# Influence of vibrations on mechanical properties of LM-25 alloy in Gravity Die Casting.

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***Abstract:*** AlSi7Mg an ISO standardized aluminium alloy commonly known as LM25 is widely used in Electrical, Marine, Transport, Chemical and Food Industries. It is Suitable where thermal properties and good corrosion resistance are required. Gravity die casting process is the most common and widely used permanent mould die casting process commonly used in industries for nonferrous alloys. Due to the wide and common use of AlSi7Mg aluminium alloy there is a need of improving Mechanical properties, Microstructure and internal defects of the casted product. In this experiment we are going to give influence of mechanical vibration on AlSi7Mg alloy by using gravity die casting method with different parameter like varying of frequency (Hz), Time (sec) as well as different Die preheating temperature (°C). At the end of the experiment it will provide the change in Mechanical properties due to mechanical vibration.

***IndexTerms* - Gravity Die Casting, Mechanical Vibration, LM 25.**

## I. INTRODUCTION

Permanent moulds are designed such that mould can be reused again and can be removed easily. The moulds are made up of metals as they are good conductor of heat as compared to expandable moulds, they also maintain high strength at high temperature. It is also called as Gravity Die Casting. In gravity die casting process gravitational force is used to pour the molten material into the Die.

**The three important stages in Gravity die casting are**:

1. The mould or Die is heated and coated with die coating material. The function of die coating material is to act as a non-sticky medium between Die and product after solidification. Its secondary function is to cool the mould face after previous product is removed from the Die.
2. Molten material is poured into the cavity by using steel ladles such that it fills all the cavities of the section. The design of gating system is done in such a way that it avoids the formation of turbulence and other casting defects.
3. After the solidification of product the die is opened manually or by any mechanical means.

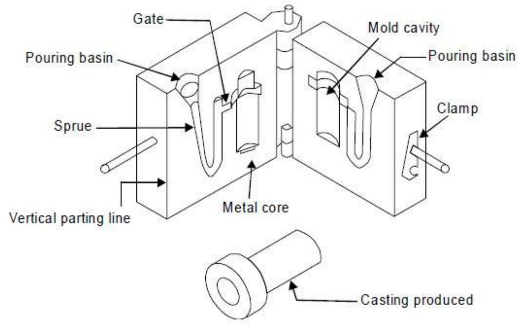


Fig 1.1: Gravity Die Casting

## II. LITERATURE REVIEW

Various works done on gravity die casting with influence of mechanical vibration are given below.

P. Sujith Kumar et al. [4] investigated that the effect of vibration with low frequency (15 Hz, 1 mm amplitude) on solidifying alloy found better in air cooling as compared to furnace cooling. Due to the influence of Vibration reduction in porosity was also observed in gravity die casting. Naoki Omura et al. [6] observation showed that grain size of rod decreased due to influence of vibration from 1800 μm (0 Hz) to 750 μm (100 Hz). The internal defect decreased with frequency of vibration below 70 Hz but internal defect increases if the frequency is more than 80 Hz. Finally the specimen cast at the vibration frequency of 70 Hz showed higher Ultimate Tensile Strength as compared to other frequencies. Rahul Kumar et al. [10] showed that with the increase in vibration frequencies grain refinement and hardness increases. It was also found that the use of grain refinement chemical additives can also be avoided. Premvat Kumar et al. [12] study result showed due to mechanical vibration there was decrease in porosity, hot tearing and solidification time. There was increase in tensile strength and ductility of alloy. The dendrite coherency point also shift towards lower temperature. Hence there was improvement in mechanical and metallurgical properties of alloy with the influence of mechanical vibration.

## III. EXPERIMENTAL SETUP

Die casting material was taken according to the standard (BS 1490:1988 and IS 617:1994). Material supplied as standard 7 kg aluminium ingots.

3.1 Vibration setup design.

The Vibration setup shows that the mould is fitted in the centre with two horizontal plates mounted with the help of C-clamps. The Vibration of mould is done with different frequency and fix amplitude during the solidification of LM 25 aluminium alloy. The speed of motor is directly changed by variable frequency drive connected with motor.

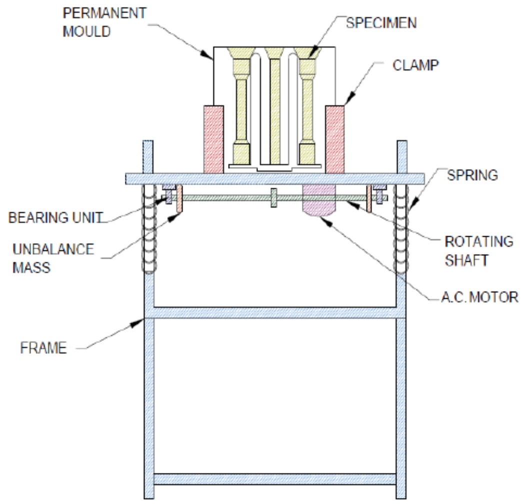


Fig 3.1 Experimental Setup

3.2 Components of Vibration Setup.

- Vibrating Tray.
- Frame.
- Spring.
- Unbalanced Mass.
- PMDC Motor.

## IV. PARAMETERS SELECTION

4.1 Cause and Effect Diagram.

Cause and effect diagram were developed by Kaoru Ishikawa in 1943 and thus are called Ishikawa Diagrams. They are also known as fishbone diagrams because of their appearance. An Ishikawa diagram (Fish Bone Diagram or Cause and Effect diagram) was plotted to identify the process parameters that influence the Gravity Die casting defects. The Process parameters are listed below:

1. Method related parameters.
2. Material related parameters.
3. Machine related parameters.
4. Man (Personnel) related parameters.

To visualize the effect of process parameters in Gravity Die casting defects following process parameters were selected.

- Vibration Frequency (Hz).
- Vibration Time (Sec).
- Die Preheating Temperature ($^{o}$C).

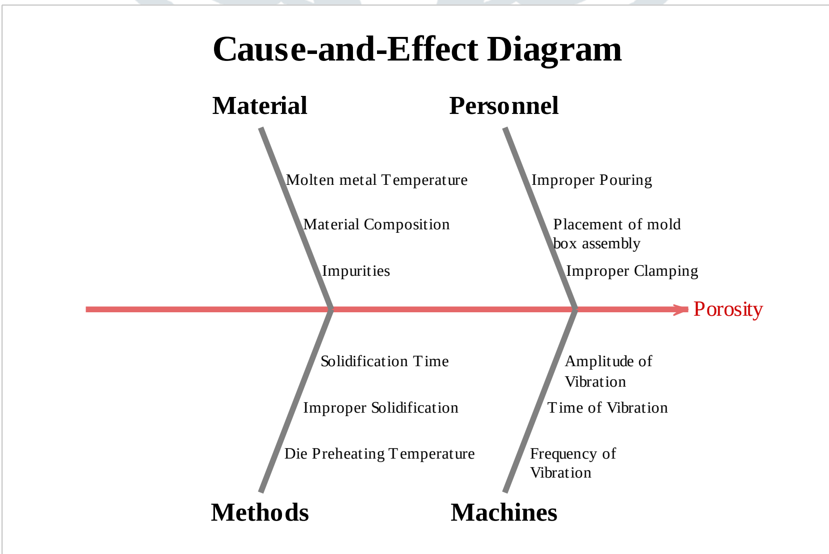


Fig 4.1 Cause and Effect Diagram.

Table 4.1 Experimental parameters

| Parameters | Units | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|---|
| Frequency of Vibration [6] | Hz | 15 | 30 | 45 | 60 | 75 |
| Time of Vibration | Sec | 10 | 20 | 30 | 40 | 50 |
| Die Pre-heating Temperature | °C | 250 | 260 | 270 | 280 | 290 |

## V. DESIGN OF EXPERIMENT

5.1 Taguchi Method in Quality Engineering

The term quality engineering encompasses a broad range of engineering and operational activities whose aim is to ensure that a product's quality characteristics are at their nominal or target values. Implementation of good quality engineering is strongly dependent on management support and direction. The field of quality engineering owes much to G.Taguchi, who has had an important influence on its development, especially in design area both product design and process design.

Some important points in relation to the above are:

- Off-line and On-line control
- Robust Design
- Loss function

5.2 Taguchi DOE Steps

Step-1: Identify The Main Function, Side Effects, And Failure Mode
Step-2: Identify The *Noise* Factors, Testing Conditions, And Quality Characteristics
Step-3: Identify The Objective Function To Be Optimized
Step-4: Identify The Control Factors And Their Levels
Step-5: Select The Orthogonal Array Matrix Experiment
Step-6: Conduct The Matrix Experiment
Step-7: Analyze The Data, Predict The Optimum Levels And Performance
Step-8: Perform The Verification Experiment And Plan The Future Action.

As we have three parameters and 5 levels we are selecting L25 orthogonal array.

Table 4.2 Experimental Parameters obtained from Taguchi L-25 orthogonal array and its results.

| Run | Frequency (Hz) | Time (sec) | Die Preheat Temperature (°C) | UTS (MPa) | Hardness (BHN) |
|---|---|---|---|---|---|
| 1 | 15 | 10 | 250 | 161.4 | 52.00 |
| 2 | 15 | 20 | 260 | 114.1 | 52.00 |
| 3 | 15 | 30 | 270 | 131.1 | 50.00 |
| 4 | 15 | 40 | 280 | 148.6 | 52.00 |
| 5 | 15 | 50 | 290 | 110.5 | 50.00 |
| 6 | 30 | 10 | 260 | 148 | 52.00 |
| 7 | 30 | 20 | 270 | 144.5 | 51.00 |
| 8 | 30 | 30 | 280 | 138.5 | 49.00 |
| 9 | 30 | 40 | 290 | 131.4 | 51.00 |
| 10 | 30 | 50 | 250 | 110.1 | 50.00 |
| 11 | 45 | 10 | 270 | 101.5 | 50.00 |
| 12 | 45 | 20 | 280 | 89 | 52.00 |
| 13 | 45 | 30 | 290 | 113.06 | 49.00 |
| 14 | 45 | 40 | 250 | 137.2 | 49.00 |
| 15 | 45 | 50 | 260 | 99 | 50.00 |
| 16 | 60 | 10 | 280 | 127 | 52.66 |
| 17 | 60 | 20 | 290 | 132.7 | 51.00 |
| 18 | 60 | 30 | 250 | 124.1 | 51.00 |
| 19 | 60 | 40 | 260 | 141.1 | 48.60 |
| 20 | 60 | 50 | 270 | 116.8 | 49.00 |
| 21 | 75 | 10 | 290 | 108.9 | 50.93 |
| 22 | 75 | 20 | 250 | 113.1 | 53.00 |
| 25 | 75 | 30 | 260 | 101.5 | 48.80 |
| 24 | 75 | 40 | 270 | 128.1 | 50.00 |
| 25 | 75 | 50 | 280 | 70.4 | 49.00 |

## VI. ANALYSIS OF VARIANCE (ANOVA)

ANOVA is a computational technique that helps to estimate the relative contributions of each control factor. It uses a mathematical technique known as the sum of squares to quantitatively examine the deviation of the control factor response average from the overall experimental mean response, which is referred to as the variation between the control factors. ANOVA provides insight into the main effects, as well as interaction effects of factors.

ANOVA table consists of number of columns; they are: sources or parameters of the experiment, degree of freedom, sum of squares (SS), mean square (MS), Fisher test value (F ratio), and P value.

In the analysis of variance, different terms are calculated such as the degree of freedom, the sum of the square, the average of the square.

- C.F. = Correction Factor
- n = Number Of Trials
- e = Error
- P = Percentage Contribution
- F = Variance Ratio
- T = Total Of Results
- f = Degree of freedom
- S = Sum Of Squares
- fe = Degree Of Freedom Of Error
- fT = Total Degree Of Freedom
- V = Mean Squares (Variance)

6.1 Analysis of Variance for Ultimate Tensile Test (UTS)

Fig shows that the relation of Frequency, Time and Die Preheating temperature against UTS. The results of ANOVA suggest the optimal combination of casting parameters levels which give the highest value of UTS

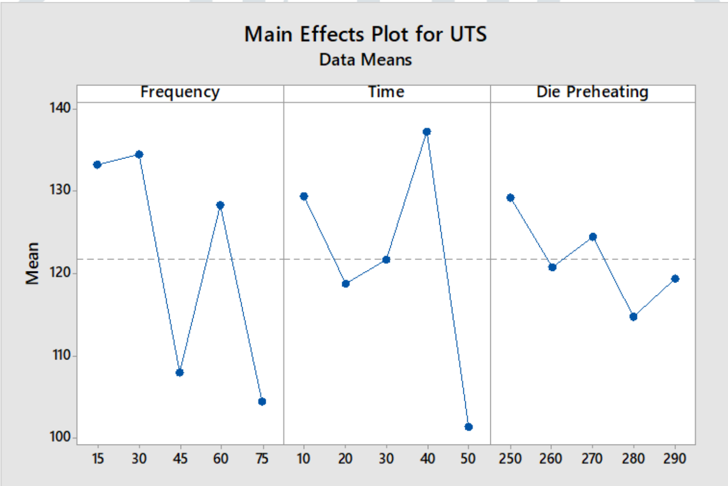


Fig 6.1 Main Effect Plots for UTS.

Table 6.1 ANOVA Table for UTS

| Source | DOF | Sum of Squares (SS) | Mean of Squares (MS) | F- Value | P-Value |
|---|---|---|---|---|---|
| **Frequency (Hz)** | 4 | 4135.5 | 1033.9 | 5.84 | 0.008 |
| **Time (sec)** | 4 | 3621.2 | 905.3 | 5.11 | 0.012 |
| **Die Preheating (°C)** | 4 | 594.3 | 148.6 | 0.84 | 0.526 |
| **Error** | 12 | 2123.9 | 177.0 | | |
| **Total** | 24 | 10477.9 | | | |

Table 6.2 Model Summary for UTS

| S | R-sq | R-sq(adj) | R-sq (pred) |
|---|---|---|---|
| 13.3038 | 79.72% | 59.45% | 12.00% |

6.2 Analysis of Variance for Hardness

Fig shows that the relation of Frequency, Time and Die Preheating temperature against hardness. The results of ANOVA suggest the optimal combination of casting parameters levels which give the highest value of hardness.

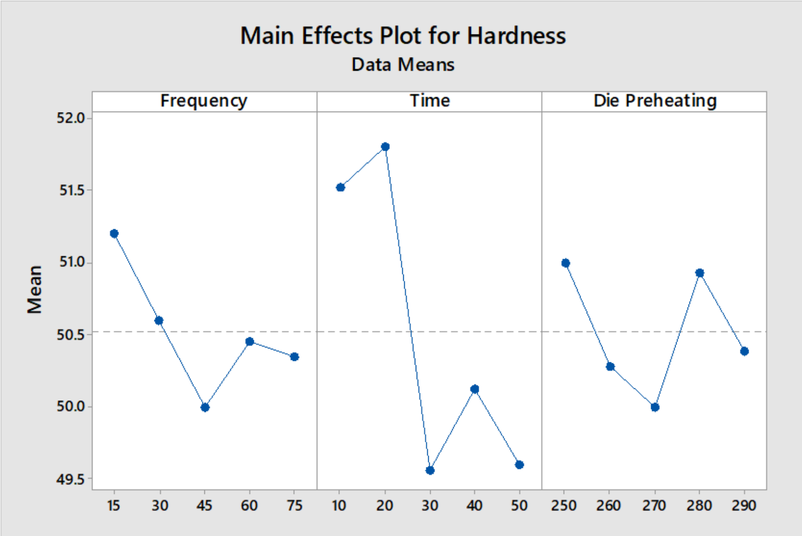


Fig 6.2 Main Effect Plots for Hardness

Table 6.3 ANOVA Table for Hardness

| Source | DOF | Sum of Squares (SS) | Mean of Squares (MS) | F- Value | P-Value |
|---|---|---|---|---|---|
| Frequency (Hz) | 4 | 3.870 | 0.9676 | 0.95 | 0.467 |
| Time (sec) | 4 | 22.812 | 5.7030 | 5.62 | 0.009 |
| Die Preheating (°C) | 4 | 3.730 | 0.9326 | 0.92 | 0.484 |
| Error | 12 | 12.178 | 1.0148 | | |
| Total | 24 | 42.591 | | | |

Table 6.3 Model Summary for Hardness

| S | R-sq | R-sq(adj) | R-sq (pred) |
|---|---|---|---|
| 1.00738 | 71.41% | 42.81% | 0.00% |

## VII. Regression Analysis.

7.1 Regression analysis for UTS.

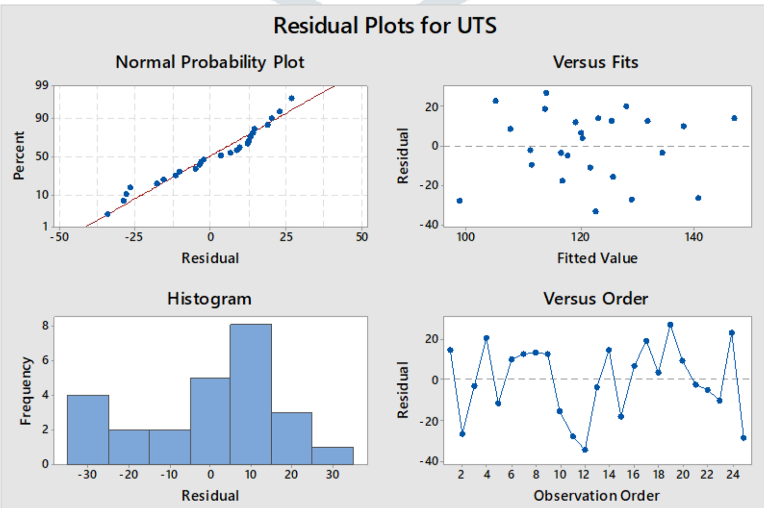


Fig 7.1 Regression analysis for UTS.

From the above graphs of residual plots for UTS we can say that residuals follow an approximate straight line in normal probability plot, approximate symmetric nature in Histogram plot indicates that residuals are normally distributed. The Histogram describes that the mean and median are close. Residuals are randomly scattered around zero variance so they possess constant variance and are plotted like mirror effect. Since residuals exhibit no clear pattern so there is no error due to data and time collection.

7.2 Regression analysis for Hardness.

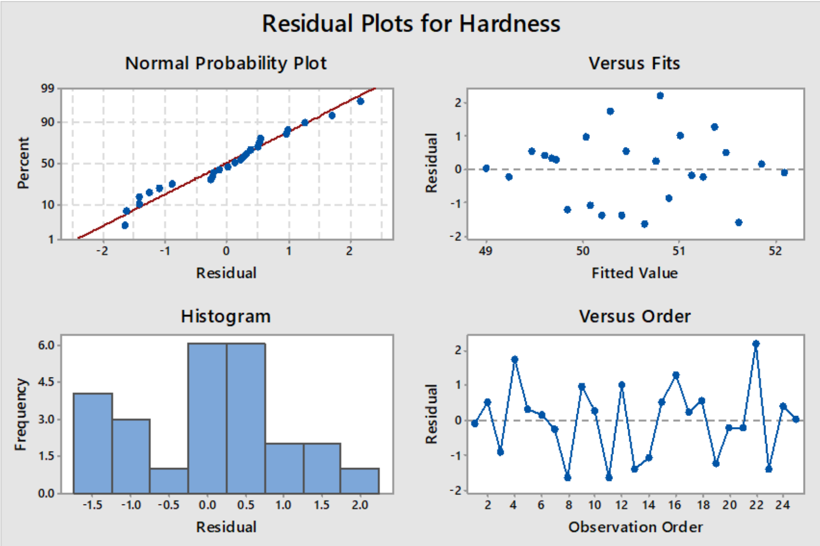


Fig 7.2 Regression analysis for Hardness.

As we can see in above graph the data falls around a straight line which indicates that the values are within control range. By diagnostic checking of residuals we can say that they fall in straight line which says that errors are distributed normally. As there is no obvious pattern and unusual structure the concluded values are within control range.

## VIII. Experiment Validation.

For Validation of experiment we have to take two values within the levels of input parameters from the range of previous experimental levels. Put the values in regression equation given above to obtain response parameters. Now we have to perform experiment by taking this levels of input parameters to get new cast specimen. Now measure the UTS and Hardness of new cast specimen. Compare this experimental result with mathematical results.

Table 8.1 Comparison table for observation of UTS

| Run | Frequency (Hz) | Time (sec) | Die preheating temp ($^oC$) | UTS (Mpa) | | Deviation % |
|---|---|---|---|---|---|---|
| | | | | Experiment Result | Mathematical Result | |
| 1 | 17 | 28 | 264 | 144 | 135.808 | 5.68 |
| 2 | 42 | 28 | 279 | 115 | 121.338 | 5.22 |
| 3 | 17 | 28 | 279 | 139 | 131.938 | 5.08 |
| 4 | 42 | 15 | 264 | 140 | 130.07 | 7.09 |
| 5 | 42 | 28 | 264 | 117 | 125.208 | 6.55 |
| 6 | 17 | 15 | 279 | 128 | 136.8 | 6.43 |
| 7 | 42 | 15 | 279 | 120 | 126.2 | 4.91 |
| 8 | 17 | 15 | 264 | 148 | 140.67 | 4.95 |
| Average Deviation | | | | | | 5.73 |

Table 8.2 Comparison table for observation of Hardness

| Run | Frequency (Hz) | Time (sec) | Die preheating temp ($^oC$) | Hardness (BHN) | | Deviation % |
|---|---|---|---|---|---|---|
| | | | | Experiment Result | Mathematical Result | |
| 1 | 17 | 28 | 264 | 54 | 51.00 | 5.55 |
| 2 | 42 | 28 | 279 | 47 | 50.61 | 7.12 |
| 3 | 17 | 28 | 279 | 53 | 50.92 | 3.93 |
| 4 | 42 | 15 | 264 | 48 | 51.41 | 6.63 |
| 5 | 42 | 28 | 264 | 47 | 50.69 | 7.28 |
| 6 | 17 | 15 | 279 | 55 | 51.63 | 6.12 |
| 7 | 42 | 15 | 279 | 49 | 51.32 | 4.53 |
| 8 | 17 | 15 | 264 | 55 | 51.72 | 5.96 |
| Average Deviation | | | | | | 5.89 |

- Comparing the Mathematical (Statistical) and Experimental Result we found that the Average deviation of UTS is 5.73 % was observed in the validation experiment of UTS for cast specimen.
- Comparing the Mathematical (Statistical) and Experimental Result we found that the Average deviation of Hardness is 5.89 % was observed in the validation experiment of Hardness for cast specimen.

- This Deviation arise due to the influence of other gravity die casting parameter or because of Environmental conditions.

## IX. Conclusion.

Mechanical vibration was induced during solidification of AlSi7Mg alloy in gravity die casting, due to which we have concluded following things.

- According to the selected input Parameters and Range (Levels) we can say that if we want high Ultimate tensile strength than we have to take Vibration frequency 15 Hz, Time of vibration 10 sec and Die preheating temperature 250 $^oC$. Compared to other cast specimen with and without Vibration.
- According to the selected input Parameters and Range (Levels) we can say that if we want high Hardness than we have to take Vibration frequency 75 Hz, Time of vibration 20 sec and Die preheating temperature 250 $^oC$. Compared to other cast specimen with and without Vibration.
- The Graphical representation and table using ANOVA for UTS shows that Vibration frequency and Vibration time are most significant parameters.
- The Graphical representation and table using ANOVA for Hardness shows that Vibration time is most significant parameter.
- Regression analysis was used to validate the experiment, after comparing with Experimental result and Statistical (Mathematical) result we get 5.73% and 5.89% deviation respectively for UTS and Hardness of AlSi7Mg cast specimen.

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