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

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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 1: Prepared sample designation

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

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.

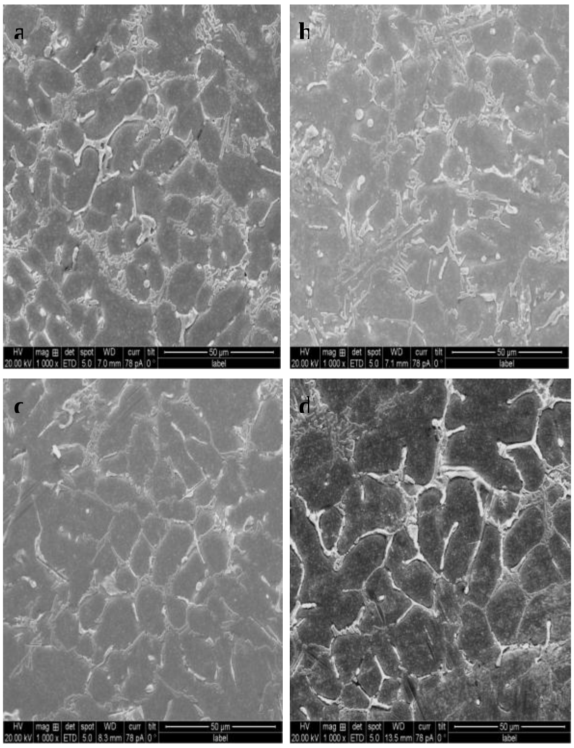

Figure 1: LM-25 samples: (a) Untreated alloy, (b) Al-5Ti-1B, (c) Al-3B & (d) Al-10Sr

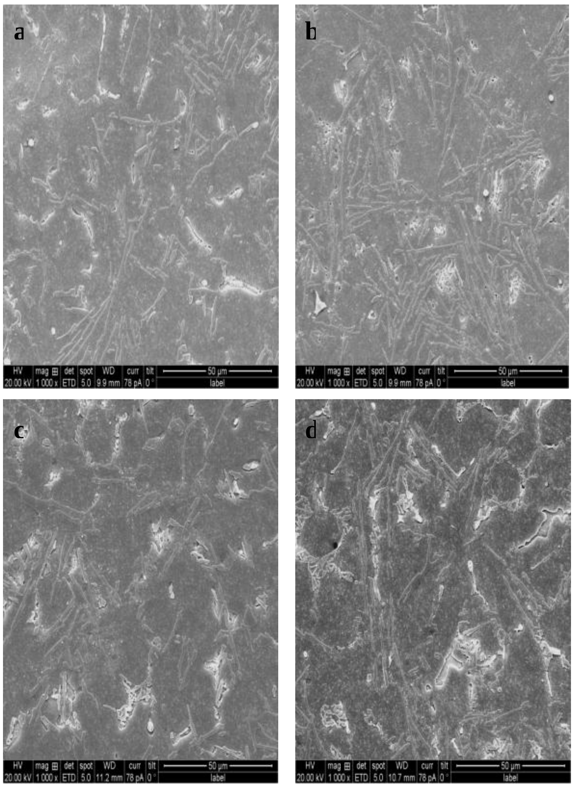

Figure 2: LM-6 samples: (a) Untreated alloy, (b) Al-5Ti-1B, (c) Al-3B & (d) Al-10Sr

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.

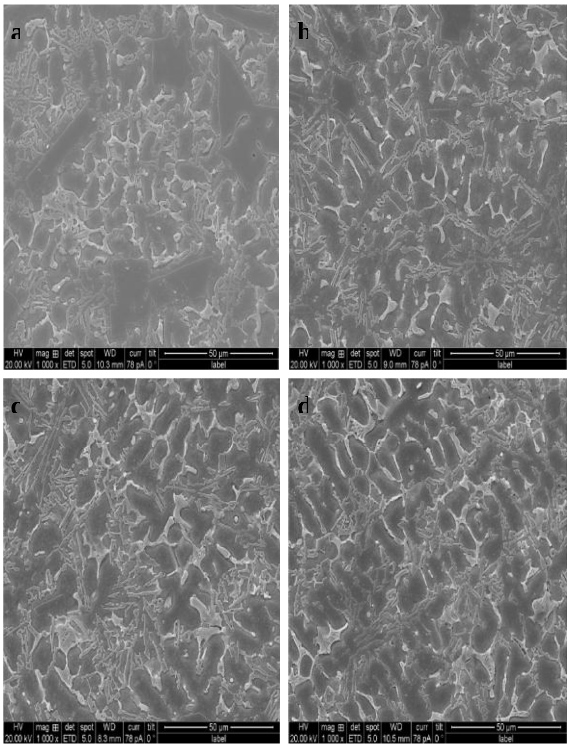

Figure 3: LM-30 samples: (a) Untreated alloy, (b) Al-5Ti-1B, (c) Al-3B & (d) Al-10Sr

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.

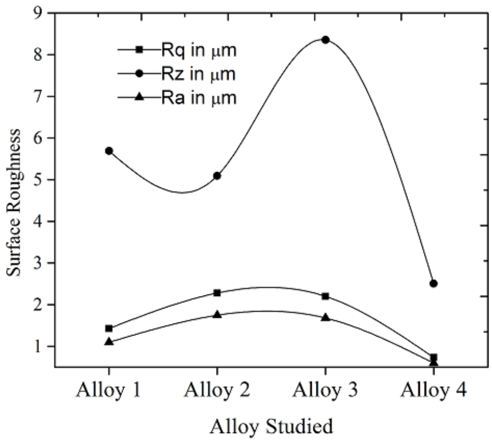

Figure 4: LM-25 Surface Roughness

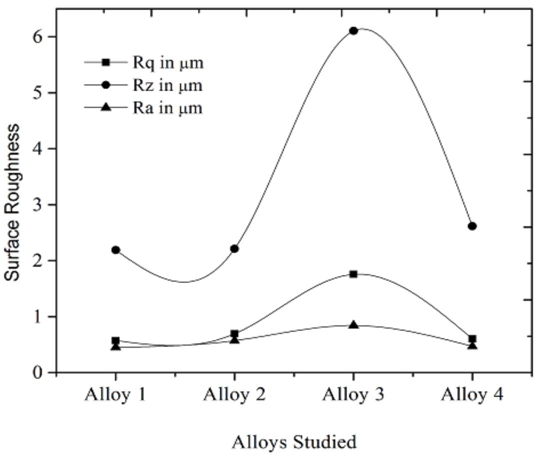

Figure 5: LM-6 Surface Roughness

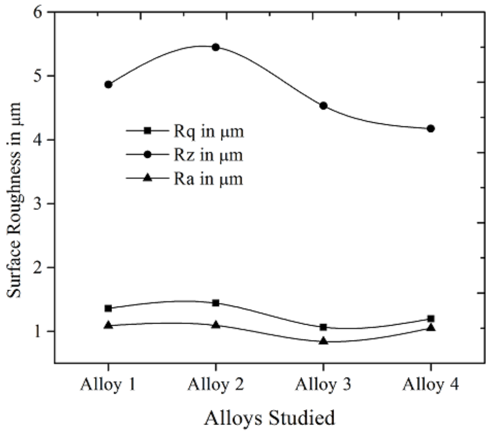

Figure 6: LM-30 Surface Roughness

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.

Table 2: ANOVA analysis of surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-value	Remarks
Regression	8	2.22113	2.22113	0.277641	0.53	0.789	Insignificant
Al	1	0.14915	0.03027	0.030271	0.06	0.825	Insignificant
Si	1	0.99100	0.03655	0.036553	0.37	0.039	Significant
Mix	1	0.49424	0.09091	0.090911	0.27	0.045	Significant
Force X	1	0.26783	0.00598	0.005980	0.01	0.922	Insignificant
Force Y	1	0.00126	0.01440	0.014403	0.03	0.879	Insignificant
Force Z	1	0.10338	0.10841	0.108408	0.06	0.680	Insignificant
Torque	1	0.01261	0.00958	0.009580	0.02	0.901	Insignificant
Thrust	1	0.20167	0.20167	0.201666	0.39	0.579	Insignificant
Error	3	1.56864	1.56864	0.522881			
Total	11	3.78977					

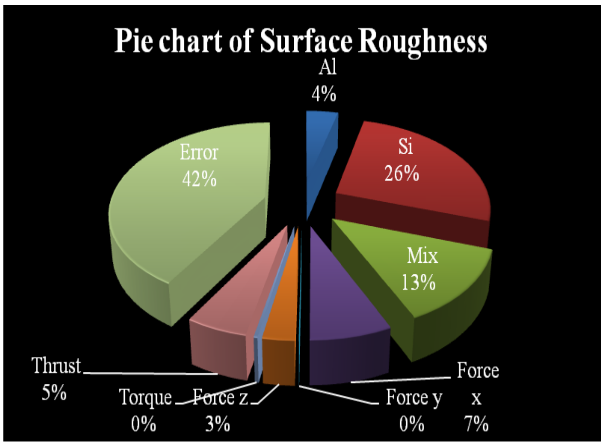

Figure 7: **P**ercentage contribution of Surface Roughness

As per Fig.7 Si has 26% and Mix has 13% contribution and the remaining parameters have least effect.

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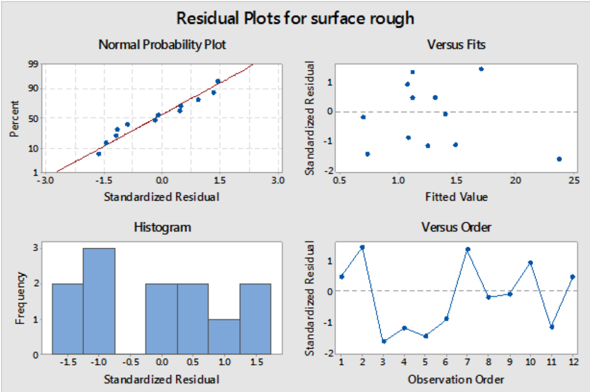

Figure 8:Residual and observation plots of Surface Roughness

Table 3: Model summary of Surface Roughness

SS	R^2	R^2 (adj)
0.723105	78.61%	75.00%

Table 4: Regression co-efficients of Surface Roughness

Terms	Coefficients	T-value	P-value
Constant	10.1	0.21	0.847
Al	-0.106	-0.24	0.825
Si	-0.172	-0.26	0.809
Mix	0.314	0.42	0.705
Force X	-0.0015	-0.11	0.922
Force Y	-0.0017	-0.17	0.879
Force Z	0.052	0.46	0.680
Torque	0.82	0.14	0.901
Thrust	0.0494	0.62	0.579

Multiple linear regression model of Surface Roughness

$$\text{Surface Roughness} = 10.1 - 0.106\,Al - 0.172\,Si + 0.314\,Mix - 0.0015\,Force\ X - 0.0017\,Force\ Y + 0.052\,Force\ Z + 0.02171\,torque + 0.0494\,Thrust \quad \text{... (Eq.1)}$$

Equation.1shows the influence of independent variables on 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.

Table 5: Measured and predicted values of Surface Roughness

Sl. No.	Measured values	Predicted values	Error
1	1.428	1.31137	0.116633
2	2.282	1.70258	0.579419
3	2.201	2.37911	-0.178110
4	0.733	1.25094	-0.517941
5	0.573	0.73055	-0.157555
6	0.693	1.08165	-0.388646
7	1.757	1.11391	0.643092
8	0.602	0.69889	-0.096892
9	1.359	1.39497	-0.035972
10	1.441	1.06936	0.371637
11	1.066	1.48359	-0.417592
12	1.197	1.11507	0.081927

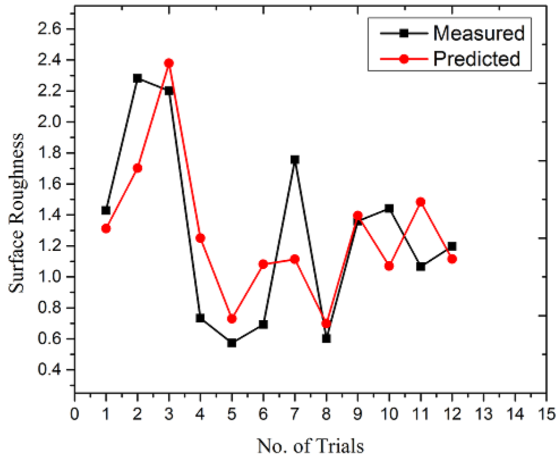

Figure 9: Measured and predicted values of Surface Roughness

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**.**

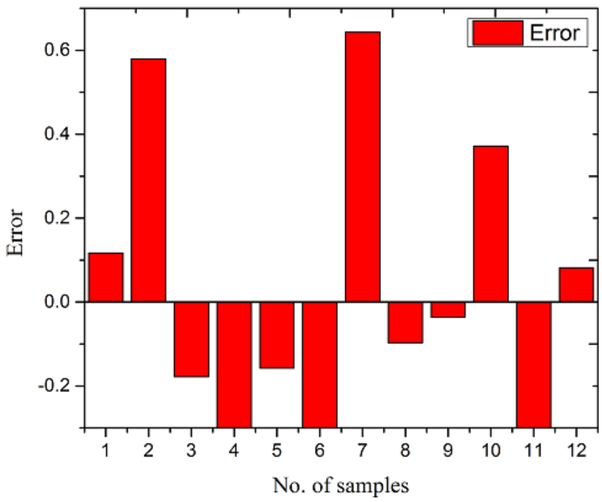

Figure 10: Error graph of Surface Roughness

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

[1] William W. Hines, Douglas C. Montgomery, David M. Goldsman and Connie M. Borror. “Probability and Statistics in Engineering”. Fourth Edition 2004. John Wiley & Sons Inc.

[2] Siddesha, H. S. (2013). Study of Cyclic Constrained Groove Pressing Factors on Hardness Behavior of Al/Sic - MMC Subjected to Severe Plastic Deformation. IOSR Journal of Engineering, 3(7), 27–35. https://doi.org/10.9790/3021-03742735

[3] Kumar, K., Ramesh, L., & Pushpa, B. (2015). Optimal Maching Parameter Using Taguchi Method On Al-Si (Lm 6), 4(6), 99–109.

[4] Panda, S. R., Senapati, A. K., & Mishra, P. C. (2017). Multi-regression prediction model for surface roughness and tool wear in turning novel aluminum alloy (LM6)/fly ash composite using response surface and central composite design methodology. International Journal of Industrial Engineering Computations, 8(1), 1–18. https://doi.org/10.5267/j.ijiec.2016.8.001

[5] Omidiji, B. V, Owolabi, H. A., Olukoga, A., & Morakinyo, T. A. (2015). Effects Of Machining Parameters On The Surface Roughness Of Al-Si Alloy Machined With Face Turning, 66–70.

[6] V.P. Patel, H.R. Prajapati , Microstructural and mechanical properties of eutectic Al - Si alloy with grain refined and modified using gravity die and sand casting, IJERA, Vol. 2, Issue 3, (2012) 147-150.

[7] Satya Prema, Shreeshail G.Y, T.M. Chandrashekharaiah, Analysis of machining parameter and surface finish of Al - Si alloys with grain refiners and / or modifier, Materials Science Forum, ISSN: 1662-9752, Vols. 830-831, (2015) 91-94

[8] Satya Prema, Murali G.E, T.M. Chandrashekharaiah, Studies of Microstructures and Mechanical Properties on Al-Si Alloy(A390) using Grain refiners and/or Modifier, International Journal of Scientific & Engineering Research, Volume 7, Issue 8, August-2016 580 ISSN 2229-5518

[9] Devappa, T.M. Chandrashekharaiah, Studies on the Effect of Minor Addition of Sr and Mg on the Microstructure and Mechanical Properties of A413 Alloy, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, IJERTV4IS060032, Vol. 4 Issue 06, June-2015

[10] Roger Lumley, Fundamentals of Aluminium Metallurgy: Production, Processing and Applications, Woodhead Publishing Series in Metals and Surface Engineering, Elsevier, 2010

[11] Bharath V., Nagaral M., Auradi V., Kori S. A., Preparation of 6061 Al- Al2O3 MMC's by Stir Casting and Evaluation of Mechanical and Wear Properties, Procedia Materials Science, 2014, 6:1658-67

[12] Yong Z. P., Jun Z., Xiuli, F., Xing A., Optimization of surface roughness based on multi-linear regression model and genetic algorithm, Advanced Materials Research, vol. 97-101, 2010, p. 3050-3054, DOI:10.4028/www.scientific.net/AMR.97- 101.3050

[13] Rana R. S., Rajesh Purohit and Das S., Reviews on the Influences of Alloying elements on the Microstructure and Mechanical Properties of Aluminium Alloys and Aluminium Alloy Composites, International Journal of Scientific and Research Publications, Vol.2, Issue 6, June 2012

[14] Angadi B. M., Chennakesava Reddy A., Auradi V., Nagathan V.V., Kori S.A., Effect of Al-5Ti-B Addition on Microstructure, Mechanical and Thermal Properties of Hypereutectic Al-20Si Alloy, International Conference on Advanced Material Technologies – 2016, 27th and 28th December 2016

[15] Somashekhara H.M., Lakshmana Swamy N., Optimizing Surface Roughness in Turning Operation using Taguchi Technique and ANOVA, International Journal of Engineering Science and Technology, Vol. 4 No.05 May 2012

[16] Satya Prema, T.M. Chandrashekharaiah, Farida Begum P., Effect of Grain Refiners and/or Modifiers on the Microstructure and Mechanical Properties of Al-Si Alloy (LM6), Materials Science Forum, ISSN: 1662-9752, Vol.969, pp 794-799 (2019)

[17] Satya Prema, T.M. Chandrashekharaiah, Farida Begum P., Study of Improvement in Mechanical Properties and Microstructure of LM25 Alloy with the Addition of Grain Refiners / Modifier, International Journal of Applied Engineering Research, ISSN:0973-4562, Vol.14, No.6, (2019) pp. 1297-1300

[18] Satya Prema, T.M. Chandrashekharaiah, Srinivasa Murthy M.K., Statistical Analysis of Ultimate Tensile Strength of Grain Refined and Modified Al-Si Alloys (LM-25, LM-6 and LM-30) Using ANOVA, International Journal of Scientific & Engineering Research, Volume 12, Issue 2, February-2021 160 ISSN 2229-5518