# Optimisation Of Aluminium Alloy Squeeze Cast Parameters Lm 13/ Sic On Mechanical Properties

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Research Article

# Optimisation Of Aluminium Alloy Squeeze Cast Parameters Lm 13/ Sic On Mechanical Properties

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## ABSTRACT

Aluminum metal matrix composites are becoming increasingly popular in a wide range of automotive applications. The squeeze casting process meets the primary demand for refined pore-free and near-net-shape composites. This paper describes the properties of an LM13 matrix created by reinforcing silicon carbide (SIC) particles using the squeeze casting method. The experiments were designed using the L9 taguchi orthogonal to investigate the effects of squeeze casting process parameters such as squeeze pressure, die temperature, and reinforcement weight percentage on density(), micro-hardness(VH), and tensile strength (Rm). Until now, no studies have been conducted to improve the properties of the composite under applied pressure conditions using silicon carbide particles with the addition of LM13 stirred under ultrasonic vibration. The absolute influence process variables that were accounted for resulted in good casting. These were to be analysed using Taguchi techniques to determine the signal-to-noise ratio. According to the findings, the squeeze pressure and weight percentage of sic are the most influential process parameters for improving mechanical properties. In order to optimise process parameter castings, microstructure analyses must be performed.

***Keywords***- squeeze casting, aluminium alloy, mechanical properties

## 1. INTRODUCTION

Squeeze casting is a process that combines forging and casting. The process results in the best mechanical properties possible in a cast product. The development of this process has the potential to be used in large-scale production for the manufacture of aluminium alloy components. It can also be useful for critical component import substitution. When molten metal is poured into the bottom half of a pre-heated die, it quickly solidifies, while the upper half of the die closes and begins applying pressure during the solidification process. Parts with significant detail can be produced despite the fact that the maximum pressure applied is significantly less than that used in forging. The high pressure used and the instant contact of the molten alloy with the metal die surface results in the least amount of porosity and the best

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mechanical properties. This process can be used to produce ferrous and nonferrous metals. [1] and [2]

Because aluminium alloys have appealing properties such as lighter high strength alloy, stiffness, and wear resistance, they are widely used in aerospace, automobile, and train companies. Metal Matrix Composites (MMCs) are regarded as the most significant advances in the development of advanced materials, with applications ranging from the marine, automobile, and aerospace industries [3]. MMCs have at least two components, one of which is a discontinuous phase such as fibres, whiskers, particles, or fillers known as reinforcement, and the other is a matrix phase, which is usually a continuous phase such as aluminium or magnesium[4].

Aluminium silicon-based LM6 (LM13)[2] with a major composition of 11 to 13 percent silicon (eutectic alloy) and 85.95 percent aluminium. Because the strength and hardness of alloys are primarily determined by their microstructure,[5] several efforts have been made to refine the microstructure of castings in order to improve the mechanical properties of aluminium alloy.

The squeeze casting process results in a 15-40% change in mechanical properties [6]. Squeeze pressure, die temperature, and pressure holding time are identified as the most significant factors in which squeeze pressure for considering improvement in tensile, hardness, and yield strength[7]. Using grey relation analysis, the effect of squeeze pressure parameter was studied and reported that the squeeze pressure of 120 MPa, die preheating temperature of 225°C, and pouring temperature of around 720°C are the optimal parameters [7]. The majority of research on squeeze casting has focused on the development of aluminium alloys to improve mechanical properties, such as LM24, LM25, A357, A535 and AA603, as well as some wrought aluminium alloys like 6061 and 7010.

Aluminium – silicon carbide composites were investigated, and the accumulation factors in weight percent of Sic reaction in increased tensile strength[8] improves mechanical and fatigue properties with wear resistance [9].

[10]. The microstructural investigation, XRD analysis, and SEM metallographic investigation are intended to detect the presence of Sic particles in the presence of homogeneous spreading and to devolve the mechanical properties[11]. The Taguchi method was used to investigate the effects of squeeze pressure, die temperature, and weight percentage on the hardness of LM20 alloy[12]. The experiments were carried out using a L9 orthogonal array of Taguchi matrix, a S/N ratio with the larger the better concept, and a Pareto ANOVA study to determine the optimum process parameter levels and the percent contribution of each process parameter[13].

The goal of global optimization is to find the "ultimate" solution in situations where there are several sub-optimal solutions. [14] The genetic algorithm solves optimization problems by mimicking the principles of biological evolution by repeatedly modifying a population of individual points with rules based on gene combinations in biological reproduction. The genetic algorithm improves the chances of finding a global solution due to its random nature. [7] As a result, they prove to be very efficient and stable in their pursuit of global optimum solutions. In order to be used as an objective function in GA to aid in global optimization, the mathematical model that best describes the relationship between input and output parameters must be developed. Genetic algorithms, also known as free-derivative methods, use a stochastic approach to find the actual optimum[15].

Previous research has shown that the mechanical properties of aluminium metal matrix composites can be identified based on the distribution of reinforcement in the matrix and bonding strength at the interface. There has been little reported effort on the use of LM13 – SiC composites. The composite produced by adapting stirred under ultrasonic vibration is still being studied in this study. The squeeze casting process is still a popular method of processing. The majority of the castings were pore-free fine structure castings. The mixing of the reinforcement is a major task, caused by agglomeration and problems, poor bonding, and so on, during solidification. The purpose of this research is to look into the effect of squeeze casting process parameters on the properties of LM13 and SIC composites. This has not been declared in the scientific community and will be optimised in the future.

## 2. Experiment techniques

### 2.1 Materials

Currently, the silicon and boron-based LM13 aluminium alloy was chosen after analysing materials with a density of 2.700 g/cm3 and showing high resistance to corrosion under atmospheric conditions, good fluidity, good hot tear resistance, good castability, good Machinability, and high specific strength. As shown in Table 3, optical emission spectrometer measurements are tabulated and compared to BS 1490:1988 standards using a purchased LM13 aluminium alloy with chemical composition analysis. Table 1 shows the chemical composition and its attractive properties such as high strength, low density, extremely high hardness, good chemical stability, and neutron absorption capability.

**Table 1. Chemical composition of LM13 aluminium alloy**

| **Elements** | **Cu** | **Mg** | **Si** | **Fe** | **Mn** | **Ni** | **Zn** | **Pb** | **Sn** | **Ti** | **A** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Standard %** | 0.7-1.5 max | 0.8-1.5 max | 10.0-13.0 max | 1.0 max | 0.5 max | 1.5 max | 0.1 max | 0.1 max | 0.1 max | 0.2 max | reminder |
| **Tested %** | 1.2 | 1.2 | 11.79 | 0.65 | 0.39 | 1.32 | 0.1 | 0.1 | 0.1 | 0.16 | reminder |

### 2.2 Experimental Setup Procedure

The setup consists of an electric furnace and a leak proof bottom pouring arrangement, with the furnace capable of reaching 1000°C with an EN8 crucible. It is commonly used to melt up to 2kg of ingot metal. The leak proof bottom pouring arrangement is linked to a preheated pathway in this case. It is used to transfer the melt without causing temperature loss in the die cavity. To control the melt temperature, pathway temperature, and die temperature thermocouples are used in conjunction with a digital indicator. The variable speed ranges from 100 to 1500 RPM and is used to stir the melt as it moves up and down as it is assembled with a stirrer. To melt while stirring, a 1000C furnace is mounted on top of the crucible with a suitable controller for heating and directly adding particles with preheated reinforced particles. A motorised hydraulic power press with a capacity of 50 tonnes and a pressure indicator is used to apply desired pressure over the melt. Figure 1 shows a graphite coated

H13 split die clamped over the base of a hydraulic power press.

1kg of LM13 aluminium alloy ingot was melted in the furnace at various temperatures to produce homogeneous liquid. During this phase, a cover flux of 8g and hexachloroethane ($C2Cl6$) of 12g are used to clean the melt and remove the entrapped gases from the molten metal. Following impurity removal, the melt is agitated by the mechanical stirrer ultrasonic vibration condition to create a fine vortex stirrer and evenly distribute the particles at a rotating speed of 600 rpm. During the stirring process, highly reinforced SiC particles with a preheated temperature of 225 are added along with wettability elements of 3 weight percent. The molten metal is then carefully poured into the preheated die cavity within a few seconds via a preheated pathway from the bottom pouring furnace. Squeeze pressure is applied to the punch of the hydraulic power press until the melt solidifies completely. Finally, the casted samples are removed from the die cavity. Vickers micro-hardness tester with 100 g load (HV100) was applied for 5 to 10 seconds on the dexterous surface and micro-hardness values were noted at three different positions on the specimen surface. The density of the specimen was calculated using the Archimedes principle. Tensile strength on the specimens was tested using a universal testing machine with a capacity of up to 100 KN and an accuracy of 0.01 percent. The tensile test specimens were prepared in accordance with the ASTM-E1012 standard. Tensile strength was measured for each specimen using a tensile test.

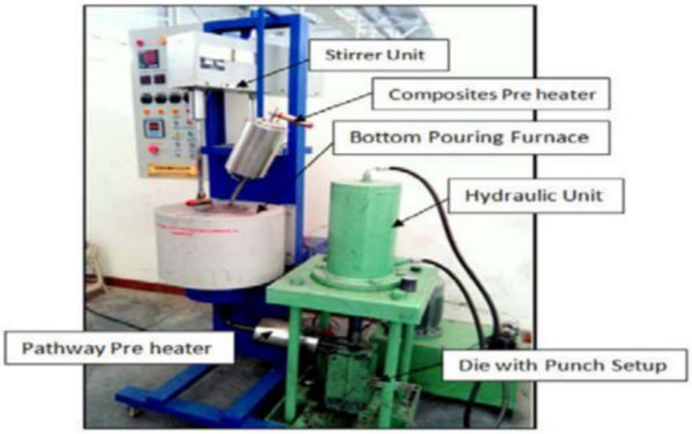


**Figure 1. squeeze casting setup**

### 2.3 Parametric Constraints:.

The important parameters influencing casting density and surface roughness are applied pressure, pressure duration, die temperature, and pouring temperature[1]. Increasing the squeeze pressure rate and pressure duration improves surface finish and casting density; thus, squeeze pressures ranging from 70 to 140 MPa are considered for. Low die and pouring temperature reactions in pre-mature solidification before applying pressure and bringing down the metal-mould interface, whereas high die and pouring temperature reactions increase cycle time, amount of flash, and affect die life[7]. As a result, die pre-heat temperatures ranging from 150°C to 300°C were considered[9][16]. Adding less weight percentage (below 4% ) of SiC particles results in cluster appearance and non-uniform particle distribution, resulting in insignificant improvement in mechanical properties. As a result, SiC ranges from 4 to 12 weight percentage (wt. percent) were considered.

## 2.4 Taughi design of experiments:

Traditional experimental techniques, such as changing one parameter while keeping the other constant, are complex and suffer from the major disadvantage of a large number of experiments, which contributes to an increase in the cost of experiments to achieve super quality products. Taguchi method is a solution tool that helps reduce the number of experiments and achieve a high-quality system without increasing costs. This technique, which combines the quality function concept and experimental design theory, has been used in the manufacturing industry to solve a variety of complex problems.

In this study, the Taguchi method was used to observe the influencing process parameters in the squeeze casting process. Taguchi statistical design is used to understand the effect of these parameters after running a few experiments and achieving strong mechanical properties. The casting parameters were studied at three different levels.

To quantify process variation, the Taguchi method employs a generic signal-to-noise ratio. In general, the (S/N) ratio is the mean(signal) to standard derivative ratio (noise). Depending on the type of characteristics involved, three types of SN ratios are applicable: higher is better (HB), lower is better (LB), and nominal is best (NB). Because the goal of this work is to maximise mechanical properties, the SN ratio with HB characteristics is required. S/N=-10log (1/n 1/Yi2)

Where n denotes the number of measurements taken in a trial under the same design condition (here n=3). In the orthogonal array (OA) table, Y represents the measurement results, and subscript I indicates the number of simulation design parameters.

A statistical analysis of variance (ANOVA) can be used to determine which process parameters 9factor are statistically significant for each quality characteristic.

Total SStotal = [(S/N) i2-T2/N SSA = [(Ai2 / nA) i2-T2/N

DOF=N-1

Where SStotal is the total sum of squares, N is the total number of experiments, SSA is the factorial sum of squares due to factor A, nAi is the number of samples for the ith level of factor A, T is the sum total (S/N) ratio of the experiments, DOF is the number of degrees of freedom, v-factor is the factor's variance, SSfactor is the factor's sum of squares, and F-factor is the factor's F

## 2.5 Assigned orthogonal array:

Experiments were carried out using Taguchi's L9 Orthogonal Array (OA) experimental design, which consists of 9 combinations of squeeze pressure, die temperature, and weight percentage of. It investigates three process parameters (without interaction) that are disparate in three discrete levels. According to Taguchi experimental design knowledge, a set of three levels assigned to each process parameter has two degrees of freedom (DOF). This gives a total of six DOF for the three process parameters chosen in this work. As a result, we have a total of 8 DOF for the factors in their experiments[17]. The nearest three level orthogonal array available that meets the criterion of determining the OA is L9 with 8 DOF. Table 2 depicts the experimental model.

## 2.6 Design of experiments with results

**Table-2 Casting parameter and responses**

| P / Mpa | Td / °C | wt % | HV 100 final | R / Mpa | ρ / g / cm3 |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 60 | 150 | 4 | 115.12 | 333.80 | 2815.23 |
| 60 | 225 | 8 | 141.12 | 351.32 | 2818.15 |
| 60 | 300 | 12 | 139.76 | 351.80 | 2825.36 |
| 100 | 150 | 8 | 155.30 | 359.72 | 2825.69 |
| 100 | 225 | 12 | 161.80 | 367.09 | 2828.23 |
| 100 | 300 | 4 | 139.30 | 352.10 | 2823.54 |
| 140 | 150 | 12 | 175.94 | 371.20 | 2833.72 |
| 140 | 225 | 4 | 149.00 | 363.39 | 2832.12 |
| 140 | 300 | 8 | 158.12 | 367.10 | 2833.43 |

## 2. RESULTS AND DISCUSSION

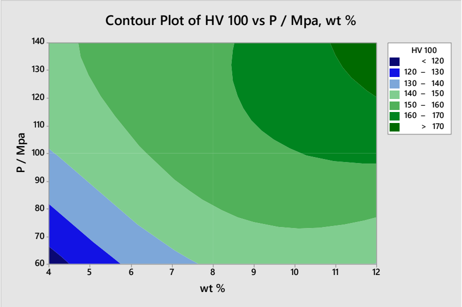
## 3.

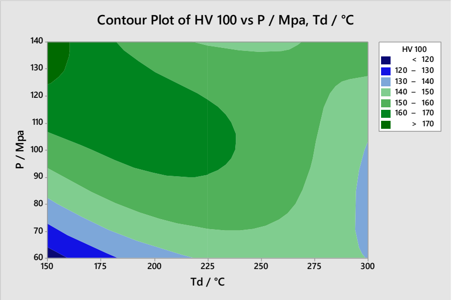
### 3.1 Taguchi Analysis

MINITAB V.17 statistical analysis software was used to compute the values for the design and investigation of experiments, as well as to run the Taguchi and ANOVA analyses and build regression models. The Taguchi method for optimising process parameters provides the value of the influence of independent parameters on the discovered quality characteristics. The statistical ANOVA analysis was used to determine how each process parameter affects the variation in quality characteristics.

### 3.2 EFFECT OF PROCESS PARAMETERS ON HARDNESS

The contour plot in Figure 2a shows that the hardness increases as the pressure increases with increasing weight percentage. In this plot, the hardness value in light green (160-170), which indicates a pressure of 120Mpa, corresponds to the weight percentage of 11%. As a result, the maximum hardness value is shown in dark green (above 170), which corresponds to a pressure of 140Mpa and a weight of 12 percent. The contour plot in figure 2b shows that the hardness increases as the pressure increases and the die temperature decreases. In this plot, the hardness value in light green (160-170) corresponds to the pressure 110-120Mpa and the die temperature 175-200 C. As a result, the maximum hardness value is shown in dark green (above 170), which corresponds to a pressure of 130-140Mpa and a temperature of 150 C. The contour plot in Figure 2c shows that the hardness increases as the weight percentage increases and die temperature decreases. In this plot, the hardness value in light green (160-170), which indicates a Wt percent of 10%, corresponds to the die temperature of 175 C. As a result, the maximum hardness value is shown in dark green (above 170), which corresponds to the Wt percent 12 percent with Td 150 C. As a result, the optimal value for maximum hardness obtained from this contour plot is pressure 140Mpa, weight percentage 12 percent, and die temperature 150 C.





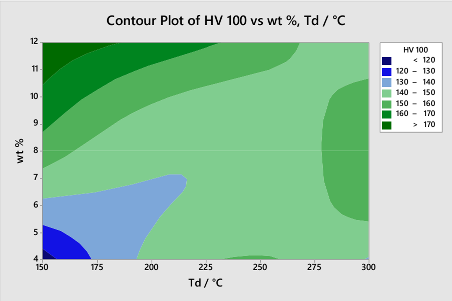


**Figure 2a,2b,2c. contour plot of hardness vs P,Td,Wt%**

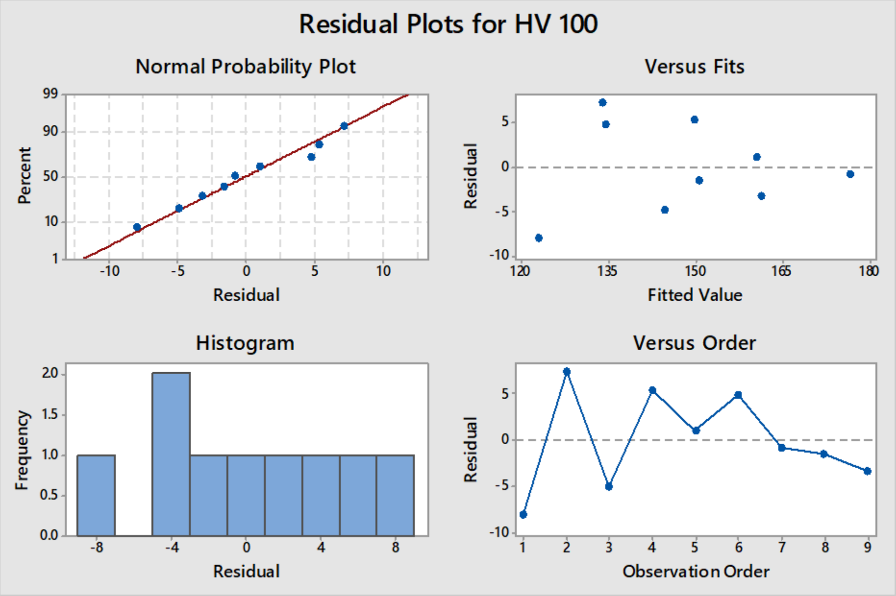


**Figure 3. Residual plots**

The scientific theory presented that produced better results for hardness at the maximum squeeze pressure is as follows: in this experiment, we concluded that the hardness gradually increases with the rate of squeeze pressure value from 60 Mpa to 140 Mpa. When considering the die temperature, the hardness increases from 150oC to 225oC after which the hardness value decreases from 225oC to 300oC. They discovered that increasing the weight percentage of SiC increased the hardness of the composite, with a better hardness produced at 12% weight of Sic. Figure 3 shows residual plots. The square values of the correlation coefficient (R) are S(6.42724), R2 (91.39 percent), and adj R2 (86.22 percent) for the modelling equation of average micro hardness, indicating that the model is highly significant. The correlations between the factors P, Td, and wt percent obtained through multiple linear regression are shown in equation 1 below. The S/N ratio with larger is better theory was chosen to analyse the rank of process parameters influence for this experiment, which was finalised as Squeeze pressure, weight percentage, followed by die temperature contribution in table 4. The ANOVA table shows that the maximum squeeze pressure contributes approximately 52.67 percent to the change in hardness when compared to the weight percentage (38.13 percent) and die temperature in the table. 4. The optimal process parameters for the required hardness value in Squeeze pressure 140 Mpa, Die temperature 225oC, and Sic weight percentage 12 percent.

## Regression Analysis: HV 100 versus P / Mpa, Td / °C, wt %

**Table-3 Analysis of Variance**

| **Source** | **DF** | **Adj SS** | **Adj MS** | **F-Value** | **P-Value** | **%contribution** |
|---|---|---|---|---|---|---|
| **Regression** | 3 | 2191.93 | 730.64 | 17.69 | 0.004 | |
| **P / Mpa** | 1 | 1263.24 | 1263.24 | 30.58 | 0.003 | 52.67 |
| **Td / °C** | 1 | 14.05 | 14.05 | 0.34 | 0.585 | .59 |
| **wt %** | 1 | 914.64 | 914.64 | 22.14 | 0.005 | 38.13 |
| **Error** | 5 | 206.55 | 41.31 | | | 8.61 |
| **Total** | 8 | 2398.47 | | | | |

Model Summary

```
      S    R-sq  R-sq(adj)  R-sq(pred)
6.42724  91.39%     86.22%      64.28%
```

Regression Equation

HV 100 = 92.0 + 0.3628 P / Mpa - 0.0204 Td / °C + 3.087 wt %...**...........................equation 1**

**Taguchi Analysis: HV 100 versus P / Mpa, Td / °C, wt %**

**Table-4 Response Table for Signal to Noise Ratios(Larger is better)**

| **Level** | **P / Mpa** | **Td / °C** | **wt %** |
|---|---|---|---|
| **1** | 42.37 | 43.32 | 42.52 |
| **2** | 43.63 | 43.55 | 43.60 |
| **3** | 44.12 | 43.26 | 44.00 |
| **Delta** | 1.74 | 0.29 | 1.48 |
| **Rank** | 1 | 3 | 2 |

## 3.3 EFFECT OF PROCESS PARAMETERS ON TENSILE STRENGTH

The contour plot in figure 4a shows that tensile strength increases as pressure increases with weight percentage. In this plot, the tensile strength in light green (360-370Mpa) corresponds to the pressure 130Mpa and the Wt percent 5-10%. As a result, the maximum value of tensile strength is shown in dark green (above 370Mpa), which corresponds to a pressure of 130-140Mpa and a weight percentage of 12 percent. The contour plot in this figure shows 4b that the tensile strength increases as the pressure increases and die temperature decreases. In this plot, the tensile value in light green (360-370Mpa) corresponds to the pressure 110-130Mpa and the die temperature 175 C-250 C. As a result, the maximum value of tensile strength is shown in dark green (above 370Mpa), which corresponds to pressure 140Mpa and Td 150 C. The contour plot in this figure shows4c that the tensile strength increases as the weight percentage increases and die temperature decreases. The tensile strength in light green (360-370Mpa) that shows the Wt percent 11 percent coincides with the die temperatures 175 C & 200 C in this plot. As a result, the maximum value of tensile strength is shown in dark green (above 370Mpa), which corresponds to the Wt percent 12 percent with Td 150 C. As a result of this contour plot, the optimal value for maximum tensile strength is pressure 140Mpa, weight percentage 12 percent, and die temperature 150 C.

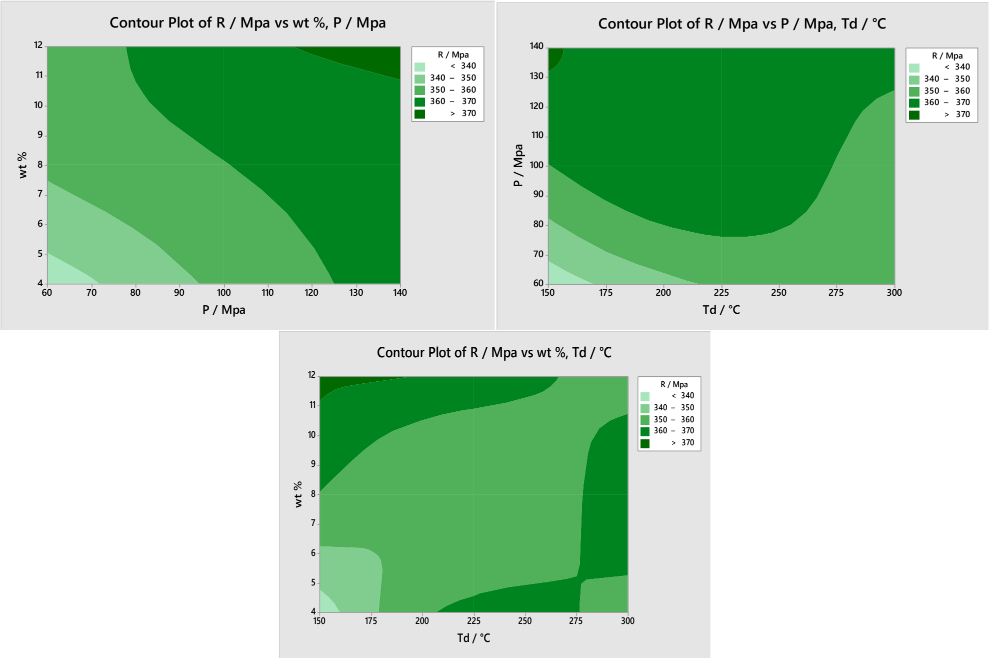


**Figure 4a,4b,4c. contour plot of tensile vs P,Td,Wt%**

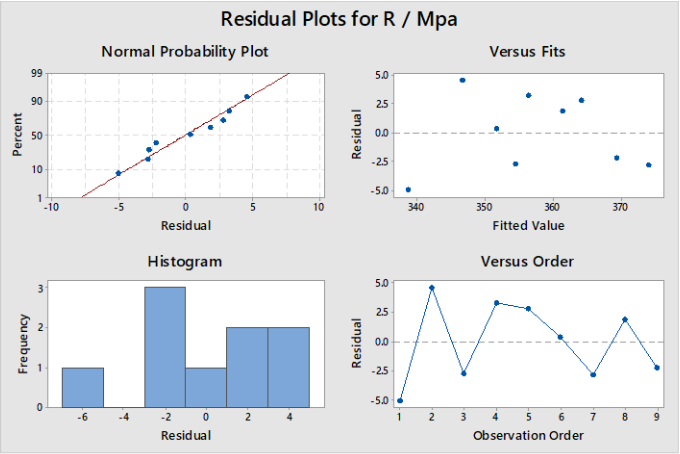


**Figure 5. Residual plots**

Since we concluded in this experiment that the tensile strength gradually increases with the rate of squeeze pressure value from 60 Mpa to 140 Mpa. Tensile strength increases from 150oC to 225oC when the die temperature is considered, and then decreases from 225oC to 300oC when the die temperature is considered. They discovered that increasing the weight percentage of SiC increased the tensile strength of the composite, with a better tensile strength produced at 12% weight of Sic. The residual plot in Figure 5 shows the optimum value of tensile strength. The square values of the correlation coefficient (R) are S(4.23712), R2 (91.63 percent), and adj R2 (86.61 percent) for the modelling equation of average tensile strength, indicating that the model is highly significant. The correlations between the factors P, Td, and wt percent obtained through multiple linear regression are shown in equation 2 below. The S/N ratio with larger is better theory was chosen to analyse the rank of process parameters influence for this experiment, which was finalised as Squeeze pressure, weight percentage, followed by die temperature contribution, as shown in table-5. In Table-5, the ANOVA table shows that the maximum squeeze pressure contributes approximately 65.16 percent to the change in tensile strength when compared to the weight percentage (25.86 percent) and die temperature. The optimal process parameters value for required tensile strength is 140 Mpa squeeze pressure, 225oC die temperature, and Sic weight percentage of 12 percent.

**Table-5 Analysis of Variance**

| **Source** | **DF** | **Adj SS** | **Adj MS** | **F-Value** | **P-Value** | **%contribution** |
|---|---|---|---|---|---|---|
| **Regression** | 3 | 983.21 | 327.735 | 18.26 | 0.004 | |
| **P / Mpa** | 1 | 699.19 | 699.192 | 38.95 | 0.002 | 65.16 |
| **Td / °C** | 1 | 6.57 | 6.573 | 0.37 | 0.572 | 0.61 |
| **wt %** | 1 | 277.44 | 277.440 | 15.45 | 0.011 | 25.86 |
| **Error** | 5 | 89.77 | 17.953 | | | 8.37 |
| **Total** | 8 | 1072.97 | | | | |

Model Summary

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| 4.23712 | 91.63% | 86.61% | 64.80% |

Regression Equation

R / Mpa = 313.77 + 0.2699 P / Mpa + 0.0140 Td / °C + 1.700 wt %...................................**equ-2**

**Table-6 Response Table for Signal to Noise Ratios(Larger is better)**

| **Level** | **P / Mpa** | **Td / °C** | **wt %** |
|---|---|---|---|
| **1** | 50.77 | 50.99 | 50.87 |
| **2** | 51.12 | 51.14 | 51.11 |
| **3** | 51.30 | 51.05 | 51.20 |
| **Delta** | 0.53 | 0.15 | 0.33 |
| **Rank** | 1 | 3 | 2 |

## 3.4 EFFECT OF PROCESS PARAMETERS ON DENSITY

The contour plot in Figure 6a shows that the density increases as the pressure increases and the die temperature decreases. The density value in light green (2828-2832 g/cm3) that shows the pressure 120Mpa coincides with the Td 175 C-275 C in this plot. As a result, the maximum density is shown in dark green (above 2832 g/cm3), which corresponds to a pressure of 130-140Mpa and a temperature of 150 C. The contour plot in this figure 6b shows that the density increases as the pressure increases with the percentage of weight. In this plot, the density value in light green (2828-2832 g/cm3) corresponds to the pressure 130Mpa and the weight percentage 5-10%. As a result, the maximum density value is shown in dark green (above 2832 g/cm3), which corresponds to a pressure of 140Mpa and a weight percentage of 12 percent. The contour plot in this figure shows 6c that the density increases as die temperature increases. In this plot, the density value in light green (2828-2832 g/cm3) indicates a Wt percent of 5% and corresponds to the die temperature of 275 C. As a result, the maximum density value is shown in dark green (above 2832 g/cm3), which corresponds to the Wt percent 12 percent with Td 150 C and Wt percent 8 percent with Td 300 C. As a result, the optimal value obtained from these density contour plots for maximum density is pressure 140Mpa, weight percentages of 12% and 8%, and die temperatures of 150 C and 300 C.

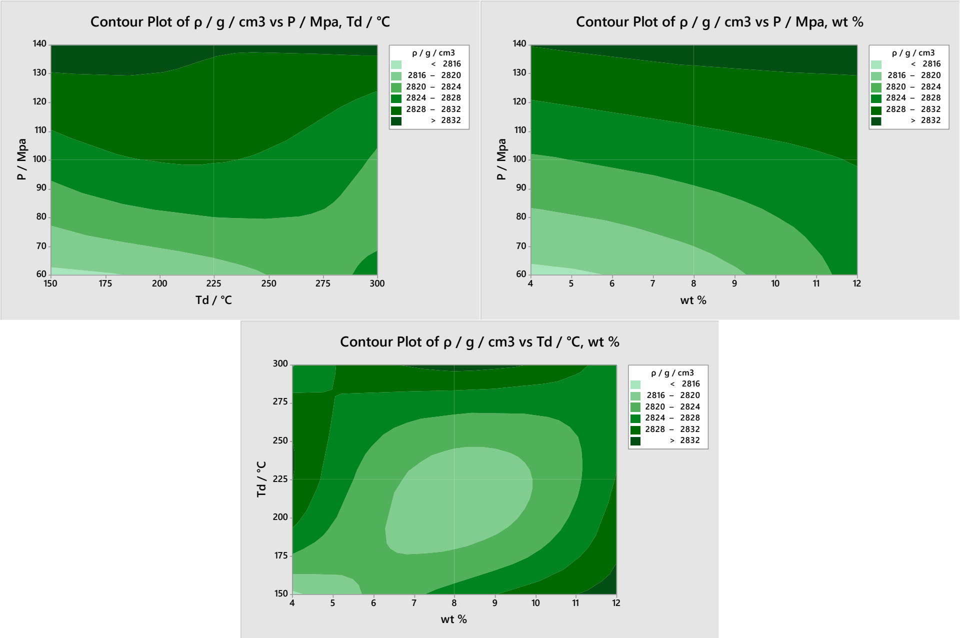


**Figure 6a,6b,6c. density plot of tensile vs P,Td,Wt%**

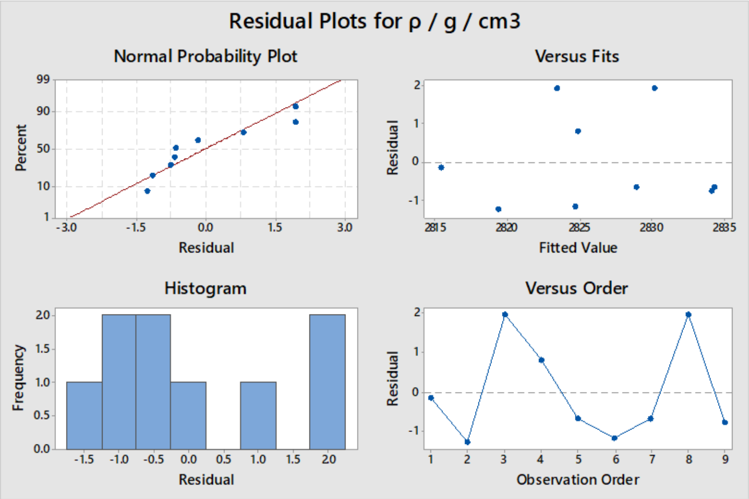


**Figure 7. Residual plots**

For in this experiment, we determined that increasing the squeeze pressure from 60 Mpa to 140 Mpa increases the density of the composite. When the die temperature is taken into account, the density of the composite increases from 150oC to 300oC. They discovered that increasing the weight percentage of SiC from 4% to 12% increased the density of the composite. Figure 7 shows the optimal composite density value. For the modelling equation of average t density of composite, the square value of correlation coefficient (R) is S(1.58688), R2 (96.31 percent), and adj R2 (94.10 percent), indicating a high significance of the model. The correlations between the factors P, Td, and wt percent obtained through multiple linear regression are shown in equation 3 below. The S/N ratio with larger is better theory was chosen to analyse the rank of process parameters influence for this experiment, which was finalised as Squeeze pressure, weight percentage, followed by die temperature contribution, as shown in table-9. In table 8, the ANOVA table shows that the maximum squeeze pressure contributes approximately 80.25 percent of the change in tensile strength when compared to the weight percentage (13.18 percent) and die temperature. The optimal process parameters for required composite density are Squeeze pressure 140 Mpa, Die temperature 300 oC, and Sic weight percentage 12 percent. Casting density should be considered a quality characteristic because it is directly related to internal casting defects such as porosity, shrinkage, and micro-voids.

**Table-8 Analysis of Variance**

| **Source** | **DF** | **Adj SS** | **Adj MS** | **F-Value** | **P-Value** | **%contribution** |
|---|---|---|---|---|---|---|
| **Regression** | 3 | 328.572 | 109.524 | 43.49 | 0.001 | |
| **P / Mpa** | 1 | 273.780 | 273.780 | 108.72 | 0.000 | 80.25 |
| **Td / °C** | 1 | 9.856 | 9.856 | 3.91 | 0.105 | 2.89 |
| **wt %** | 1 | 44.936 | 44.936 | 17.84 | 0.008 | 13.18 |
| **Error** | 5 | 12.591 | 2.518 | | | 3.68 |
| **Total** | 8 | 341.163 | | | | |

Model Summary

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| 1.58688 | 96.31% | 94.10% | 84.94% |

Regression Equation

ρ / g / cm3 = 2799.96 + 0.1689 P / Mpa + 0.01709 Td / °C + 0.684 wt %.... ……………..**equ-3**

**Table-9 Response Table for Signal to Noise Ratios(Larger is better)**

| **Level** | **P / Mpa** | **Td / °C** | **wt %** |
|---|---|---|---|
| **1** | 69.00 | 69.02 | 69.02 |
| **2** | 69.02 | 69.02 | 69.02 |
| **3** | 69.05 | 69.03 | 69.03 |
| **Delta** | 0.04 | 0.01 | 0.02 |
| **Rank** | 1 | 3 | 2 |

## 4.CONCLUSION

Squeeze casting techniques were used to successfully fabricate LM13 aluminium alloy squeeze castings with varying levels of squeeze pressure, die preheating temperature, and weight percentage of (Sic). The following conclusions were reached.

- The hardness and tensile strength of (LM13-SiC) composites increased as the squeeze pressure and reinforcement weight percentage increased. These refinements may be responsible for the strong matrix/reinforcement, grain refinement, and porosity reduction obtained by squeezing.

- In the density analysis, the weight percentage of SiC particles (4 percent to 12 percent) increased as the squeeze pressure increased, as did the density of the composites. In squeeze casting, the porosity of the composites was significantly reduced.
- The ANOVA was used to investigate the effect of process parameters on the hardness, tensile strength, and density of the LM13-SiC alloy, as squeeze pressure has the greatest influence on the properties, followed by SiC weight percentage and die temperature.

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