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A Comparative Study on Material Characteristics of Al384.1-Mgo and Al384.1-SiC_p Metal Matrix Composites

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ABSTRACT: A **comparative study of mechanical behavior under tensile strength has been estimated to obtain the optimal results and the contribution of percentage and particle size of Magnesium oxide (MgO), reinforcement is compared with SiC_p has also been studied. The effectiveness of particle size and the percentage of composites has been analyzed here and the objective of this experimental work investigates the aluminum matrix composites, Al384.1 alloys, particulate reinforced by varying percentage of MgO and SiC at 5%, 10%, 20% and the particle size at 0.053µm, 0.106µm, and 0.220µm were employed to fabricate the best combination of most desirable design of metal matrix composites (MMCs) has been achieved by using Taguchi method. Finally, it has also been verified experimentally by the confirmation test.**

Keywords: Composites; Metal matrix composites; Magnesium oxide MgO and Taguchi method.

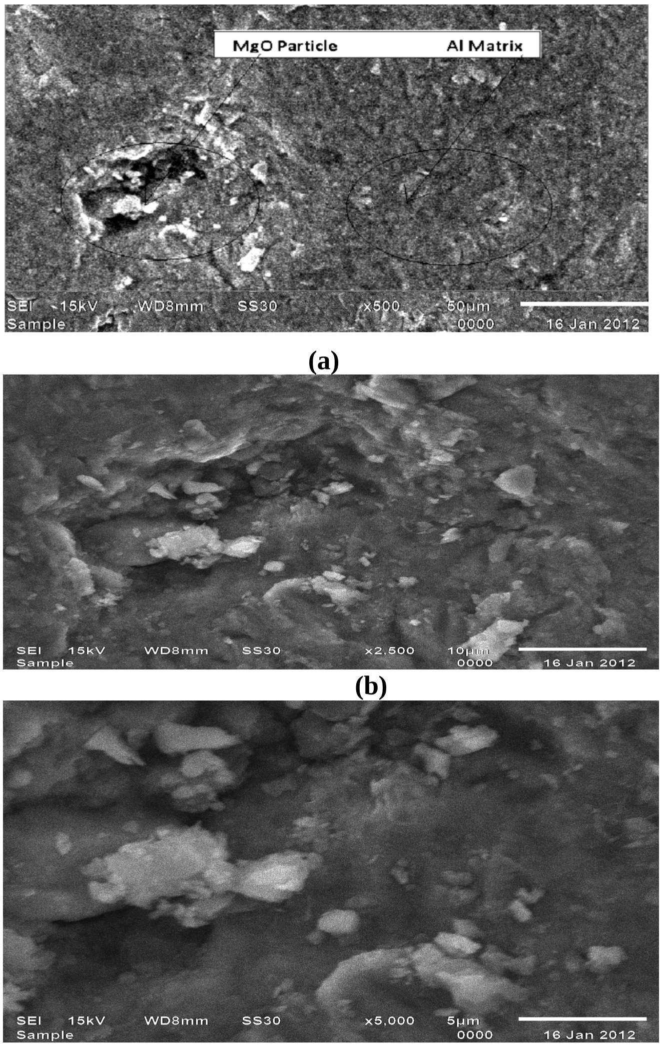
INTRODUCTION: Aluminum alloys based composites has been numerous engineering applications including automobile, aerospace and heat resistant materials developed for industrial applications and possesses excellent mechanical strength [1-2]. Aluminum is the most popular matrix for the metal matrix composites. The aluminum alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and damping capacity [3]. Al384.1 alloy is highly corrosion resistance which makes it appropriate material for automotive applications and also much better in nature for elevated temperature applications when reinforced with ceramic particle [4-5]. Composite materials has lighter weight, cost effective and high performance materials for use in a variety of structural and non-structural applications have resulted in the need for fabrication of metal matrix composites (MMCs) of various types. MMCs and highlighted the basic properties of SiC and MgO and the advantages of using MgO over other Al/Al alloy based Metal Matrix by scrupulously choosing the balance of the reinforcing phases and particularly focusing on reinforcing content, together with some technological parameter of the mechanized process, it is possible to optimize the properties of metal matrix composites while fabrication of such materials [6-7]. An optimized combination of surface and bulk mechanical properties may be accomplished, although Al-MMCs are processed with a controlled gradient of reinforcing particles and moreover by adopting a better method of manufacturing [8]. While there is no clear relation between mechanical properties of the composite, volume fraction, type and nature of reinforcements, the reduced size of the reinforcement particles is supposed to be effective in improving the strength of the composites. From application point of view, the mechanical properties of the composites are of enormous importance [9-10]. The strength of MgO and SiC particulate reinforced Al-MMCs are found to increase at the cost of reduced ductility, by increasing the volume percentage of ceramic phase and by decreasing the size of the reinforcement in the composite. In general, the particle reinforced Al-MMCs are found to have higher tensile and compressive strength over monolithic alloys. The reported literature regarding the variations of the compression strength of ceramic filled aluminum composites are meager. The aim of this paper is to verify the results by experimental setup and procedure that a comparison study on both materials as reinforced with MgO and SiC and tensile strength of which composite is more effective can be studied by considering percentage and particle size [11].

MATERIAL AND METHOD:

Sample Preparation: The base matrix and reinforcing phase for the present studies selected were A384.1 having percentage composition of 5%, 10%, 20% and particles of 0.053µm, 0.106µm, and 0.220µm. Table 1 presents the chemical composition of matrix and reinforcing materials. The Stir casting is a primary process of composite production whereby the reinforcement ingredients material is incorporated into the molten metal by stirring. While magnesium matrix composites reinforced with particulates and this involves stirring the melt with ceramic particles and then allowing the mixture to solidify. This can usually, prepared by means of fairly traditional processing equipment and can be carried out on a continuous and semi-continuous basis by the use of stirring mechanism [12-13]. This method is most economical and in this process, matrix alloy Al384.1 was firstly, superheated over its melting temperature and then temperature was lowered gradually below the liquid's temperature to keep the matrix alloy in the semi-solid state [14]. At this temperature, the preheated MgO and SiC particles were embedded into the slurry and mixed. Furthermore, the composite slurry temperature was increased to fully liquid state and automatic stirring was continued approximately used for 5 min at an average stirring speed of 300~350 rev/min [15]. And finally, poured into the cast iron permanent mold of round tension test samples of 5 mm diameter and 25 mm gauge length of product is obtained. Figure1 (a), (b) and (c) shows the specimen's microstructure at different magnifications.

Table 1: Chemical composition of Al384.1 by weight percentage.

Chemical Composition	**Si**	**Cu**	**Zn**	**Fe**	**Mn**	**Ni**	**Sn**	**Mg**	**Other**	**Al**
Al384.1	10.5	3.0	2.9	1.0	0.5	0.5	0.35	0.1	0.06	Rest



(a) **(b)** **(c)**

Figure 1: SEM images of Al384.1- MMC: (a) 10% MgO (X 500) (b) 10% MgO (X 2500) (c) 10% MgO (X 5000).

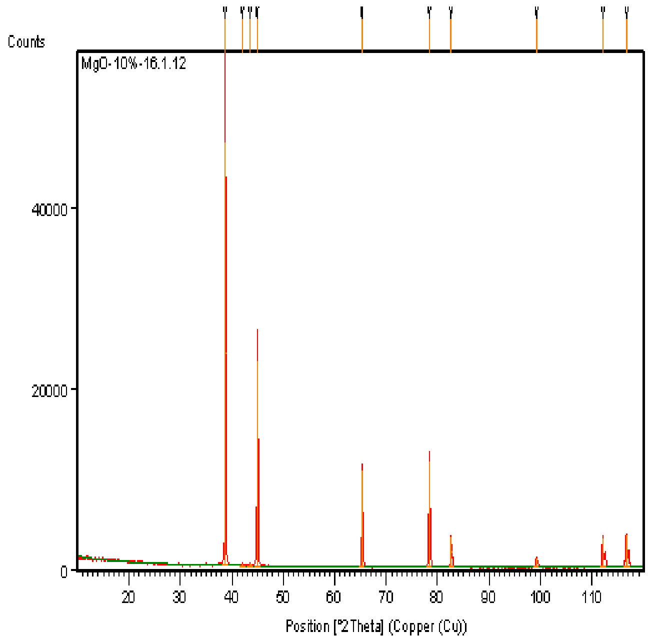
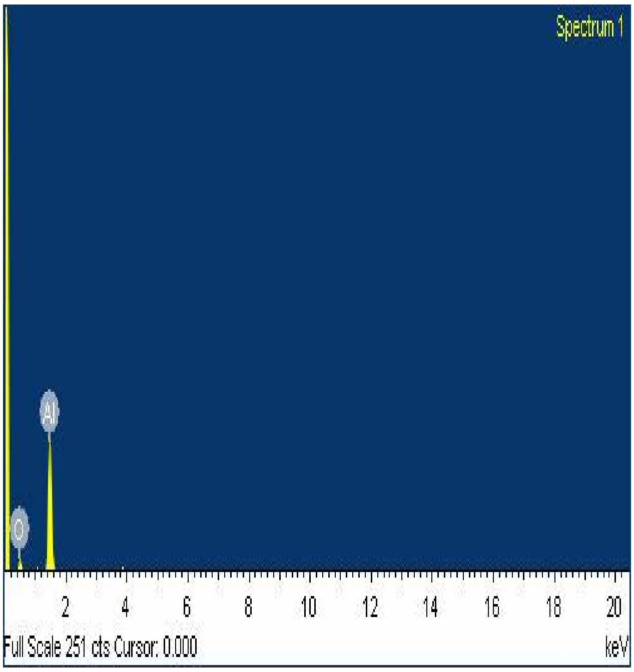
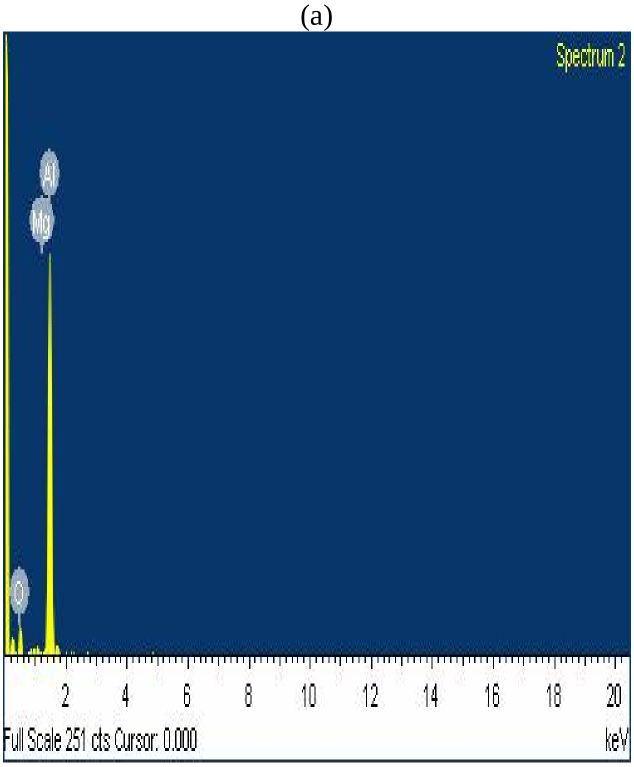


Figure 2: X-Ray Diffraction.

The X-Ray Diffraction and SEM study shows that the addition of MgO particles in different amount of sizes and varying percentage of particle sizes in the casting is also found to be observed the strengthening of composites particularly, at 10% of MgO can be moderated in terms of dispersion strengthening due the reinforcements of particles at literal value, 0.053μm as shown in Figure 2. After going through the literature survey as much work is done on SiC based Al-MMCs as compared with MgO based Al-MMCs. The metal matrix with MgO particulates can be exploit through facilitate SEM, EDS and XRD attempt. The EDS spectra of different phases observed by analysis has confined as transition phase existing between MgO, shown in Figure 3.



(a)



(b)

Figure 3: Illustrate EDS Spectra of different phases observed in SEM micrographs (a) MgO (b) Al-Mg-O.

Experimental Setup and Procedure: The UTM apparatus was used to investigate the tensile strength of the composite as per ASTM E4 standards using H50KS tensile testing machine on round tension test samples of 5mm diameter and 25mm gauge length. The specimen is placed in the machine between the grips by which the load is applied. The strength of interest can be measured in terms of either the stress necessary to cause appreciable plastic deformation or the maximum stress that the material can withstand. The technical specifications as per Standard Universal Testing Machine was used for this test: Model Number TUS-3; Loading accuracy ±1%; Maximum capacity (tonne) 40; measuring range (tonne) 0-40,0-20, 0-10, 0-4; clearance for tensile at fully descended working piston (mm) 50-700; clearance between columns (mm) 500; ram stroke (mm) 200; specimen dimensional range (mm) 0-40; width 65.

Plan of experiment: Taguchi method drastically reduces the number of experiments and accomplishes the highest possible performance is obtained by determining the optimum combination of design factors. In present study, design of experiment was performed as L_9 orthogonal array was chosen, which has 9 rows and 2 columns as shown in Table 2.

Table 2: Experimental layout using L_9 (3^2) orthogonal array.

L_9 (3^2)Experimental Trail	Level 1	Level 2
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

RESULTS AND DISCUSSIONS: The given parameter selected for the experiment was (1) Percentage (%) of MgO and SiC_p, and (2) Particle size shown in Table 3. The experiment consists of 9 tests, each row in the orthogonal array and the columns were assigned with parameters.

Table 3: Process parameter with their values at three levels.

Factors	Level 1	Level 2	Level 3
1. Percentage(%) of MgO and SiC_p	5	10	20
2. Particlesize (µm)	0.22	0.106	0.053

Table 4: Orthogonal array L9 of Taguchi.

$L_9(3^2)$ Experimental Trail	Parameters		Response
	% of SiC	Particle size (µm)	UTS (MPa)
1	5	.22	432
2	5	.106	428.1
3	5	.053	430
4	10	.22	449
5	10	.106	431
6	10	.053	447
7	20	.22	449
8	20	.106	429
9	20	.053	442

The experimental results shown by using orthogonal array including the tensile strength calculations whereby in use with three level of observations with percentage (%) of SiC_p and MgO besides, the levels of particle size as shown in Table 4 and table 5. We have three samples of each composite so that's why three levels of observations were taken for both cases. An experiment through the product design stages, involves the materials used in manufacturing the experimental product which affects the final quality outcomes. This step should lead to some considerate the basic design of experiment principles. As far as the benefits from the technique are concerned, experimental planning is the mainly important. Taguchi method it emphasizes a mean performance characteristic value close to the target value rather than a value within certain specified limits, thus improving the product quality. Additionally, Taguchi method is used to identify problems in a manufacturing process from data already in existence.

Table 5: Orthogonal array L9 of Taguchi.

$L_9(3^2)$ Experimental Trail	Parameters		Response
	% of MgO	Particle size (µm)	UTS (MPa)
1	5	.22	424
2	5	.106	430
3	5	.053	432
4	10	.22	447
5	10	.106	447
6	10	.053	449
7	20	.22	447
8	20	.106	446
9	20	.053	446

Analysis Of Variance (ANOVA): Utilize this step to review a number of standard analyses to build the confidence in interpreting the experimental results. The purpose of the analysis of variance (ANOVA) was to investigate which parameters significantly affected as the percentage contribution of MgO is 92.953% the quality characteristics as shown in Table 6. The collective error associated was approximately about 6.851%. Even the particle size (40.305%) having greater collision than percentage (%) of SiC_p in the results. And the main purpose of analysis of variance (ANOVA) can be used to investigate which parameters significantly affects the percentage contribution of SiC_p as the quality characteristics as shown in Table 7. The purpose of the analysis of variance (ANOVA) was to investigate which parameters significantly affected as the percentage contribution of SiC is 31.494% the quality characteristics.

Table 6: ANOVA.

Column # Factors	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F – Ratio (F)	Pure Sum (S')	Percentage P (%)
1 % MgO	2	674.862	337.431	55.278	662.654	92.953
2 Particle size	2	13.609	6.804	1.114	1.4	0.196
Other error	4	24.415	6.103	-	-	6.851
Total	8	712.888	-	-	-	100.00%

Table 7: ANOVA

Col# / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F- Ratio (F)	Pure-Sum (S')	Percent P(%)
1.% of SiC_p	2	256.069	128.034	5.467	209.234	31.494
2.Particle Size	2	314.602	157.301	6.717	267.767	40.305
Other/Error	4	93.67	23.417	-	-	28.201
Total:	8	664.342	-	-	-	100.00%

4.2 Main Effects

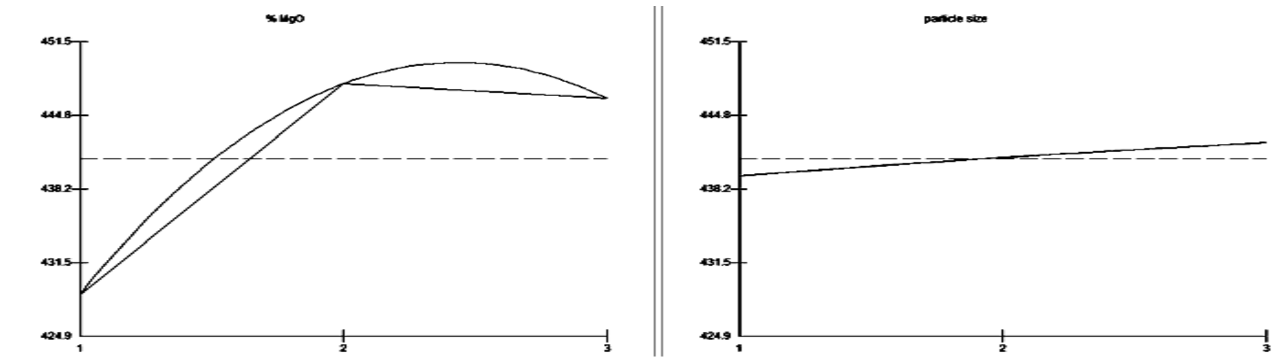


Figure 4: Multiple-graphs, main effects of Mgo based Al-MMC.

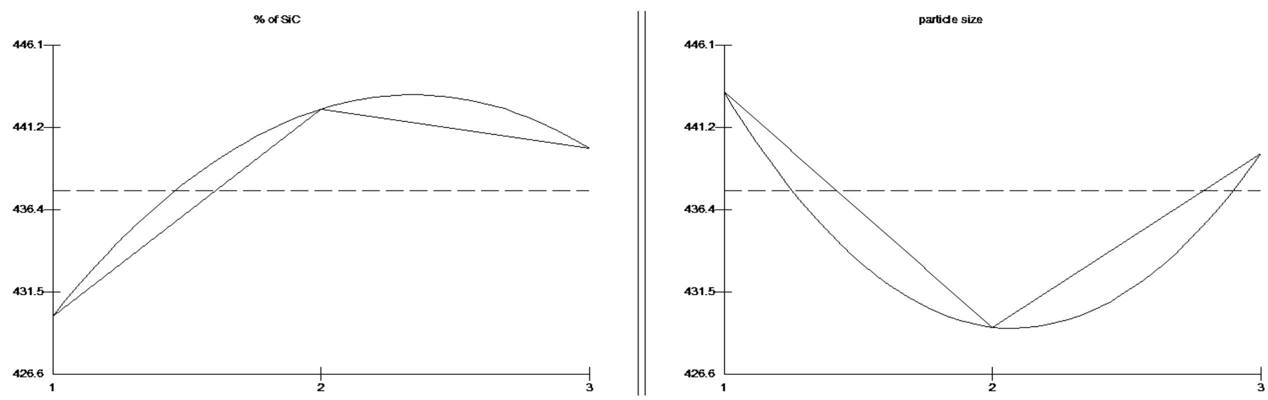


Figure 5: Multiple-graph, main effects of SiC_p based Al-MMC.

In this type bigger is better present the main effect graph. The average values of levels at L1, L2, L3 of given particle size; 439.333MPa, 441.0MPa, and 442.333MPa. The quality characteristics investigated in this study that the combination of parameters and their levels make the best combination articulate optimal quality characteristic to be achieved.

Interaction: And the average effects of percentage (%) can be confirmed that with increase in the particle size first there is a increase in the tensile strength upto the numeric value 449MPa articulate optimal value of MgO based Al-MMCs and then there is slight decrease in value. And values as average at the point are 428.666MPa, 447.666MPa, and 446.333MPa and the main effect graph shown in

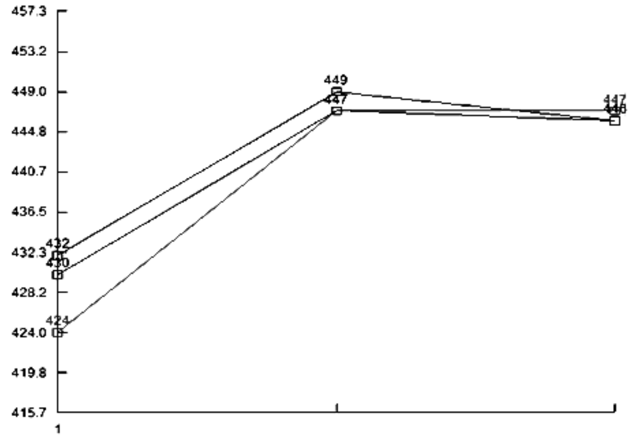


Figure 6: Effects of Interaction between two factors (2, 3 or 4 levels).

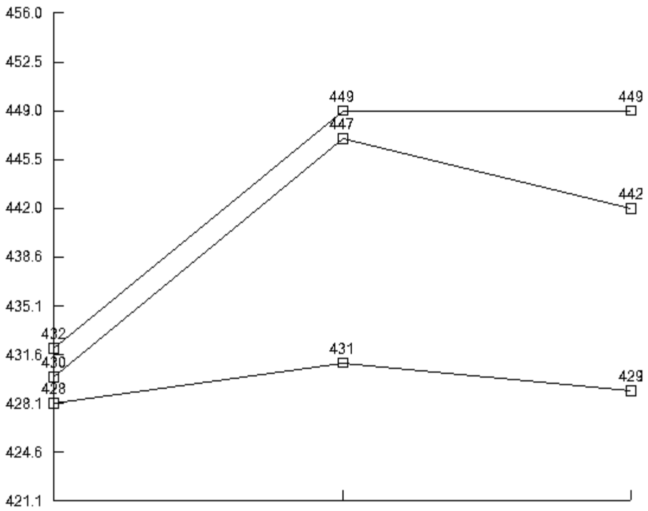


Figure 7: Effects of Interaction between two factors (2, 3 or 4 levels).

And the average effects of percentage (%) of SiC at level 1, 2, and 3 respective values as average at the point are 430.033MPa, 442.333MPa, and 440.0MPa, as the main effect graph Firstly, as there is increase in tensile strength and then at level 3 the value becomes remain same articulate optimal value is 449MPa shown in Figure 7. The optimum condition is determined based on the

Table 8: Optimum conditions.

Column # Factors	Level description	Level	Contribution
1 % MgO	10	2	6.777
2 Particle size	.053	3	1.444

Total Contribution From, All Factors 8.221Current Grand Average of Performance 1.444 Expected Result, At Optimum Condition 449.109 quality characteristic selected for the analysis. It is a common practice to only include the significant factor in calculating the expected performance. At level 2 and 3 this shows that the contribution of the percentage (%) of MgO based Al-MMCs, more significant the optimum outcomes of both factors are shown in Table 8.

Table 9: Optimum Conditions.

Column# / Factor	Level Description	Level	Contribution
1. % of SiC	10	2	4.877
2. Particle Size	0.22	1	5.877

Total Contribution From all Factors: 10.753 Current Grand Average of Performance: 437.455 Expected Result, At Optimum Condition: 448.20

At level 2 and 1 this shows that the contribution of the particle size is more significant than the percentage (%) of SiC_p, the optimum outcome of both factors are shown in Table 9.

Confirmation test: The confirmation tests were performed by selecting the set of parameters of MgO based Al-MMCs as shown in Table 8. And the confidence level is taken as 95%. The best value is 449.109MPa.and it is an expected result at optimum condition. From the analysis, error is shown in Table 6. However, the error associated with all the experimental results were up to 25%. This may be due to the multiphase microstructure of the composites. The confirmation test was performed for SiC_p based Al-

MMCs as shown in Table 9. The expected result at optimum condition is 448.20MPa and the experimental value was 449MPa with assorted error was about 28% as shown in Table 7.

CONCLUSION: The present results shows by varying the percentage and the particle size of MgO and SiC based Al-MMCs at different levels the results of study suggest that with increase in composition of MgO and SiC an increase in tensile strength of Al384.1 have been observed. The experimental results illustrate the Al384.1 under tensile strength the optimal condition and performance at percentage (%) MgO: 10%, and the particle size: 0.053μm, and expected results for UTS: 449.0MPa, and whereas the Percentage of SiC_p: 10%, particle size: 0.022μm, and expected results for UTS: 449.0MPa, the most desirable design of products and best parameters combination from the process, and permanent solution and it can be inveterate by confirmation test. Therefore, the percentage (%) and UTS expected values are remain same and there is only the variation of particle size can be experiential.

As the particle size point of view, larger particle size of MgO, 0.053μm and it is suitable for better interfacial relation in between the matrix and the reinforcement of MgO composites. Therefore, the contribution of larger particle size is more significant than SiC_p the Smaller particle size of SiC_p; 0.022μm of composites gives the best result as compare to its counterparts while keeping the same percentage of obtained results. Thus, a compare study results SiC_p based composites gives more suitable results of particulates reinforcement as per mechanical strength point of view.

As the percentage point of view, the contribution of percentage of MgO is about 92.9% as it is more compared to the percentage of SiC_p as it is 31.49%. Thus, the optimal condition of results shows that the percentage (%) of MgO reinforcement based composites contribution is larger.

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