Statistical Analysis of the Parameters Influencing the Surface Roughness of Grain Refined and Modified Al-Si Alloys (LM25, LM6 and LM30) using ANOVA

Satya Prema
Assistant Professor, Department of Mechanical Engineering, J N N College of Engineering, Shivamogga-577204, Karnataka, India.

Chandrashekharaih T M
Professor, Research centre, Department of Mechanical Engineering, Kalpataru Institute of Technology, Tiptur - 572 202, Karnataka, India.

Abstract
Aluminium is used in all the spheres of applied engineering and manufacturing sectors. The mechanical properties of commercially available Al-si alloys can be altered to suit the technical and economic requirement of specific application with the addition of grain refiners and / or modifiers. In the present study the commercially available LM25 (hypoeutectic < 12% Si), LM6 (eutectic 12% Si) and LM30 (hypereutectic > 12% Si) Al - Si alloys are grain refined with 0.2%Al-5Ti-1B, 1%Al-3B and modified with 0.3%Al-10Sr master alloys. The surface roughness of these samples is measured and the process parameters considered for ANOVA analysis to predict the percentage contribution of the independent variables on dependent variable are Al, Si, Mix(Grain refiner), Force X, Force Y, Force Z and thrust. The ANOVA results conclude that Si and mix (grain refiner) have higher statistical significance and influence the surface roughness of these alloys.

Keywords: Al-Si, alloy, hypereutectic, eutectic, hypoeutectic, surface roughness, ANOVA.

Introduction
Commercially available hypoeutectic (Si ≤12%), eutectic (Si ≈12%) and hypereutectic (Si ≥12%) Al- Si alloys are grain refined with 0.2%Al-5Ti-1B, 1%Al-3B and modified with 0.3%Al-10Sr master alloys in this study. A total of twelve samples are tested for surface roughness. The performance of a mechanical component in terms of friction and wear rate is dependent on the surface roughness. Rough surfaces indicate higher friction and wear out early. The results are statistically analysed using ANOVA to predict the percentage contribution of the independent variable on dependent variable.

Experimental Method
The commercially available hypoeutectic LM25, eutectic LM6 and hypereutectic LM30 Al-Si alloys were heated individually in an induction furnace at 720°C and the melt was degassed with hexachloroethane. A portion of the Al-Si melt was poured into the graphite mould and the untreated specimen was cast. Next the estimated amount of Al-5Ti-1B master alloy chips were added to the alloy melts and stirred approximately for about 30sec. After holding for 5 minutes, a part of the melt was poured and the designated specimen was cast. The same procedure was repeated by adding calculated amount of Al-3B and Al-10Sr to the melt, and the specimen were designated accordingly. The size of the specimen was 25mm diameter and 100mm length. These experiments were conducted without addition of any lubricants or coolant. A total of 12 specimens were obtained as shown in Table 1.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Al-Si alloy</th>
<th>Grain refiners / Modifier</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LM-25</td>
<td>Nil (untreated)</td>
<td>Nil</td>
</tr>
<tr>
<td>2</td>
<td>LM-25</td>
<td>Al-5Ti-1B</td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>LM-25</td>
<td>Al-3B</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>LM-25</td>
<td>Al-10Sr</td>
<td>0.3</td>
</tr>
<tr>
<td>5</td>
<td>LM-6</td>
<td>Nil (untreated)</td>
<td>Nil</td>
</tr>
<tr>
<td>6</td>
<td>LM-6</td>
<td>Al-5Ti-1B</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>LM-6</td>
<td>Al-3B</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>LM-6</td>
<td>Al-10Sr</td>
<td>0.3</td>
</tr>
<tr>
<td>9</td>
<td>LM-30</td>
<td>Nil (untreated)</td>
<td>Nil</td>
</tr>
<tr>
<td>10</td>
<td>LM-30</td>
<td>Al-5Ti-1B</td>
<td>0.2</td>
</tr>
<tr>
<td>11</td>
<td>LM-30</td>
<td>Al-3B</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>LM-30</td>
<td>Al-10Sr</td>
<td>0.3</td>
</tr>
</tbody>
</table>

The surface roughness was measured perpendicular to the turning direction, at three locations around work piece circumference. The turned surfaces of the samples were tested for surface roughness and $R_a$, $R_z$ and $R_q$ values of surface measurement were noted. The lathe machine having 112-1800 rpm of spindle speed and 1 H.P motor was used and values in X, Y & Z directions in KN v/s samples of untreated and treated LM-25, LM-6 and LM-30 alloy samples are observed by giving a constant feed and speed N= 770rpm, depth of cut was 2 mm with 5° rake angle. Similarly the drill tool dynamometer readings were noted for thrust and torque.

Discussion on Microstructure
The research of more than two decades in the field of grain refinement and modification has established the fact that there is an improvement in the mechanical and tribological properties of $Al – Si$ alloys due to change in microstructure.
And this results in products which are cost effective and have better quality. The electron magnifying instrument used to obtain SEM micrographs is Energy Dispersive X-Ray Spectroscopy (EDS) (Model- FEI Quanta-200, scanning electron microscope, NE Dawson Creek Drive, Hillsboro, USA). The micrographs of untreated and treated samples of LM-25, LM-6 and LM-30 are shown in Fig.1 to Fig.3 respectively.

The microstructure of the untreated samples has coarse grain structure. With the addition of the grain refiners and modifier it is observed that the treated samples have smoother grains.

**Results**

The $R_a$, $R_z$ and $R_q$ values of surface measurement of untreated and treated samples for LM-25, LM-6 and LM-30 are plotted in Fig.4 to Fig.6 respectively.
As the $R_a$ values of LM-25 show that the surface finish improves by 45.7% when LM-25 is grain refined with 0.3wt% (Al-10Sr), hence addition of 0.3wt%(Al-10Sr) to LM-25 increases surface finish.

**Statistical Analysis**
ANOVA analysis establishes the significant factors which influence the dependent variable. The process parameters selected for performing ANOVA for surface roughness are Al, Si, Mix(Grain refiner), Force X, Force y, Force Z, torque and thrust.

Table 2 depicts the ANOVA analysis of surface roughness for all the samples. Si and mix (grain refiner) are the parameters with maximum influence with a $F$ ratio of 0.37 and 0.27 respectively with high statistical significance.

**Figure 7**: Percentage contribution of Surface Roughness
As per Fig.7 Si has 26% and Mix has 13% contribution and the remaining parameters have least effect.
Multiple linear regression model of Surface Roughness

\[
\text{Surface Roughness} = 10.1 - 0.106 \text{ Al} - 0.172 \text{ Si} + 0.314 \text{ Mix} - 0.0015 \text{ Force X} - 0.0017 \text{ Force Y} + 0.052 \text{ Force Z} + 0.02171 \text{ Torque} + 0.0494 \text{Thrust}
\]  

Equation 1 shows the influence of independent variables on the dependent variable of surface roughness. Table 3 and 4 shows the coefficient of determination of 78.61% with a T-value which is more for Si and Mix (grain refiner). Table 5 shows the measured and the predicted values of the surface roughness.

A graph of predicted values against experimental values is plotted for all the samples as depicted in Fig.9. The error between the variables from the predicted equation is shown in Fig.10. It is observed that the error is less than 5% and the predicted values are close to the measured ones. Hence the predicted equation is of good predictive capability with the acceptable accuracy.
Conclusion

It is observed that there is decrease in surface roughness of LM-25 treated with 0.3wt% Al-10sr due to the modification and spheroidization of Si particles. Surface finish improves by 45.7% and 22.7% respectively with the addition of 0.3wt% Al-10Sr to hypoeutectic LM-25 alloy and the addition of 1wt% Al-3B to hypereutectic LM-30 alloy. The ANOVA analysis predicts that for surface roughness Si content and grain refiners have maximum influence compared to the other parameters.

References


