	2	2	2		
	A2	B3	C3		
	10%	10 min	700^{0}C		

2) Pareto ANOVA for hardness

Table 8
Pareto ANOVA for Hardness

Factors	A	B	C	E	Total
Sum at factor level	166.454	177.494	174.944	167.734	531.49
	178.148	173.426	181.272	179.166	
	186.888	180.570	175.274	184.590	
Sum of squares of difference	630.136	77.045	76.124	444.233	1227.538
Degree of freedom	2	2	2	2	8
Contribution ratio	51.333%	6.276%	6.201%	36.188%	100%
Optimum level	1	2	1		
	A1	B1	C1		
	5 %	10 min	650^{0}C		

3) Pareto ANOVA for wear

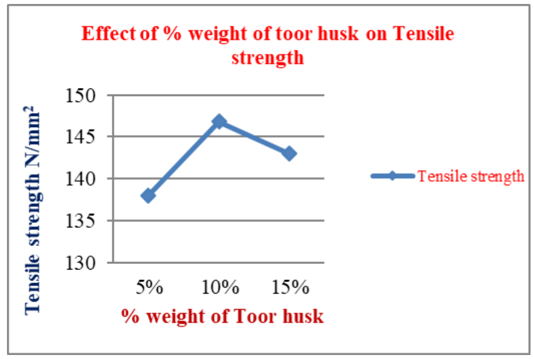
Table 9
Pareto ANOVA for Wear

Factors	A	B	C	E	Total
Sum at factor level	166.454	177.494	174.944	167.734	531.49
	178.148	173.426	181.272	179.166	
	186.888	180.570	175.274	184.590	
Sum of squares of difference	630.136	77.045	76.124	444.233	1227.538
Degree of freedom	2	2	2	2	8
Contribution ratio	51.333%	6.276%	6.201%	36.188%	100%
Optimum level	1	2	1		
	A1	B1	C1		
	5 %	10 min	650^{0}C		

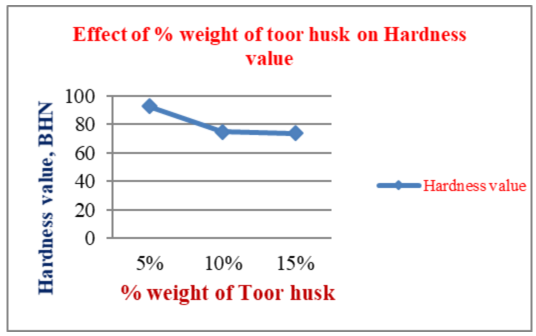
C. Effect of variables on properties of MMC

1) Effect of %weight of Tur husk on Tensile strength, Hardness and wear

The graph-1 shows that the tensile strength increases after increasing the % weight of tur husk and further increase in % weight of tur husk decreases the tensile strength of AA7068.

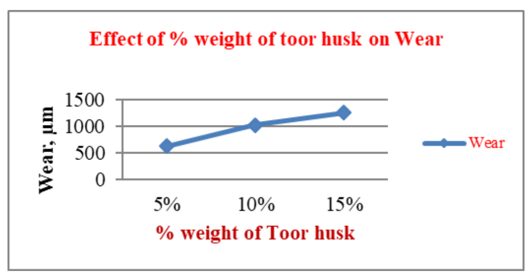


Graph-1: Effect of % weight of Tur husk on Tensile strength



Graph-2: Effect of % weight of Tur husk on Hardness value

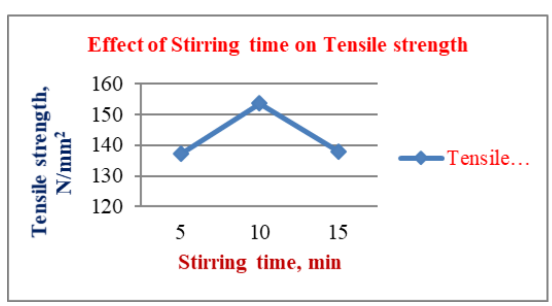
The above graph shows that the tensile strength decreases after increasing the % weight of tur husk and further increase in % weight of tur husk there is little effect on the tensile strength of AA7068.



Graph-3: Effect of % weight of Tur husk on Wear

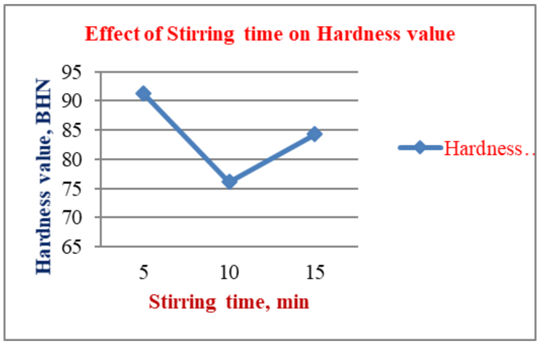
The above graph shows that the Wear value of AA7068 increases after increasing the % weight of tur husk.

2) Effect of Stirring time on tensile strength, hardness and wear



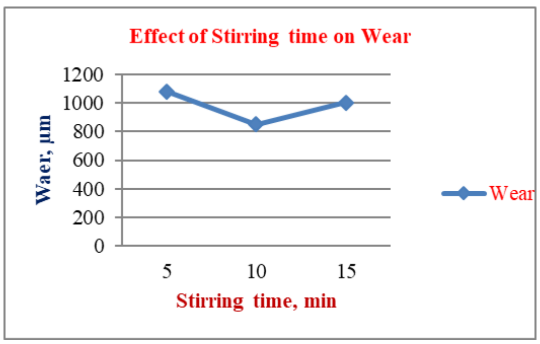
Graph-4: Effect of Stirring time on Tensile strength

The above graph shows that the Tensile strength of AA7068 increases after increasing the stirring time and decreases further increase in still increase in stirring time.



Graph-5: Effect of Stirring time on Hardness value

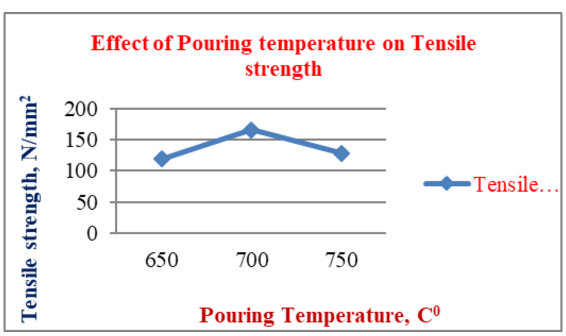
The above graph shows that the Hardness value of AA7068 decreases after increasing the stirring time and increases after further increase in stirring time.



Graph-6: Effect of Stirring time on Wear

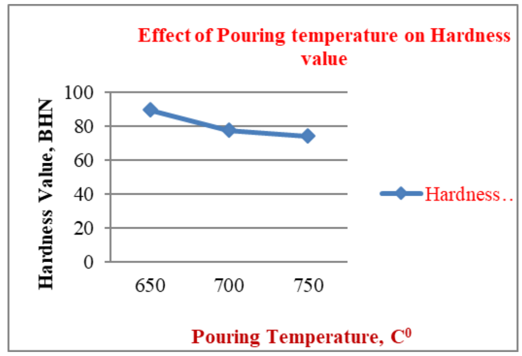
The above graph shows that the Wear value of AA7068 decreases after increasing the stirring time and further increase in stirring time increases the wear of AA7068.

3) Effect of pouring temperature on tensile strength, hardness and wear



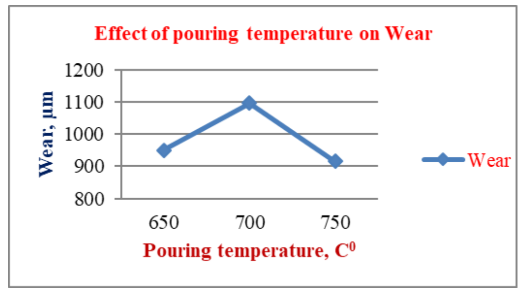
Graph-7: Effect of Pouring temperature on Tensile strength

The above graph shows that the Tensile strength of AA7068 increases after increasing the pouring temperature and decreases further increase in pouring temperature.



Graph-8: Effect of Pouring temperature on Hardness value

The above graph shows that the Hardness value of AA7068 decreases after increasing the pouring temperature.



Graph-9: Effect of Pouring temperature on Wear

The above graph shows that the Wear value of AA7068 increases after increasing the pouring temperature and further increase in pouring temperature decreases the wear of AA7068.

D. Wear test results

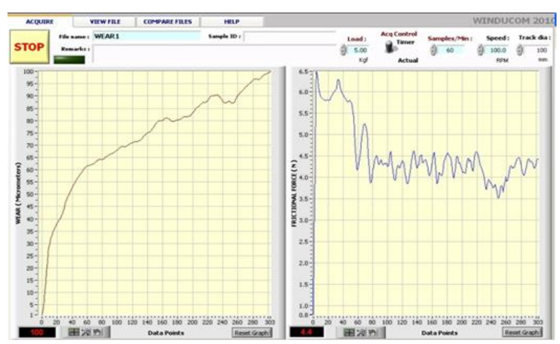


Fig. 15. Wear value for sample 01

Fig. 16. Wear value for sample 02

Fig. 17. Wear value for sample 03

Fig. 18. Wear value for sample 04

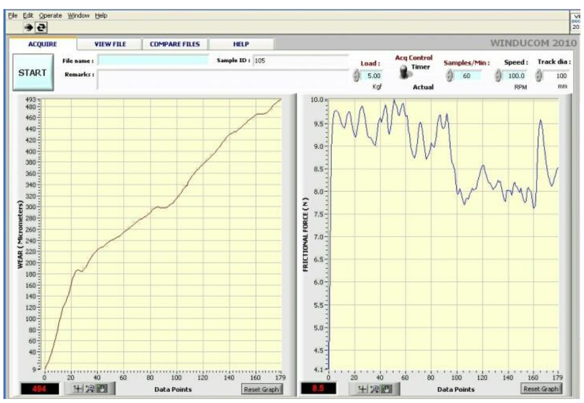


Fig. 19. Wear value for sample 05

Fig. 20. Wear value for sample 06

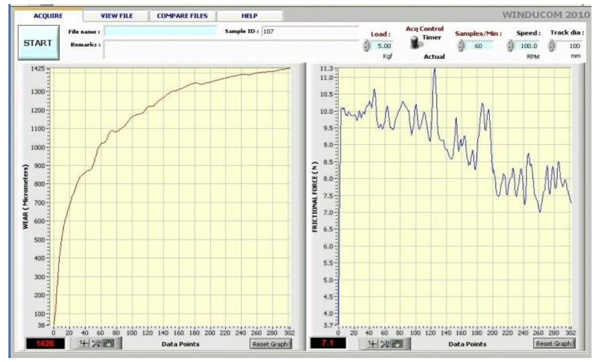


Fig. 21. Wear value for sample 07

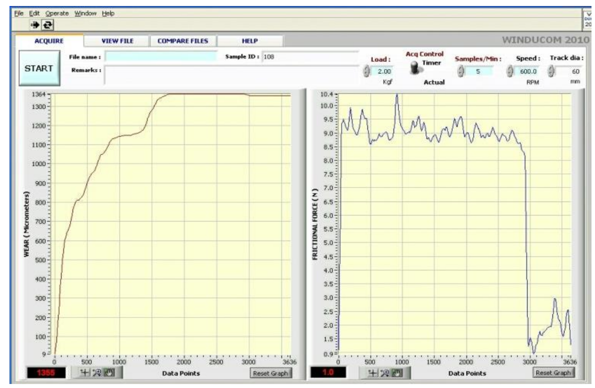


Fig. 22. Wear value for sample 08

Fig. 23. Wear value for sample 09

E. Discussions

From table 7, it can be seen that the second level of factor (A) give the highest summation (i.e. A2, which is 10% weight of Tur husk). The highest summation for factor (B) is at the second level (i.e. B2, which is 10 minutes stirring time) and the highest summation for factor (C) is at the second level (i.e. C2, which is 700^{0}C pouring temperature). These predicted parameters (2-2-2) are not used in the casting sample preparation which indicated in table 4.

We conducted sample 10 experiment at the predicted parameters (A=10% Tur husk, B=10 minutes stirring time and C=700^{0}C pouring temperature), and tested the resulted sample by Tensile test. The resulted tensile strength is 188 N/mm^2 which is greater than the tensile strength values in table 6. These results have proved the success of Taguchi method in the prediction of the optimum parameters for higher tensile strength

In table 8, it can be seen that the highest summation is at A1 (5% weight of Tur husk), B1 (5 minutes stirring time), and C1 (650^0C pouring temperature). These predicted parameters (1-1-1) are used in the casting sample preparation which indicated in table 4.

From table 9, it can be seen that the first level of factor (A) give the lowest summation (i.e. A1, which is 5% of Tur husk). The lowest summation for factor (B) is at the second level (i.e. B2, which is 10 minutes stirring time) and the lowest summation for factor (C) is at the first level (i.e. C1, which is 6500C pouring temperature). These predicted parameters are not used in the casting sample preparation which indicated in table 4.

Again we conducted sample 10 experiment at the predicted parameters (A=5% Tur husk, B=10 minutes stirring time and C=650^0C pouring temperature), and tested the resulted sample by wear test. The resulted wear value is 355 µm which is smaller than the wear values in table 6. These results have proved the success of Taguchi method in the prediction of the optimum parameters for lower wear value.

In table 7, it is found that the pouring temperature contributes a larger impact on Tensile strength of the casting samples when compared to % weight of Tur husk and stirring time. In table 8 % weight of Tur husk contributes a larger impact on Hardness of the casting samples when compared to pouring temperature and stirring time. Similarly, in table 9, it is found that the pouring temperature contributes a smaller impact on wear of the casting samples when compared to % weight of Tur husk and stirring time.

F. Summary

In tables 7, it is found that the pouring temperature contributes a larger impact on Tensile strength of the casting samples when compared to % weight of Tur husk and stirring time. In table 8 % weight of Tur husk contributes a larger impact on Hardness of the casting samples when compared to pouring temperature and stirring time. Similarly, in table 9 it is found that the pouring temperature contributes a smaller impact on wear of the casting samples when compared to % weight of Tur husk and pouring temperature.

7. Conclusions

From the experimental observation the following conclusions are made

- The tensile strength increases after increasing the % weight of tur husk and further increase in % weight of tur husk decreases the tensile strength of AA7068. The Hardness value of AA7068 decreases after increasing the % weight of tur husk. The Wear value of AA7068 increases after increasing the % weight of tur husk.
- The Tensile strength of AA7068 increases after increasing the stirring time. The Hardness value of AA7068 decreases after increasing the stirring time. The Wear value of AA7068 increases after increasing the stirring time and further increase in stirring time decreases the wear of AA7068.
- The Tensile strength of AA7068 increases after increasing the pouring temperature. The Hardness value of AA7068 decreases after increasing the pouring temperature. The above graph shows that the Wear value of AA7068 increases after increasing the pouring temperature and further increase in pouring temperature decreases the wear of AA7068.

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