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Identification of Optimal Composition of Al6063 Alloy

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Abstract: The Al6063 alloy finds extensive application across several industries owing to its advantageous blend of mechanical characteristics and ease of extrusion. The objective of this research is to ascertain the optimum Al6063 alloy composition by means of a systematic investigation of various alloying components and their impact on mechanical performance. The percentages of silicon, magnesium, and manganese have been varied while maintaining the same amounts of the other components to vary the alloy compositions. Using common testing methods, mechanical attributes like hardness, and tensile strength were assessed for every alloy combination. A microstructural investigation was also carried out to comprehend the grain structure. The findings suggest that certain compositions have better mechanical qualities than others, which emphasizes the significance of alloy optimization. For engineers and manufacturers looking to improve the performance of Al6063 alloy in real-world applications, this research offers insightful information.

Keywords: Die Casting, DOE, Tensile strength, Hardness, Microstructure analysis

1. Introduction

Aluminium metal is one of the most popular base metals to alloy because of how common it is and its great material properties. There are numerous aluminium alloys, each with different types and compositions of alloying elements, and they each possess some benefit in terms of strength, workability, weldability, etc.

1.1. Literature

G. Das, et al., [1] studied, an instrumented ball indentation technique has been applied to determine a few mechanical properties of a 6063 Al alloy to establish a correlation between microstructure and its mechanical properties. The as-received 6063 alloy sample was in cast and homogenized condition. It was solutionized at 520 ◦C with two aging treatments. It was found that solutionized material with subsequent aging at 220 ◦C for 3 h does not produce any noticeable variation in mechanical properties. Whereas, transmission electron microscopy (TEM) and scanning electron microscopy (SEM) on solutionized samples after 7 h aging at 220 ◦C of the same material revealed precipitation of sub-micron size (of the order of 60 nm) Mg2Si phase and this subsequently resulted in variation in the mechanical properties of the alloy. P.S. Sivasakthivel, et al., [2] presented a study on the effect of process parameter on surface roughness in end milling process. Response surface methodology was employed to create a model to predict surface roughness in terms of machining parameters such as helix angle of cutting tool, spindle speed, feed rate, axial and radial depth of cut. The experiments were conducted on Al 6063 by HSS end mill cutter and surface roughness value was measured using Surftest SJ201. The adequacy of the model was verified using analysis of variance. The direct and interaction effect of the machining parameter with surface roughness were analysed. Neural network model was developed to predict surface roughness. Error percentages of both predicted response of response surface and neural model are found to be less than 5%. Mr. Mangesh R. Phate1, et al., [3] paper highlighted the detailed methodology of mathematical model formulation for the surface roughness during the dry turning process. This paper also represents the detailed about the formulation of field data-based model to analyze the impact of various machining field parameters on the surface roughness of aluminum 6063 during the dry sturning operation. In Indian scenario where majority of total machining operation are still executed manually which needs to be focused and develop a mathematical relation which simulate the real input and output data directly from the machining field where the work is being executed. The advantages and limitations of the developed mathematical models are identified and the models are classified in terms of application range and goals. The findings indicate that the topic understudy is of great importance as no such approach of field data based mathematical simulation is adopted for the formulation of mathematical model. Pragnesh. R. Patel, et al., [4] Metal matrix Composites are new class of material which offers superior Properties over alloys. Problem associated with MMCs is that they are very difficult to machine due to the hardness and abrasive nature of Carbide particles. The main objective of this paper is to investigate the effects of different cutting parameters (Cutting Speed, feed rate, Depth of cut) on surface roughness and Power Consumption in turning of 6063 AL alloy TiC (MMCs). PCD tool was used as wear resistive tool to achieve desire surface finish. Full factorial Design in design of experiment was adopted to planning the experimental runs. Analysis of Variance was used to investigate percentage Contribution of Each process parameters on output Response. Results show that feed rate is significant parameter, which effect on surface roughness; and Cutting Speed is effective parameter which effect on power consumption. Conclusion based on results with Future direction is discussed at final section. P.S. Sivasakthivel, et al., [5] focused on the effect of machining parameters such as helix angle of cutter, spindle speed, feed rate, axial and radial depth of cut on temperature rise in end milling. A prediction model of the temperature rise was developed using response surface methodology. The experiments were conducted on Al 6063 by high-speed steel end mill cutter based on central composite rotatable designs consisting of 32 experiments. The temperature rise was measured using K-type thermocouple. The adequacy of the model was verified using analysis of variance. The given model is utilized to analyze direct and interaction effect of the machining parameters with temperature rise. The optimization of machining process parameters to obtain minimum temperature rise was done using genetic algorithms. A source code using C language was developed to do the optimization. The obtained optimal machining parameters gave a value of 0.173 °C for minimum temperature rise.

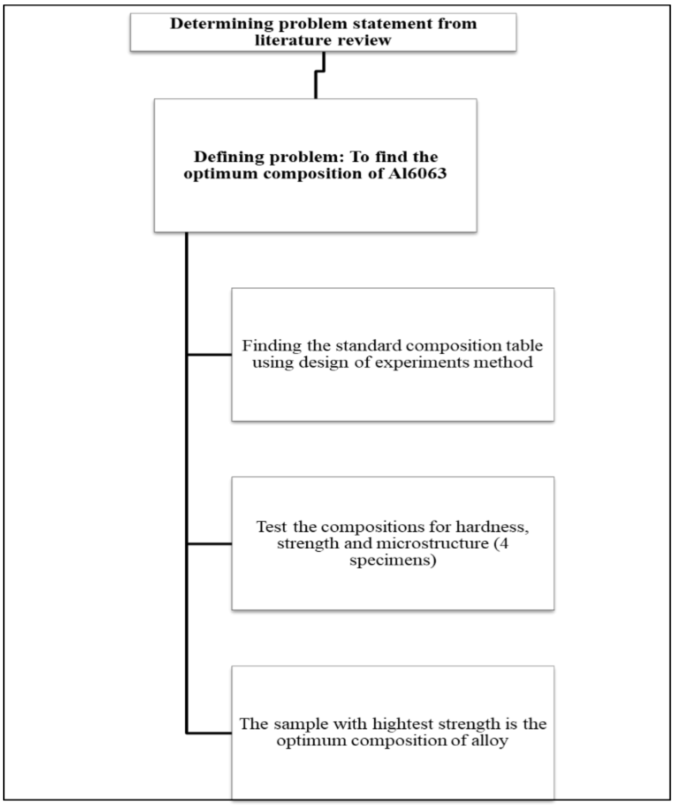

Fig 1: Flowchart of the study

2. Experimentation

2.1 Introduction to Design of Experiments (DOE)

The design and analysis of experiments revolves around the understanding of the effects of different variables on other variable(s). In mathematical jargon, the objective is to establish a cause-and-effect relationship between several independent variables and a dependent variable of interest. The dependent variable, in the context of DOE, is called the response, and the independent variables are called factors.

Table 1: 2^2 Full Factorial Design Matrix

	FACTOR	
RUN	**A**	**B**
1	-	-
2	+	-
3	-	+
4	+	+

In current work, the two factors are silicon and magnesium whose values vary from 0.2-0.6% and 0.45-0.9% respectively. Using the DOE of two factors at two levels, for silicon the high level (+) is 0.6% and low level (-) is 0.2%. Similarly, for magnesium, the high level (+) is 0.9% and the low level (-) is 0.45%. Substituting these values, we get the following table:

Table 2: 2^2 Design matrix for Al6063

	FACTOR	
RUN	**A (Silicon %)**	**B (Magnesium %)**
1	0.2	0.45
2	0.6	0.45
3	0.2	0.9
4	0.6	0.9

2.2 Die Casting Process

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mould cavity. The main die casting alloys are: zinc, aluminium, magnesium, copper, lead, and tin; although uncommon, ferrous die casting is also possible.

Fig 1: Die casting equipment

(a) (b) (c)

Fig 2: (a) Molten form of all metals rotating in the vessel (b) Clamping the moulds using pins (c) Solidification of metal after pouring in the mould

3. Results and discussions

The casted specimens are subjected to various machinability tests like tensile test and hardness test and microstructure analysis is also conducted.

Table 3: Tensile test results

S NO	ULTIMATE TENSILE STRENGTH (N/mm^2 or MPa)	ULTIMATE LOAD (kN)	ELONGATION (%)
Sample 1	111.345	14.240	6.600
Sample 2	109.317	14.960	3.720
Sample 3	88.747	11.420	4.200
Sample 4	84.134	10.160	1.600

Four samples of different compositions have been tested using universal testing machine and results of each of the sample have been evaluated. The observations are presented in the table-3. The results show that the sample 1 which has the composition of silicon as 0.2% and magnesium as 0.45% has the highest ultimate tensile strength among others.

Table 4: Hardness test results

S NO	OBSERVED VALUES IN HBW 5MM/ 250			
	Impression 1	Impression 2	Impression 3	Impression 4
Sample 1	62.4	62.4	61.8	62.20
Sample 2	61.2	61.8	61.8	61.60
Sample 3	56.8	56.8	57.3	56.97
Sample 4	60.1	5t6.8	60.6	59.17

Brinell hardness test is performed on the four specimens and indentations were made on three different locations on the specimen. The indentor used in the process is of 5 mm diameter and the load applied during the process was 250 kgf. The observations are presented in the table-4. The highest hardness is observed in sample 1in which the composition of silicon is 0.2% and magnesium is 0.45%.

Examination of the microstructure of aluminium and its alloys requires a well-executed chain of steps carefully developed based upon scientific understanding and practical experience. The microstructure of the first sample containing the composition of silicon as 0.2% and magnesium as 0.45% was analysed and the results show the interdendritic network eutectoid silicon and some particles of Mg2Si in the matrix. The etchant used in the procedure was Kellers Etch and the magnification was 100X.

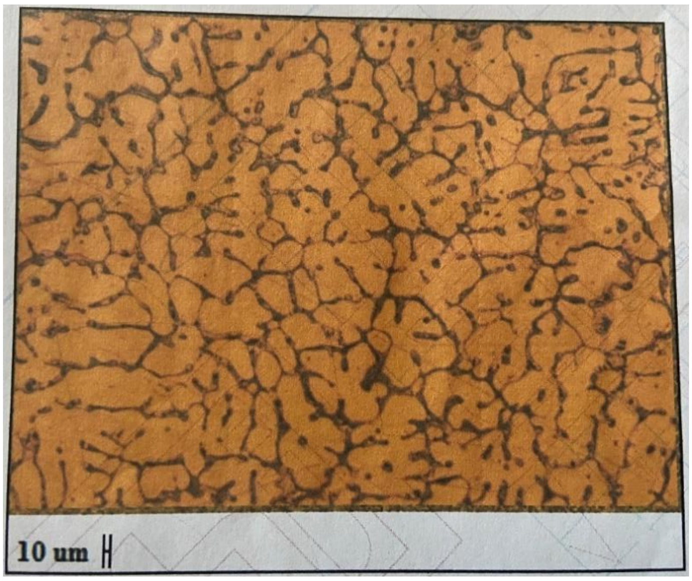

Fig 3: Microstructure of Al6063 (0.2% Si, 0.45% Mg) in 100X magnification

4. Conclusions

From the findings, it was observed that the sample with the composition of silicon as 0.2% and magnesium as 0.45% had the highest strength which was found out to be 111.345 MPa. The microstructure analysis on this specimen showed the interdendritic network of eutectoid silicon and some particles of Mg2Si in the matrix.

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