Impact Factor (SJIF): 2.125

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 1, January-2016

Optimization of squeeze casting parameters on hybrid aluminium composites using Taguchi method

Jein Samdhas R[1], B. Rajeswari[2],

[1]*PG scholar, Department of Mechanical Engineering, Government College of Technology, Coimbatore*

[2]*Asisstant professor, Department of Mechanical Engineering, Government College of Technology, Coimbatore*

***Abstract* —** The squeeze casting of aluminum composites is a rapidly developing process that offers the potential for widespread utilization in automobile and aerospace industries, in squeeze casting process metal is solidified under mechanically applied pressure. The near net shaped components can be produced by squeeze casting. It has been shown that squeeze casting enhances the mechanical properties of cast metals. In the present work, the elemental SiC and Al_2O_3 powders are mixed with aluminum molten metal to produce the Al-SiC- Al_2O_3 hybrid composites. Optimization is one of the techniques used in manufacturing sectors to get best manufacturing conditions. Experiments were conducted based on L_9 orthogonal array by varying the input parameters. Mechanical properties such as ultimate tensile strength, hardness and wear rate were taken as output responses. Experiment results reveal that squeeze pressure is the most influencing factor on mechanical properties .Good agreement between confirmatory and experimental results has been found from confirmatory tests.

***Keywords*- Squeeze casting; Aluminium composites; Process parameters; Mechanical properties; Taguchi method**

I. INTRODUCTION

The squeeze casting process has the capability of producing near net shape castings that are essentially pore free. The high pressure during solidification keeps the molten metal in direct contact with the die surface providing true to die dimensions in the casting, the close contact with the die surface during solidification results in rapid solidification of the casting. This rapid solidification produces a fine secondary dendrite arm spacing in the castings, so that good strength and ductility can be attained.

The main aim of making metal matrix composites is to combine the desirable properties of metals and ceramics. Due to easy availability, high strength to weight ratio and ductility aluminium is the most widely used metal in automobile and aircraft industries. In motor-cars metal matrix composites (MMCs) are employed in braking systems and engine components. Senthil et al., studied the influence of squeeze pressure, melt temperature, die preheating temperature, die insert material and compression holding time on mechanical properties of LM24 aluminium alloys and concluded that squeeze pressure is the major contributing factor for the improvement of mechanical properties [1]. While preparing metal matrix composites, the selection of reinforcement particle size also influences the strength of material in the squeeze casting process. The smaller the grain size the better the improvement in properties [2].In squeeze casting the major parameters influencing the casting density and surface roughness are applied pressure, pressure duration, die and pouring temperature. Increase in squeeze pressure and pressure duration improves surface finish and casting density but it affects die life [3] Vijian et al. reported that squeeze casting exhibited remarkable grain refinement and substantial improvement in mechanical properties [7]. Kim et al. stated that squeeze casting accounted for a 15%–40% improvement in mechanical properties from the gravity die casting process [10].

Though many research works on squeeze cast aluminum alloys have been reported in literature, some gaps have been identified from the literature. Previous studies using squeeze casting technology to fabricate alloys only. It is understood that addition of ceramic materials can enhance the mechanical properties and life of components. This study aims at optimizing the fabrication process in order to achieve improved strength and mechanical properties. The effect of squeeze casting process parameters like squeeze pressure, pouring temperature, die preheating temperature on mechanical properties of Al6061/SiC/Al_2O_3 hybrid aluminium composites was investigated. Optimum parameters are found by taguchi method. Materials are selected to meet the growing needs of automobile industry.

II. EXPERIMENTS

2.1 Orthogonal array design

Taguchi Method is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter [15]. Taguchi method is based on performing evaluation or experiments to test the sensitivity of a set of response variables to a set of control parameters (or independent variables) by considering experiments in "orthogonal array" with an aim to attain the optimum setting of the control parameters. Orthogonal arrays provide a best set of well balanced (minimum) experiments. There are three forms of signal to noise (S/N) ratio that are of common interest for optimization by taguchi method, they are larger-the-better, smaller-the-better and the nominal-the- best

2.2 Experimental setup

The squeeze casting setup consists of two stainless steel spacers, stainless steel plunger, die, and base as shown in Figure.1 The cylindrical die is designed in order to minimize leakage, provide uniform pressure, and ensure smooth ejection of the cast . The die cavity has an internal diameter of 50 mm with length 250 mm. White graphite is used as lubricant. Main purpose of using lubricant is, it prevents adhesion and sticking of the composite specimen to the inner die wall. Pressure is applied by using the hydraulic plunger. A ceramic electric heater of capacity 400 °C was used to preheat the die. Aluminium 6061 alloy was melted in electric resistance crucible furnace. Homogenous distribution of reinforcement particle into the matrix material is the major factor which decides the final quality of casting. To attain the uniform distribution, silicon carbide and alumina powders are added with molten metal in the furnace and thoroughly mixed with the help of mechanical stirrer. After degassing the melt, a metered quantity of molten alloy was poured into the preheated die cavity.

Fig 1. Squeeze casting die

2.3 Tensile test

Tensile properties dictate how the material will react to forces applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit and reduction in area, tensile strength, yield point and other tensile properties. The specimens are prepared according to ASTM- E8 standards

Fig .2 Tensile test samples

2.4 Hardness test

Hardness test involves a small indenter being forced into the surface of the material being tested under controlled conditions of load and rate of application. The depth or size of the resulting indentation is measured, which in turn is related to a hardness number the brinell hardness test method consists of indenting the test material with a 5 mm diameter ball subjected to a load of 250 kg. The full load is applied for 1 minute. The diameter of the indentation left in the test material is measured by microscope.

Fig 3. Hardness test samples

2.5 Wear test

A computerized pin- on- disc test machine was used for wear tests. The wear testing was carried out at a constant sliding velocity of 1m/sec with normal loads of 10N. A cylindrical pin of size 10mm diameter and 25mm length prepared from composite casting was loaded through a vertical specimen holder against horizontal rotating disc. Before testing, the flat surface of the specimens was abraded by using 2000 grit paper. The rotating disc was made of carbon steel of diameter 120mm. Wear tests were carried out at room temperature without lubrication for 2 minutes.

Fig 4 Wear test samples

III. RESULTS AND DISCUSSION

If there is an experiment having 3 factors which have three levels, then total number of experiment is 27. Then results of all experiment will give 100 accurate results. In comparison to above method the Taguchi orthogonal array make list of nine experiments in a particular order which cover all factors. Those nine experiments will give 99.96% accurate result [15]

The analysis was done using MINITAB 15. The squeeze casting cast process parameters, namely squeeze pressure, pouring temperature and die preheating temperature at 3 levels are arranged in L_9 orthogonal array. Effect of each control factor on tensile strength, hardness and wear rate was carried out with the S/N response table. The response tables for tensile strength, hardness and wear rate are also presented in table 2, 3, 4. It could be seen from these tables that the factor squeeze pressure have strongest influence on UTS, hardness and wear rate. Regardless of the category of performance characteristics, the greater S/N ratio gives better performance. Therefore, the optimal level of process parameters is the level with the greatest S/N value. The response graph shows the change of the S/N ratio when the setting of the control factor is changed from one level to the other. The best tensile strength, hardness and wear rate were at the higher S/N values in the graphs. It could be seen in Fig. 5 that the optimum process condition became A3B2C2 for main control factors. That is, the optimal process parameters for the tensile strength, hardness and wear rate are the squeeze pressure at level 3, pouring temperature at level 2 and die preheating temperature at level2

Table 1.Experimental observations and S/N ratio

S.no	Squeeze pressure (MPa) A	Melt temperature (°C) B	Die preheating temperature (°C) C	UTS (MPa)	Hardness values (BHN)	Wear rate (mm^3/m)	S/N Ratio for UTS	S/N Ratio for hardness	S/N Ratio for wear rate
1	50	650	150	201	65	0-00057	46.063	36.230	64.852
2	50	700	200	219	66	0.00051	46.808	38.387	65.848
3	50	750	250	204	58.5	0.00061	46.192	35.342	64.293
4	75	650	200	228	71.5	0.00048	47.158	37.054	66.357
5	75	700	250	232	73.5	0.00049	47.309	37.276	66.196
6	75	750	150	231	68	0.00053	47.272	36.605	65.514
7	100	650	250	236	67	0.00041	47.458	36.495	67.937
8	100	700	150	238	76	0.00043	47.531	37.535	67.330
9	100	750	200	232	78.5	0.00046	47.309	37.833	66.749

Table 2. S/N ratio response table for UTS

Level	A	B	C
1	46.36	46.89	46.96
2	47.25	47.22	47.09
3	47.43	46.92	46.99
Delta	1.08	0.32	0.14
Rank	1	2	3

Table 3. S/N ratio response table for hardness

Level	A	B	C
1	35.99	36.59	36.79
2	36.98	37.07	37.09
3	37.29	36.59	36.37
Delta	1.30	0.47	0.72
Rank	1	3	2

Table 4. S/N ratio response table for wear rate

Level	A	B	C
1	65.00	66.38	65.90
2	66.02	66.46	66.32
3	67.34	65.52	66.14
Delta	2.34	0.94	0.42
Rank	1	2	3

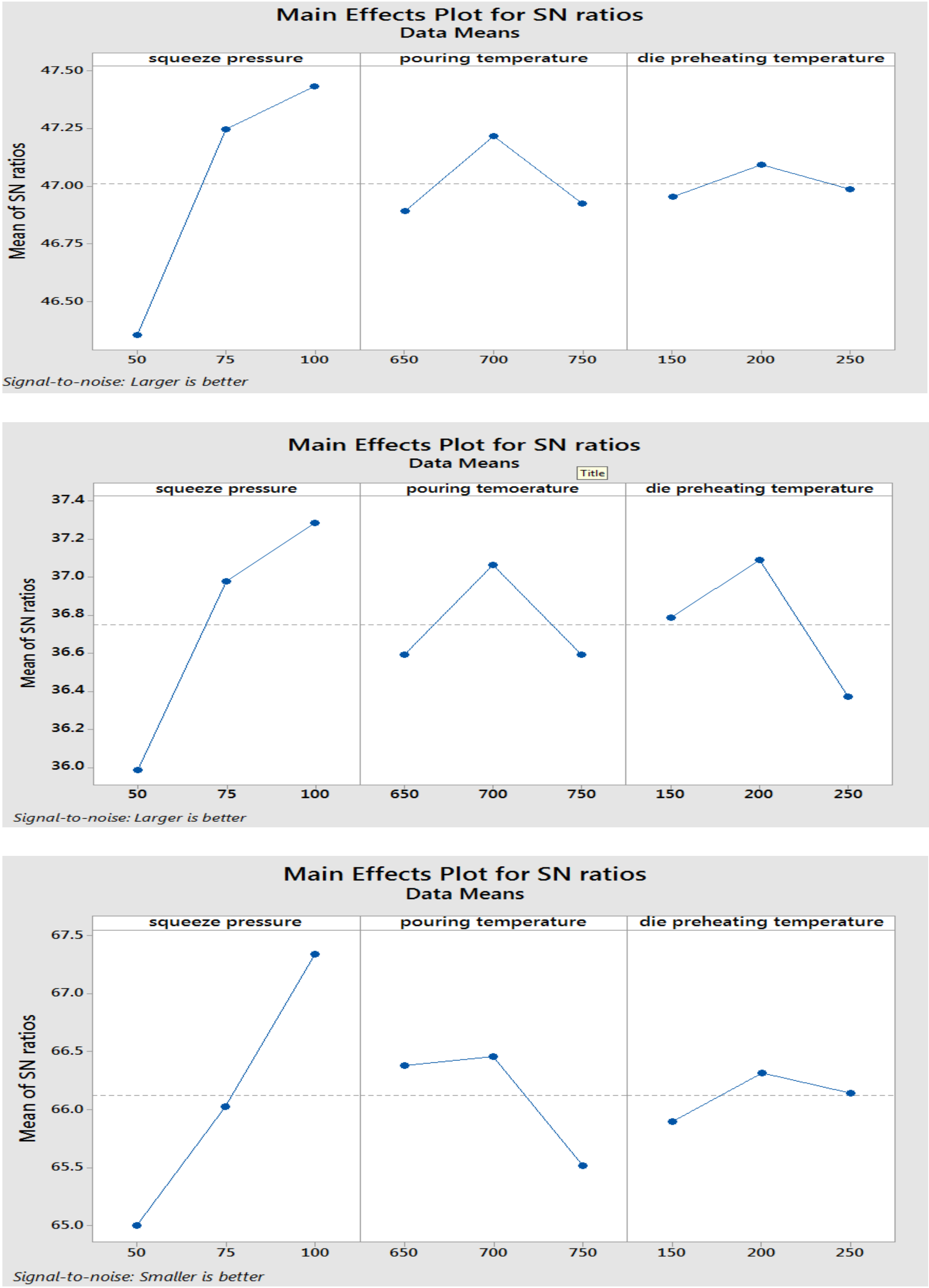

Fig 5. Response curve for UTS, Hardness and Wear rate

3.1 Analysis of variance

Using Minitab 15, ANOVA is performed to determine which parameter and interaction significantly affect the performance characteristics. Table shows the ANOVA results for tensile strength hardness and wear rate respectively.

ANOVA calculates the F- ratio, which is the ratio between regression mean square and mean square error. In general when the F- value increases, the significance of the parameter also increases. From ANOVA results it is seen that squeeze pressure is the most significant factor influencing the UTS, hardness and wear rate

Table 5. Analysis of variance- tensile strength

Source	SS	DOF	MSS	F ratio	P value
Squeeze pressure	1270	2	635.4	15.84	0.059
Melt temperature	118.2	2	59.11	1.47	0.404
Die preheating temperature	14.89	2	7.44	0.19	0.843
Error	80.22	2	4.11		
Total	1484	8			

3.2 Regression analysis

The correlations between the factors (squeeze pressure, pouring temperature, die preheating temperature) and the measured parameters (tensile strength hardness and wear rate) were obtained by multiple linear regressions. Eventually, the following equations were fitted for UTS, hardness and wear rate

UTS = 177.6 + 0.547 squeeze pressure + 0.0067 pouring temperature + 0.0067 die preheating temperature
Hardness = 66.2 + 0.200 squeeze pressure - 0.0200 pouring temperature+ 0.0167 die preheating temperature
Wear rate = 0.000379 - 0.000003squeeze pressure

3.3 Confirmatory tests

The optimum settings were verified by conducting confirmatory experiments. From the table given below, it can be seen that the actual and predicted values fall within 10% variation. Therefore, these optimal settings are suggested for the preparation of this composite. The confirmatory test results are shown in table

Responses	**Predicted**	**Confirmatory**
Ultimate tensile strength (MPa)	238.33	236
Hardness (BHN)	75.54	78
Wear rate (mm^3/m)	0.00034	0.00038

IV. CONCLUSION

In this study, the optimal squeeze casting parameters of Al6061-Sic-Al_2O_3 composites have been specified using the Taguchi method, the experiments were conducted based on L_9 orthogonal array by considering three factors and three levels. The parameters considered in this work are squeeze pressure, pouring temperature and die preheating temperature According to the results; the following conclusions have been made

- The combination A3 B2 C2 that means squeeze pressure 100 MPa, melt temperature 700 °C and die temperature 200 °C are recommended to obtain higher mechanical properties in squeeze casting of $Al6061-SiC-Al_2O_3$ composites.
- From ANOVA. It was found that the influence of squeeze pressure has the large impact on UTS, hardness and wear.
- The enhanced mechanical properties in squeeze cast composites are due to the microstructural refinement. Optical microscope image shows the fine microstructure

REFERENCES

[1] P.Senthil, K,S. Amirthagadeswaran "Optimization of squeeze casting parameters for non-symmetrical A2C2A aluminium alloy casting through Taguchi method" ,Journal of mechanical science and technology 26(4)/2012/1141-1147

[2] M. Dhanashekar , V. S. Senthil Kumar "Squeeze Casting of Aluminium Metal Matrix Composites- An overview", Procedia Engineering 97 / 2014/ 412 – 420

[3] Manjunath Patel G C, Prasad Krishna1 and Mahesh B. Parappagoudar "Optimization of squeeze cast process parameters using taguchi and grey relational analysis," Procedia Technology 14/ 2014 / 157 – 164

[4] Olivier Beffort , Siyuan Long , Cyril Cayron , Jakob Kuebler , Philippe-Andre´ Buffat "Alloying effects on microstructure and mechanical properties of high volume fraction SiC-particle reinforced Al-MMCs made by squeeze casting infiltration", Composites Science and Technology 67 (2007) 737–745

[5] Adem Onat "Mechanical and dry sliding wear properties of silicon carbide particulate reinforced aluminium–copper alloy matrix composites produced by direct squeeze casting method" Journal of Alloys and Compounds 489 (2010) 119–124

[6] M.S. Yong , A.J. Clegg "Process optimization for a squeeze cast magnesium alloy metal matrix composite" Journal of Materials Processing Technology 168 (2005) 262–269

[7] P. Vijian ∗, V.P. Arunachalam, "Optimization of squeeze cast parameters of LM6 aluminium alloy for surface roughness using Taguchi method" Journal of Materials Processing Technology 180 (2006) 161–166

[8]P. Vijian , V.P. Arunachalam "Modelling and multi objective optimization of LM24 aluminium alloy squeeze cast process parameters using genetic algorithm" Journal of Materials Processing Technology 186 (2007) 82–86

[9] Yuan Lu, Jianfeng Yang, Weizhong Lu, Rongzhen Liu, Guanjun Qiao, Chonggao Bao, "The mechanical properties of co-continuous Si3N4/Al composites manufactured by squeeze casting", Materials Science and Engineering A 527 (2010) 6289–6299

[10] Yixiong Liu , WeipingChen, ChaoYang , DezhiZhu, Yuanyuan Li "Effects of metallic Ti particles on the aging behavior and the influenced mechanical properties of squeeze cast (SiC+ Ti) /7075 al hybrid composites Materials Science&EngineeringA620(2014)190–197

[11]Shi-bo BIN, Shu-ming XING, long-mei TIAN, Ning ZHAO, Lan LI "Influence of technical parameters on strength and ductility of AlSi9Cu3 alloys in squeeze casting "Trans. Nonferrous Met. Soc. China 23(2013) 977_982

[12] Yanling Yang, Liming Peng;, Penghuai Fu, Bin Hu, Wenjiang Ding and Baozheng Yu "Effects of Process Parameters on the Macrostructure of a Squeeze-Cast Mg-2.5 mass%Nd Alloy Materials Transactions", Vol. 50, No. 12 (2009) 2820 – 2825

[13] Hashem F. El-Labban , M. Abdelaziz , Essam R.I. Mahmoud "Preparation and characterization of squeeze cast-Al–Si piston alloy reinforced by Ni and nano-Al2O3 particles" Journal of King Saud University – Engineering Sciences (2014)

[14] Najib souissi, Mohamed Ben Amar "Optimization of squeeze casting parameters for 2017 a wrought Al alloy using taguchi method."

[15] Krishnakant,Jatin Taneja,Mohit Bector,Rajesh kumar Application of taguchi method for optimizing turning process by the effects of machining parameters International Journal of Engineering and Advanced Technology (IJEAT)