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THREE POINT BENDING OF ALUMINIUM MATRIX COMPOSITE PLATE PRODUCED BY STIR CASTING AND STATISTICAL ANALYSIS BY TAGUCHI METHOD

Shriyash S. Shinde, S. G. Kulkarni, S. S. Kulkarni

SKN Sinhgad College of Engineering, Pandharpur.

Abstract— Aluminium matrix composites (AMC's) are finding huge application in aerospace and automobile due their high performance, economic and environmental benefits owing to properties like reduced weight, low cost and high strength to weight ratio. Stir casting is one of the cheaper and conventional routes for manufacturing of particulate composites. Plates play a major role in modern day large size applications like aircraft, turbines and other structural components. The present investigation has been done to study effect of different input parameters namely aspect ratio, thickness and percentage reinforcement on three point bending. The three parameters i.e. aspect ratio (1, 1.5 and 2), thickness (3 mm, 6 mm and 9 mm), percentage reinforcement (4%, 8% and 12%) are used to produce plate samples by stir casting method. Statistical analysis is done by Taguchi method to study effect of these parameters.

Keywords— Aluminium matrix composite, plate, stir casting, aspect ratio, thickness, percentage reinforcement, Taguchi method.

INTRODUCTION

Modern day technology is growing at very rapid rate. It requires high performance materials with effective properties which conventional monolithic materials are unable to provide [1]. Composite materials are those formed by combining two or more materials on a macroscopic scale such that they have better engineering properties than the conventional materials [2]. Some of the properties that can be improved by forming a composite material are stiffness, strength, weight reduction, corrosion resistance, thermal properties, fatigue life, and wear resistance [3].

Aluminium and its alloys have attracted the most attention as matrix material in metal matrix composites [4]. In AMC one of the constituent is aluminum, which forms percolating network and is termed as matrix phase. The other constituent is embedded in this aluminum and serves as reinforcement [5]. In present wok production of AMC by stir casting method is done by taking aluminium alloy A356 as matrix material and alumina (Al_2O_3) as reinforcement. The present investigation has been done to study effect of different input parameters namely aspect ratio, thickness and percentage reinforcement on three point bending. The three parameters i.e. aspect ratio (1, 1.5 and 2), thickness (3 mm, 6 mm and 9 mm), percentage reinforcement (4%, 8% and 12%) are used to produce the plate samples. Statistical analysis is done by Taguchi method to study effect of these parameters.

MATRIX MATERIAL:

Aluminium alloy A356 is selected as matrix material for current experimentation. The various composition limits for A356 is,

Name of constituent	Cu max	Mg	Mn max	Si	Fe max	Zn max	Ti max	Other	Al
Percentage	0.25	2.25 to 0.45	0.35	6.5 to 7.5	0.6	0.35	0.25	0.05	Bal

Table 1. Composition of A356 [3].

Aluminium alloy A356 is ever more accepted in aircraft and automobile due to their high strength-to-weight ratio and its thixotropic structure. A356 based alloys have been developed with significant ductility, strength, elongation, hardness and toughness at room temperature in cast state [6].

REINFORCEMENT MATERIAL:

Reinforcement used in current work is Alumina. Alumina is used to increase the material strength, hardness & toughness. Aluminum oxide (alumina) possesses strong ionic inter atomic bonding giving rise to its desirable material characteristics. It has high hardness, excellent dielectric properties, refractoriness and good thermal properties which are applicable to wide range of applications [7].

COMPOSITE FABRICATION:

Stir casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibres) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies [8]. In preparing aluminium matrix composites by stir casting method some of the factors that need considerable attention are as follows [9],

- To achieve uniform distribution of the reinforcement material
- To achieve wettability between the two main substances
- To minimize porosity in the cast metal matrix composite.

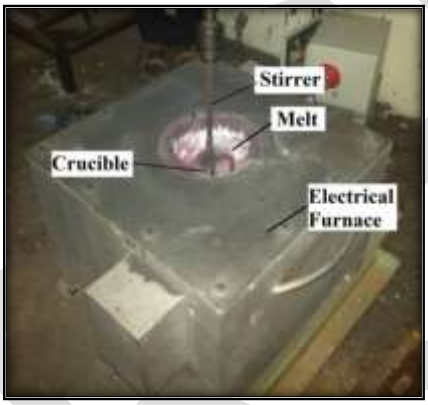

Fig 1. Stir casting setup.

The process of stir casting starts with placing an empty crucible in the furnace. The heater temperature is then gradually increased up to 800°C. Aluminium alloy is cleaned to remove dust particles, weighed and charged in the crucible for melting. Required quantities of reinforcement powder and magnesium powder are weighed on the weighing machine. Reinforcements are heated for 45 minutes at a temperature of 500°C. When matrix was in the semisolid stage condition at 650°C, one percentage by weight of pure magnesium powder is used as wetting agent. After five minutes the scum powder is added which forms a scum layer of impurity on liquid surface which to be removed. Heater temperature is then gradually increased to 800°C. At this heater temperature stirring is started and continued for five minutes. Stirring rpm is gradually increased from 0 to 300 RPM with the help of speed controller. Preheated reinforcements are added during five minutes of stirring. Reinforcements are poured manually with the help of conical hopper. The flow rate of reinforcements measured is 0.5 gram per second. Stirrer rpm is then gradually lowered to the zero. Then molten composite slurry is poured in the metallic mould without giving time for reinforcement to settle down at crucible bottom. Mould is preheated at 500°C temperature for one hour before pouring the molten slurry in the mould. This is necessary to maintain slurry in molten condition throughout the pouring. While pouring the slurry in mould the flow of the slurry is kept uniform to avoid trapping of gas, also distance between crucible and mould plays a vital role in quality of casting.

BEND TEST:

Three point bending tests are used to assess the strength of the composites by applying the force required to bend a plate. The data is often used to select materials for parts that will support loads without bending. Bend test is often used due to ease of the specimen preparation and testing [10]. For plate specimens three different parameters are considered as follows:

1. Aspect ratio: 1, 1.5 and 2.
2. Thicknesses: 3mm, 6mm and 9mm.
3. Reinforcement weight percentage: 4%, 8% and 12%.

The experimental design proposed by Taguchi involves use of orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows the collection of the necessary data to determine which factors are most affecting the product quality with a minimum amount of experimentation, hence it saves time and resources [13]. Knowing the number

of parameters and the number of levels, the proper orthogonal array can be selected. For this case L9 orthogonal array is selected from Array Selector. Aspect ratio, thickness of plates and percentage reinforcement are the three parameters with three levels are as follows,

Sr.No.	Aspect ratio	Thickness (mm)	Percentage Reinforcement
1	1	3	4
2	1	6	8
3	1	9	12
4	1.5	3	8
5	1.5	6	12
6	1.5	9	4
7	2	3	12
8	2	6	4
9	2	9	8

Table 2. Process parameters and levels.

Fig 2. Test setup for three point bending.

RESULT AND DISCUSSION:

The present investigation is to study deflection and load carrying capacity of composite plate. The deflection of plate should be minimum and load carrying capacity should be maximum. The parameters considered here are aspect ratio, thickness and percentage reinforcement. All the calculations are performed using Minitab software.

Analysis of signal of noise ratio:

The analysis for deflection of plate is carries out using smaller the better criteria and the same is expressed as,

S/N = -10*log10(sum(Y^2)/n).

Level	Aspect Ratio	Thickness	Percentage reinforcement
1	-9.816	-13.711	-9.018
2	-7.732	-7.816	-9.823
3	-8.412	-4.433	-7.120
Delta	2.084	9.278	2.703
Rank	3	1	2

Table 3. Response Table for S/N Ratios Smaller is better.

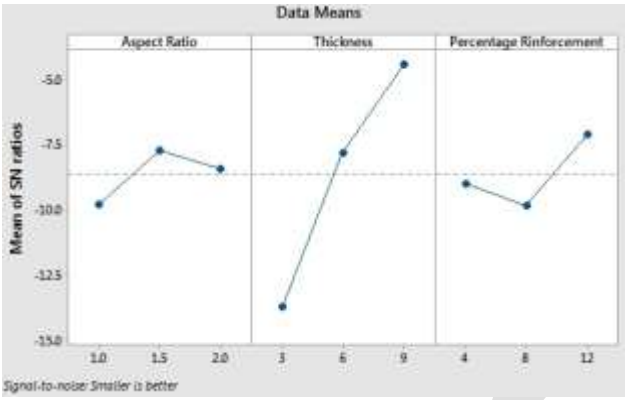

Fig 3. Main effect plot for SN ratios deflection.

The mean S/N ratio for each level of the three parameters is shown. The response table includes ranks based on Delta value. Rank 1 is assigned to the parameter with highest Delta value, rank 2 to second highest Delta value and so on. In this case thickness has the highest Delta value thus rank 1 is assigned to thickness. The effects of individual process parameters on the deflection of composite plate can be clearly seen. Maximum S/N ratio corresponds to minimum deflection and minimum S/N ratio corresponds to maximum deflection. It is observed that deflection of plate is minimum for aspect ratio 1.5, thickness 9mm and percentage reinforcement 12%.

The analysis for load carrying capacity of plate is carried out using larger the better criteria and the same is expressed as,

S/N (dB) = -10*log10(sum(1/Y^2)/n).

Level	Aspect Ratio	Thickness	Percentage reinforcement
1	81.87	79.80	81.05
2	80.96	80.29	80.54
3	80.14	82.88	81.39
Delta	1.73	3.08	0.85
Rank	2	1	3

Table 4. Response Table for Signal to Noise Ratios Larger is better.

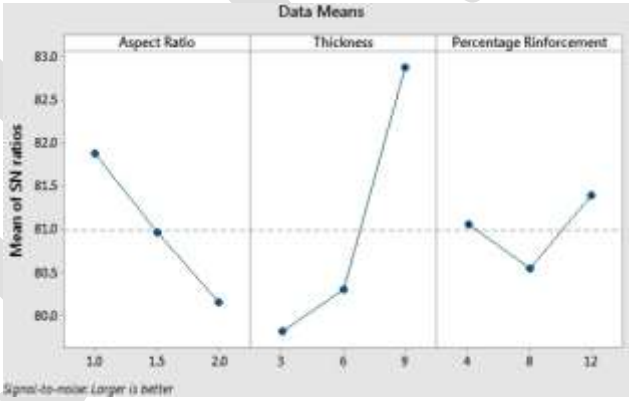

Fig 4. Main effect plot for SN ratios maximum force.

In this case also rank 1 is assigned to thickness. The effects of individual process parameters on the wear of the composite can be clearly seen. Maximum S/N ratio corresponds to maximum deflection and minimum S/N ratio corresponds to minimum deflection. It is observed that load carrying capacity of plate is maximum for aspect ratio 1, thickness 9 mm and percentage reinforcement 12%. In main effects plot the significance of each parameter can be judged by the inclination of plot. The parameter with highest inclination line has greater significance than the rest.

CONCLUSION:

1. AMC can be successfully manufactured by stir casting method at low cost. Uniform distribution of reinforcement, porosity and wettability of cast composite is greatly affected by process parameters.

2. The deflection and load carrying capacity of Al-Al_2O_3 aluminium matrix composite plate is studied by varying aspect ratio, thickness and percentage reinforcement using Taguchi orthogonal array. In main effects plots the significance of each parameter can be

judged by the inclination of plot. The parameter with highest inclination line has greater significance than the rest. From the main effects plot, it is seen that the parameter thickness is the most significant parameter while other parameters aspect ratio and percentage reinforcement are also significant parameters.

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