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Characterization of Fabricated A 384.1-MgO Based Metal Matrix Composite and Optimization of Tensile Strength Using Taguchi Techniques

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ABSTRACT

The present work consecutively on synthesis and characterization of composites, Al/Al alloy A 384.1 as matrix in which the main ingredient as Al/Al-5% MgO alloy based metal matrix composite. As practical implications the low cost processing route for the fabrication of Al alloy A 384.1 and operational difficulties of presently available manufacturing processes based in liquid manipulation methods. As all new developments, complete understanding of the influence of processing variables upon the final quality of the product. And the composite is applied comprehensively to the acquaintance for achieving superiority of information concerning the specific heat measurement of a material through the aid of thermographs. Products are evaluated concerning relative particle size and mechanical behavior under tensile strength. Furthermore, Taguchi technique was employed to examine the experimental optimum results are achieved, owing to effectiveness of this approach.

Keywords: MMC, Thermographs, Tensile strength, Taguchi technique, Optimal parameters

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INTRODUCTION

Al and Al alloy based ceramic particulate composites have been characteristic as futuristic materials for a number of engineering purposes. And the material are more preferred by engineers because of their great strength, low density, enhanced and tailored high refractoriness properties, stiffness and damping capabilities [1-2]. The principle advantage is that MMCs can be use to a significantly higher temperature. Increasing quantities metal matrix composites MMCs being used to replace conventional materials in numerous applications, especially in the automobile and recreational industries. MMC's provide a better combination of Specific strength and modulus compared to monolithic alloys [3] like aluminum, magnesium, copper, nickel and steel in relevance, commonly light weight and energy savings are essential design considerations. Although magnesium is less dense than aluminum, these alloys are high-quality for their relative lightness and strength [4]. The alloy designation for Al is based on four digits subsequent to the principle alloying elements. The mainly important alloying elements in aluminum alloy systems are Copper (2xxx), Manganese (3xxx), Silicon (4xxx), Magnesium (5xxx), and zinc (7xxx). Particle reinforced composites have superior plastic forming capabilities than whisker or fiber reinforced ones. Magnesium alloys are valuable light weight structural materials because of their low density, good die-cast ability, weld ability, recyclability and abundance [5]. Grain refinement is an effective practice to enhance the mechanical properties of magnesium alloys. There are extremely few materials that are improved than reinforced aluminum composites [6]. The Magnesium oxide has various striking characteristics: fire resistance, moisture resistance, mold and mildew resistance, strength, and general repair applications. While current applications for this class of material are primarily limited to aerospace and automobile applications, their development continuous with resulting novel products for instance high voltage transmission lines and heat sinks for electronic components. It is likely that, as MMC applications continue to expand, the spectrum of materials and processes employed will remain relatively wide.

The aluminum based ceramic of Mg O, particles are embedded in the form of reinforcement that is eminent for excellent temperature and weight reduction in material relevance. The metal matrix can be strengthened by various thermal and mechanical treatments [7]. And solidification characteristic of metals and alloys in various metallurgical processes which help in producing quality materials and improving age hardening factor of the materials [8-9]. By observing the difference in heat flow between the sample and reference, differential scanning calorimeters are able to measure the amount of heat absorbed or released in such transitions. The metal matrix composites (MMCs) being of very high interest for the aerospace industry, particularly to build up thermal-structural components, it is important to have available technique which are easy and simple to conduct for characterization of the mechanical strength of the material. [10-11]. Furthermore, Taguchi techniques for investigate variation in experiments, and generally approach of system, parameter and acceptance aim have been significant in improving [12] man-made quality worldwide. And 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 [13-14].

MATERIALS AND METHODS

A. Materials

The material selected for the present investigation was based on the Al-Mg-Si matrix alloy, designated by the aluminum associated as A 384.1. The MgO particles, which were used to fabricate the composite, have an average particle size of 0.22µm. The MgO particle reinforcement assorted from 0 to 0.20 wt. % and the nominal chemical composition (in wt. pct) of the matrix alloy is given in Table 1.

TABLE I Chemical composition of investigated alloy AL-384.1(WT %)

Elements	Mass Fraction (Wt/%)
Mg	4.98
Cu	1.91
Si	2.92
Fe	0.84
Mn	0.73
Zn	0.61
Ni	0.94
Sn	0.75
Ti	0.47
Pb	0.04
Cr	0.01
Al	Rest

B. *Preparation of the Composite*

In which Stir casting is a primary process of composite production whereby the reinforcement ingredient material is incorporated into the molten metal by stirring. While magnesium matrix composites reinforced with particulates and short fibers [15] show improved creep resistance, dispersion-strengthening holds the highest potential for improvement of high temperature properties of magnesium, as shown in several other metal systems [16]. This involves stirring the melt with ceramic particles and then allowing the mixture to solidify. This can be frequently prepared by means of fairly conventional processing equipment and can be carried out on a continuous and semi continuous basis by the use of stirring mechanism [17-18]. This method is mainly cost-effective to fabricate composites with particulates. In this process, matrix alloy (Al-384.1) was firstly superheated over its melting temperature and then temperature was lowered gradually lower than the liquidus temperature to keep the matrix alloy in the semi-solid state [19]. As this temperature, the preheated MgO particles were introduced into the slurry and mixed. The composite slurry temperature was increased to fully liquid state and automatic stirring was continued for 5 min. at an average stirring speed of 300~350 r/min [20]. The melt was then superheated above liquidus temperature and finally poured into the cast iron permanent mold of product is obtained having microstructure as shown in figure1.

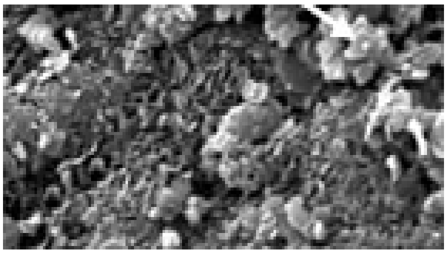

Fig: 1. Photo micrographic image of Al-MgO

C. Thermal Characterization by DSC Techniques

Apart from the more common applications to polymers, glasses, and pharmaceuticals calorimetery, applied extensively to the analysis of light metals; especially Al, Mg, and Ti based alloys. Thermal analysis methods specifically, measure the heat evolution from a sample in a controlled temperature program. For light metals for structural applications, DSC is used mostly for analysis of solid-solid reactions with precipitation, dissolution and re-crystallization, for determining temperatures of incipient melting, and for solidification studies. The technique is broadly used as a routine quality test and as a research tool and the equipment is a rapid and reliable practice of thermal analysis. The fundamental principle underlying this technique as the sample undergoes a material transformation for instance phase transitions, relatively heat will necessitate to flow to it than the reference to maintain both at the same temperature. By observing the difference in heat flow between the sample and reference, differential scanning calorimeters are capable to activities the amount of heat absorbed or exposed during such transitions. Thermal analysis is used to persistence solidification characteristics of metals and alloys in a extend of metallurgical processes which facilitate in producing quality materials and civilizing age hardening factor of the materials. In present study, shows that the differential scanning calorimetery (DSC) may enable us to measure the energy of cohesion in the matrix interface area of an aluminum composite reinforced by MgO whiskers. The sample is positioned in a suitable pan and sits upon a constantan disc on a platform in the DSC cell with a chromel wafer instantaneously underneath.

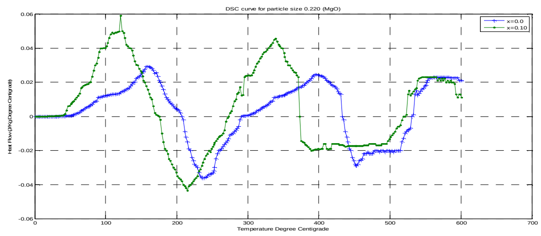

Fig:2. Typical DSC curve for partical size,(0.220) verses MgO, (x=0.10)

Heat flow is measured by comparing the disparity in temperature across the sample and the reference chromel

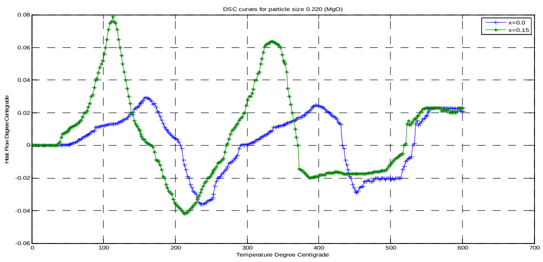

Fig: 3. Typical DSC curve for particle size, (0.220) verses MgO, (x=0.15)

wafers. The homogenization and solution treatment Al/MgO based alloys are found in the present study and DSC is effective as it provides a quick assessment of the temperature range for dissolution of soluble phase. The material used for the present investigation was a MgO particle reinforced A 384.1 aluminum alloy composite. The composite has reinforcement of MgO content by volume with an average particle size 0.22µm. The powder of A 384.1 alloy used in the experiment was prepared by the argon supersonic atomization. In the course of the DSC measurements, a high purity Al sample of the similar mass to that of the specimen was used as reference. The study of the material in the form of varying particle size, range from x=0.10 to 0.20µm. The characteristic of different particles are shown in Figure1, 2, and 3. The effects of particle can change accordingly the climax patterns.

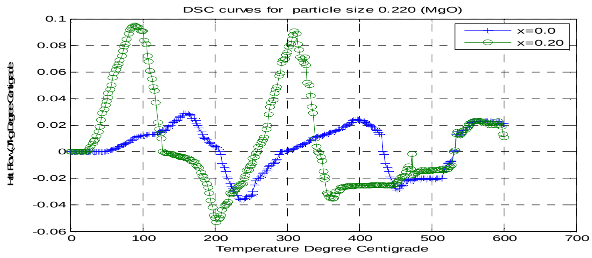

Fig:4. Typical DSC curve for particle size,(0.220) verses MgO, (x=0.20)

There is slight variation take place as the percentage of MgO increases from with respect to x at the same particle size of 0.22µm. DSC has proven to be a very practical and reproducible technique for the study of phase transformations and has been extensively applied to study precipitation in Al/MgO alloys.

RESULTS AND DISCUSSION

Taguchi the design of experiment is a technique to lay out experimental say investigation, studies, survey or tests plan in most logical, economical, and statistical ways. Potentially benefit from it and determine the: most desirable design of product, best parameters combination from the process, most robust recipe for formulation and permanent solution for production problems. While some of the statistical aspects of the Taguchi methods are questionable, there is no dispute that they are frequently applied to different processes. Taguchi method, which is effective to deal with responses, was influenced by multi-variables. This method drastically reduces the number of experiments and achieving the highest possible performance is obtained by determining the optimum combination of design factors. The experimental results are analyzed using analysis of means and variance to study the influence of factors. The main trust of Taguchi's techniques is use of parameter design, which an engineering method for product or process design that focuses on determining the parameter (factor) setting producing the best levels of a quality characteristic (performance measure) with minimum variation. Orthogonal arrays are often employed in industrial experiments to study the effect of numerous control factors. An Orthogonal array is a type of experiment wherever the columns for the independent variables are orthogonal to one another. By orthogonal array the analysis is simple and large saving in the experiment effort. To describe an orthogonal array, one must identify

TABLE II Experimental layout using $L_9\,(3^2)$ orthogonal array

$L_9\,(3^2)$ Test	1	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

In present study, the experiments were performed as per the standard orthogonal array. The assortment of the orthogonal array was based on the condition that the degree of freedom for the orthogonal array should be greater than or equal to the sum of varying parameters. At this time investigation an L_9 orthogonal array was chosen, which has 3 rows and 2 columns as shown in Table2. Although, Taguchi's approach was built on traditional concepts of design of experiments (DOE) is a body of statistical techniques for the effective and efficient set of data for a number of purposes. Two significant ones are the investigation of research hypotheses and the accurate resolve of the relative effects of the many different factors that influence the quality of a product or process. DOE can be employed both in product design phase and production phase. The given parameter selected for the experiment was (1) % MgO (x), and (2) Particle size of MgO as shown in Table3. The experiment consists of 9 tests (each row in the orthogonal array) and the columns were assigned with parameters.

TABLE III Process parameters with their values at three levels

Level	% MgO (x)	Particle size
1	0.05	0.053
2	0.10	0.106
3	0.20	0.220

Table4 indicates the factors and their levels. The main effects of MgO and Particle size values of the different levels shown in Table4. In which the observed values affects the overall process which can exist in terms of L2-L1.

TABLE IV Main effects (average effects of factors and interactions)

Column # Factors	Level 1	Level 2	Level 3	L2-L1
1 % MgO	428.666	447.666	446.333	19
2 Particle size	439.333	441	442.333	1.666

In this type bigger is better as shown in Table4 presents the main effect graph. The average values of levels at L1, L2, L3 of given particle size; 439.333, 441, and 442.333. The quality characteristics investigated in this study that the combination of parameters and their levels make the best combination say optimal quality characteristic to be achieved.

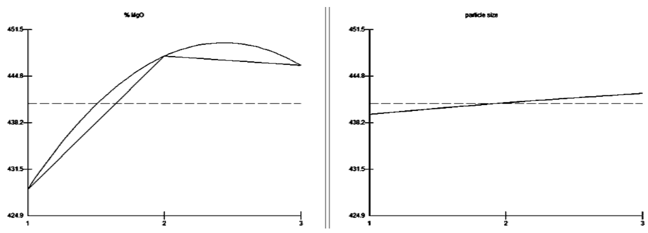

Fig: 5. Multiple- graphs of main effects

and the average effects of percentage of MgO as shown in Figure 5. At level 1, 2, and 3 respective values as average at the point are 428.666, 447.666, and 446.333 and the main effect graph shown in figure6.

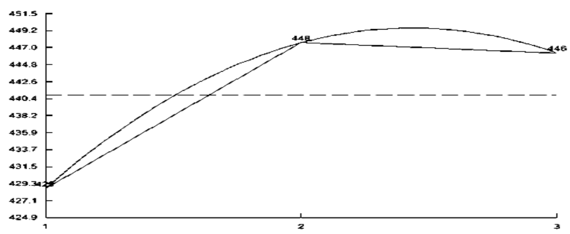

Figure6. Main effect graph between average effects of % MgO and levels of % MgO

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 Table5. The collective error associated in the ANOVA table was approximately about 6.851%.

TABLE V 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 VI Optimum conditions and performance

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

Contribution From, All Factors are 8.221, Current Grand Average of Performance 1.444 and Expected Result, at Optimum Condition 449.109 observed. The optimum table represents the predictive equation for performance of the optimum condition and or any other possible condition. The numbers shown are computed for the optimum condition. The optimum condition is determined based on the quality characteristic selected for the analysis. It is a common practice to only include the significant factor (not pooled) in calculating the expected performance. At level 2 and 3 this shows that the contribution of the percentage (%) MgO, more significant the optimum outcome of both factors are shown in Table6. And the optimum condition and performance can be obtained by these results and which can be participate and in concert a significant task as working on various tests.

A. Effects of Interaction between two factors

The control factor in the inner array by combining with an outer array of noise factor provides "full information" on control-by-noise interactions is emphasized. Two factors 1 and 2 are considered to have interaction between them when one has influence on the effect of the other factor respectively. The interaction facilitates as:

- Interaction is an effect or output and does not modify the trail condition.
- Interaction can be determined even if no column is reserved for it.
- Interaction can be fully analyzed by keeping appropriate columns empty.
- Interaction affects the optimum condition and the expected results.

The total number of sample available divided by the number of repetitions capitulated the size of the array for design. The array size dictates the number of factors and their appropriate levels included in the study as shown in Figure7.

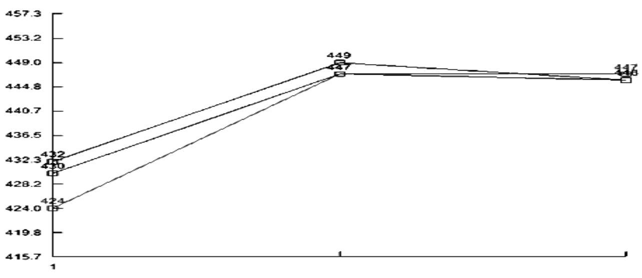

Fig: 7.Effects of Interaction between two factors (2,3or4 levels).

B. Relative Influence of factors and Interaction

Significant factor and interaction influences to perform experiments; at this step it is important to randomize the trails in order to diminish the systematic error and the error means there are various other factors which can be considered in general practice.

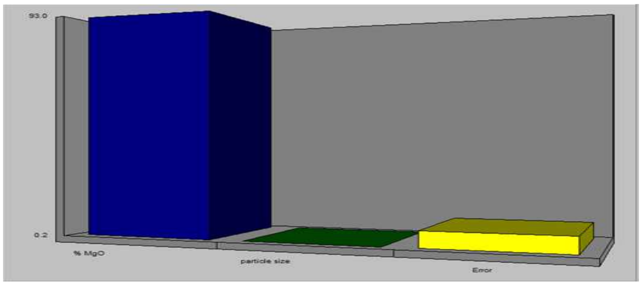

Fig: 8. Relative influence of factors and interactions.

C. Confirmation Test

The confirmation tests were performed by selecting the set of parameters as shown in Table6. And the confidence level is taken as 95%. The best value is 449.109. It is an expected result at optimum condition. From the analysis, error is shown in figure7. However, the error associated with all the experimental results were up to 25%. This may be due to the multiphase microstructure of the composites.

CONCLUSION

Metal matrix composites derive their excellent mechanical strength from combination of a hard reinforcement phase as MgO and a ductile matrix material, aluminum in which particle reinforcement aluminum formed using liquid metal handling particularly stir casting by varying the % MgO at different levels ranging from 0.05%, 0.10%, and 0.20% and the particle size 0.053, 0.106, and 0.22 correspondingly and the result of study suggest that with increase in composition of MgO, an increase in tensile strength have been observed. The Al/MgO based alloys in which the type, shape and spatial arrangement of the reinforcing phase in metal matrix composites are key constraint in determining their mechanical behavior by relating particle size 0.22 by thermal analysis to determine solidification characteristic of metals and alloys in various metallurgical processes, which help in producing quality materials and improving age hardening factor of the materials by showing thermal properties relating to fabricated material. Taguchi the design of experiment is a technique to illustrate experimental analysis under tensile strength of various results within which to attain the optimal condition and performance at % MgO: 0.10, and particle size: 0.053, and expected results for UTS: 449, is the most desirable design of product, best parameters combination from the process, and permanent solution and it can be verified by confirmation test.

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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