STATASTICAL ANALYSIS BY TAGUCHI METHOD FOR BUCKLING OF ALUMINIUM MATRIX COMPOSITE PLATE MANUFACTURED BY STIR CASTING

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***Abstract*— Aluminium Matrix Composites plays vital role in advanced applications like structural, aerospace, marine, automotive etc. Stir casting method is used for manufacturing of AMC's which is cost effective. Stir casting method is also useful to increase the mechanical properties of AMC's. In current work the effect of input parameters such as percentage reinforcement, aspect ratio and thickness of plate structure is studied. By using MINITAB software, results are drawn. This paper gives idea about Taguchi approach of statistical analysis and stir casting method.**

***Index Terms*— Aluminium Matrix Composite, Metal matrix composite, Stir casting, Taguchi.**

I. INTRODUCTION

Aluminium is most continuous metal in earth's crust and it makes up about 8% by weight of Earth's solid surface [1]. Aluminium and their alloys are widely used due to easy availability, high strength to weight ratio, easy machinability, durable, ductile & malleable. Further, Aluminium based Metal Matrix composites (MMC) have received increasing attention in recent decades as engineering materials due to their enhanced high strength, hardness and wear resistance over conventional Al alloy [2]. Aluminium is found wide range of applications for rail coaches, aircraft industry, bearing materials, piston material, transmission lines etc. But due to their low melting point and low hardness they will wear and deformed easily [1]. But only Alminium metal can't complete all requirements satisfactorily. So it is future need to develop the aluminium based materials that could have all combinational properties satisfying all our engineering requirements. Metal reinforcement in powder form such as SiC, Si, Cu and Mg etc. can be added in AMC for their high strength, stiffness and thermo-mechanic properties [2-3]. Some homogeneous and nonhomogeneous or hybrid reinforcement can also be added in matrix [3].Hence large amount of research is going on in stir casting method using various reinforcement bonding to improve mechanical properties of AMC's.

A metal matrix composite (MMC) is composite material with at least two constituent parts in which a metal used as matrix. The other material may be ceramic or organic compound. Generally, a MMC is composed of reinforcement (fibbers, particles, flakes) embedded in a matrix (metals).

Matrix-A356 alloy

The matrix is monolithic material into which reinforcement is added & which is completely continuous in nature. The matrix holds the reinforcement to form the desired shape and the reinforcement improves the overall mechanical properties of the matrix. Here, matrix material Aluminium has advantage of lighter weight &major silicon content of alloy may help to improve castability. In current work aluminium A356 alloy is used as matrix. Typical composition of A 356 alloy is given in the following table [4].

Element	Si	Cu	Mg	Mn	Fe	Zn	Ni	Ti	Al
% wt	7.20	0.02	0.29	0.01	0.18	0.01	0.02	0.11	Balance

Table-1Chemical composition of A356 alloy.

Reinforcement-Fly Ash

The high electrical resistivity, low thermal conductivity and low density properties of fly-ash are helpful for making a light weight composites. Typical composition of fly ash being used is given in the table [5].In current study 4, 8 and 12% of fly ash is used.

Element	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	LOI
Content % wt	59.00	21.00	3.70	6.90	1.40	1.00	0.90	4.62

Table-2Chemical composition of Fly Ash.

II EXPERIMENTAL PROCEDURE

StirCasting-

Stir casting is liquid state method of composite manufacturing.

It includes the formation of molten matrix phase at high temperature following the addition of reinforcement to increase mechanical properties of matrix.

Manufacturing of composite-

Stir casting starts with placing empty graphite or cast iron crucible inside the furnace. Then setting heater temperature of induction furnace is then gradually increased up to 800^{o}C. (90 to 120 min approximate)After this Al alloy 356 is cleaned neatly and then placed inside the crucible. Then measured amount of hexachloroethane powder and scum powder is added in melt at temperature 700^{o}C.After 10-15 min the scum is generated on upper surface of melt.This scum is removed by using saddle. Addition of Hexachloroethane powder reduces impurities and entrapped gases inside melt. Scum powder reduces impurities of melt.1% of pure Magnesium powder is added in semisolid form of matrix at 650^{o}C. Magnesium increase wettability of reinforcement and matrix. After 5-10 min measured quantity of scum powder is added. This forms a layer of scum on top surface of melt which is then removed. As furnace temperature is reached 800^{o}C the stirring is gradually started from 0 to 400 rpm for 8 min with speed control unit. Preheated reinforcement is gradually added during stirring. Reinforcement is poured manually with the help of conical hopper. The constant flow rate of 0.5 gram per second of reinforcement is maintained throughout [7]. The stirrer speed is gradually lowered to zero. The melt is hold at 800^{o}C for 5 min inside crucible. The melt is then directly poured in the metallic mould without giving time for reinforcement to settle down. The MS mould is heated at 500^{0}C to increase the fluidity of composite before pouring melt in the mould. A constant rate of pouring is maintained to avoid trapping of gas. The distance between crucible and mould should be as minimum as possible to increase quality of casting.

The following diagram shows the schematic set up of stir casting.

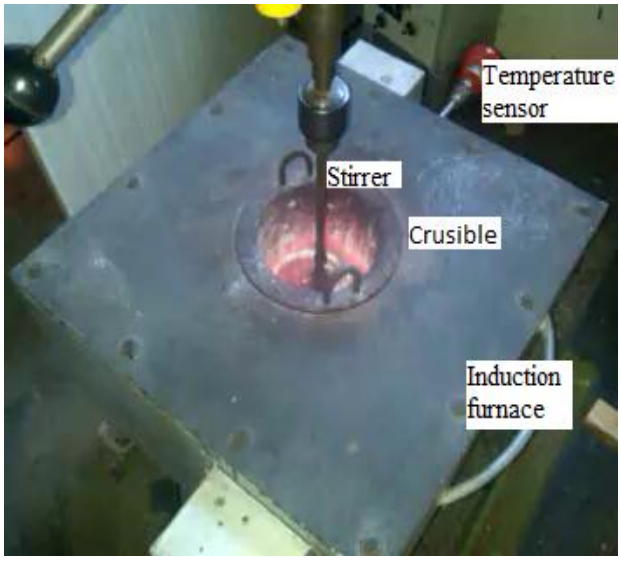


Fig-3: Experimental setup of stirring mechanism for the fabrication of MMC.

Buckling Test-

Vertical in line compression load is applied by using UTM machine. The vertical load causes the failure of various plate samples of various aspect ratios, thickness and reinforcement.

Fig-4: Experimental setup of buckling by using UTM.

III TAGUCHI METHOD

Taguchi method is based on performing experiments to test the sensitivity of a set of response variables to a set of control parameters i.e. independent variables by using orthogonal array with an aim to attain the optimum setting of the control parameters. In this study the Taguchi approach is used to see effect of input parameters on final output. The DOE process is made up of three main phases, the planning phase, the conducting phase, and the analysis phase. A major step in the DOE process is the determination of the combination of factors and levels which will provide the desired information. Analysis of the experimental results uses a signal to noise ratio to determine the best process designs. The Taguchi technique is a powerful design experiment tool for acquiring the data in a controlled way and to analyse the influence of process variable over some specific variable which is unknown function of these process variables and for the design of high quality systems.The signal to noise ratios (S/N), which are log functions of desired output, serve as the objective functions for optimization, help in data analysis and the prediction of the optimum results. The Taguchi method treats the optimization problems in two categories, static problems and dynamic problems. The major aim of current study is to analyze the effect of input parameters i.e. aspect ratio, thickness and fly ash reinforcement on output parameters. By knowing the input parameters the specific orthogonal array can be selected. In this study I have selected L9 orthogonal array [6].

The following table gives idea about input parameters.

Sr No	Factors	Parameter	Level 1	Level 2	Level 3
1	Aspect Ratio	A	1	1.5	2
2	Thickness	B	3	6	9
3	FA Reinforcement (%)	C	4	8	12

Table4-Process parameters and levels.

IV RESULTS AND DISCUSSION

The aim of investigation is to study effect of input parameters on deflection and load carrying capacity of composite plate under buckling. By considering parameters as mentioned above and using MINITAB software following results can be drawn.

Case (I)

Taguchi Analysis: Max Deformation versus AR, THK, and REIN for smaller is better.

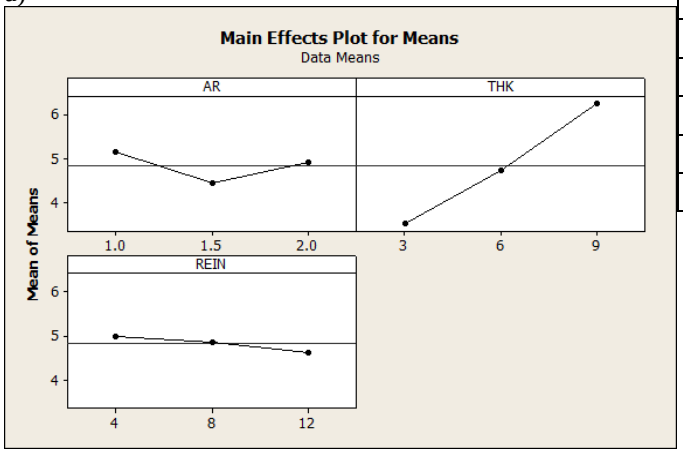
Level	AR	THK	REIN
1	-14.10	-10.91	-13.86
2	-12.61	-13.44	-13.37
3	-13.56	-15.92	-13.03
Delta	1.49	5.00	0.83
Rank	2	1	3

Table5- Response Table for Means

Level	AR	THK	REIN
1	5.150	3.533	5.000
2	4.433	4.717	4.867
3	4.917	6.250	4.633
Delta	0.717	2.717	0.367
Rank	2	1	3

Table6- Response Table for SN ratio

a)



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b)

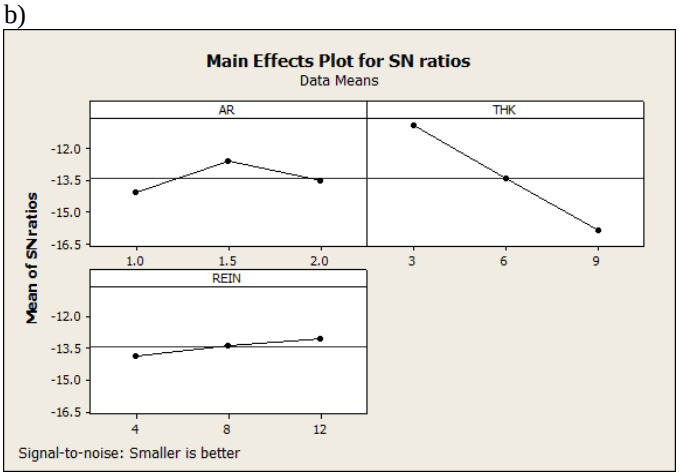


Fig-5: a) Main effect plot for mean and b) S/N Ratio for maximum deformation.

Fig 5 a) shows mean deformation as function of all three parameters. The mean plot shows for 1.5 aspect ratio, 3 mm thickness and 12% Fly ash reinforcement gives better prediction. For other parameters the conditions are as shown in fig. Fig 5 b) shows S/N ratios for smaller is better condition. In this case for aspect ratio 1, thickness 9 and 4% reinforcement the graph shows least value of deformation. Here rank 1 is assigned to thickness hence it greatly affects on deformation.

Case (II)

Taguchi Analysis: Max Load versus AR, THK, REIN for larger is better.

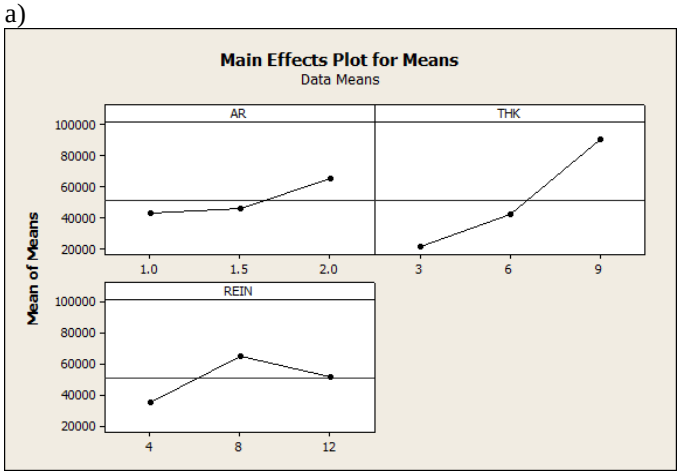
Level	AR	THK	REIN
1	90.28	85.85	89.81
2	92.83	92.22	93.91
3	93.43	98.48	92.82
Delta	3.15	12.63	4.10
Rank	3	1	2

Table7- Response Table for Means

Level	AR	THK	REIN
1	42516	20634	35875
2	45420	41902	64933
3	64775	90175	51903
Delta	22259	69541	29059
Rank	3	1	2

Table8- Response Table for SN ratio

a)



b)

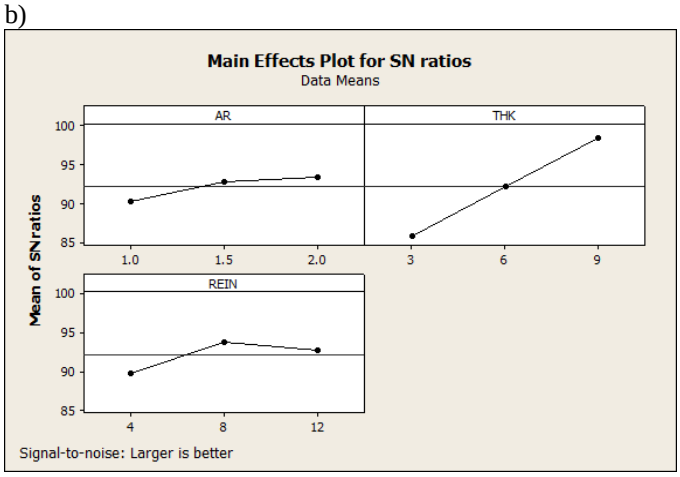


Fig-6: a) Main effect plot for mean and b) S/N Ratio for maximum load.

For above case effect of all three input parameters is analyzed on max load sustained by composite plate samples. Fig 6 a) shows mean plot for larger is better condition. In which for aspect ratio 2, thickness of 9 and for FA reinforcement of 8% the model shows maximum value of load sustainability.

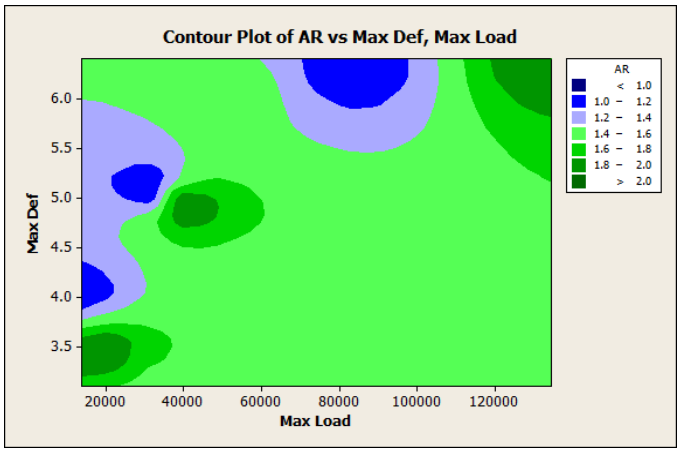
For 12% reinforcement it slightly reduces. Fig 6 b) shows the S/N ratios of data values in which load sustainability goes on increasing as parameter values increases. Here also the rank 1 is assigned to thickness.

Contour plots

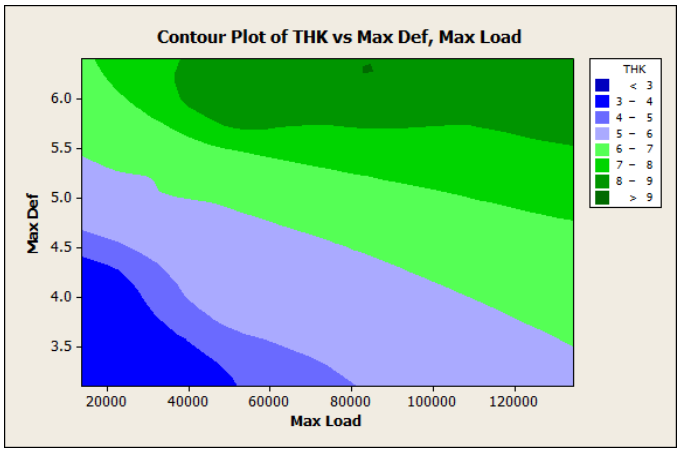
Contour plot gives overall effect of various parameters in different combinations.

The following plot shows effect of aspect ratio, thickness and reinforcement on max load and deformation. From bellow graph it is clear that as reinforcement and thickness increases the buckling strength increases. The deformation goes on decreasing as thickness increases

a)



b)



c)

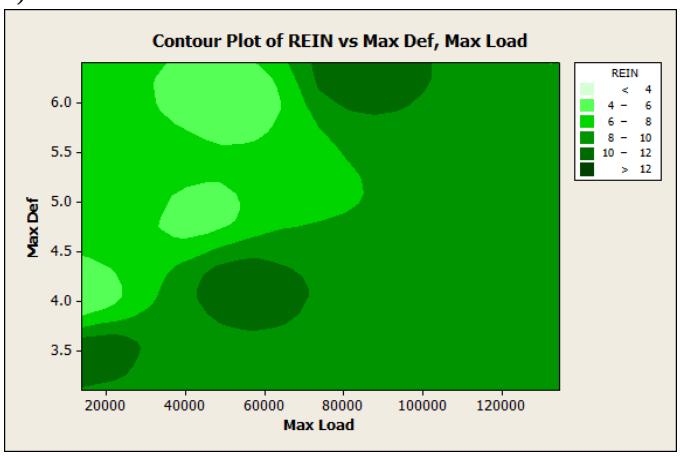


Fig-7: a) Contour plot for a) aspect ratio b) Thickness and c) Reinforcement

V 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 buckling of composite plate structures are investigated by subjecting to axially compressive loading along the axis.

3) It was revealed that the buckling strength of composite increased with increasing the weight percentage of Fly Ash particles.
4) The Signal-to-noise ratio showed the effect of each parameter at each level i.e. aspect ratio, thickness and percentage reinforcement on deformation and load bearing capacity of composite.
5) Taguchi analysis is successfully done for various levels and parameters.
6) Buckling load increases as aspect ratio and reinforcement increases but thickness of plate greatly effect on buckling strength.

VI. REFERENCES

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