OPTIMIZATION OF SQUEEZE CASTING PROCESS PARAMETERS OF ALUMINIUM LM25

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Abstract

Squeeze casting has been introduced to overcome the defects that incurred during the conventional casting processes. In squeeze casting process, the high pressure applied during solidification can eliminate porosity caused by both gases & shrinkages and increased cooling rate caused by improved thermal contact between the casting and die results in the formation of fine grained structure. Aluminium alloys which has been extensively used in the variety of different application has been selected as a base matrix material in this research work. Taguchi L9 orthogonal array has been incorporated to prepare the samples. Various samples has been prepared by varying the process parameters such as melting temperature, squeeze pressure and squeeze time. The prepared samples have been tested for micro-hardness, wear properties and micrograph has been taken to analyse the wear mechanisms. Optimal parameters have been found for maximum hardness and minimum wear rate. Conformation tests have been conducted for validating the results obtained.

Keywords: Squeezecasting,Minitab,Micro-hardness test, Pin-on-Disc,Microstructure Analysis.

1. INTRODUCTION

Aluminium and its associated alloysdue to the low density, excellent mechanical and tribological properties were extensively used in variety of different applications such as automotive industries, aerospace industries, food processing industries. The fabrication of such alloys can be associated with different manufacturing method. One among the easiest and economical method was casting method.However such casted product tends to fail due to the defects which arises during casting method such as porosity, blow holes, shrinkage[1-3].

Squeeze casting has been introduced to overcome the defects that incurred during the conventional casting processes[4]. This squeeze casting could be the combination of two variety of manufacturing route which includes casting followed by forging operation[5]. The degree of soundness of the cast product obtained was mainly associated with the pressure applied after the molten metal poured into the die. The quality of the fabricated product was also depends on melting temperature, squeeze time and preheat temperature of the die[6-8].

The parameters such as melting temperature, squeeze pressure and squeeze time improves the alloy's mechanical properties and its wear behaviour[9]. However varying the squeeze pressure, melting temperature and die preheat temperature greatly influences the alloy properties that includes improved mechanical properties, refrained grain sizes and enhanced tribological behaviour. [10-13]. Various research works has been also carried out to optimize the various process parameters of the squeeze casting for different materials and its alloys[14-16].

In this research work, LM25 alloy was fabricated using the squeeze casting technique. Hardness experiment, wear analysis and microstructure of the worn surface has been studied. Optimization of the process parameters of thesqueeze casting was also carried out.

2. Material and Experimental details

2.1 Material selection

LM25 alloys offers good corrosion resistant,good fluidity and casting defects were rarely seen in this alloys. However shrinkage allowance for this alloy also very low.Ultimately LM25 offers good weldability comparing to other alloys[17]. Chemical composition of LM25 were shown in table1.

Table 1.Chemical composition of LM25

Element	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Al
Wt (%)	0.1	0.2-0.6	6.5-7.5	0.5	0.3	0.1	0.1	0.1	0.05	0.2	91.85

2.2 Design of Experiment

The parameters which generally affects the mechanical strength andtribological behaviour were applied pressure, pressure duration and pouring temperature. Increasing the squeeze pressure and pressure duration generously improves the mechanical properties considerably, but the die life and problem of punch retraction arises. However lowering the pressure and pressure duration results in entrapment of gases and reduces the mechanical strength. Improving the mechanical properties and tribological properties can be achieved mainly by controlling the process variables[18]. In this research work Taguchi design was adopted to bring the optimal condition by conducting minimum number of experiments. Process parameters and their levels shown in table 2.

Table 2. Process parameters and their levels

Process parameters	Levels		
	-1	0	1
Temperature (°C)	675	700	725
Pressure (MPa)	50	100	150
Time(minutes)	5	10	15

2.3 Taguchi method

Taguchi method involves achieving the high quality product at low cost by reducing the variation in the process through robust design of experiments. In this research work, Taguchi method was adopted to find the optimal cast product among the other cast produced.

The signal to noise ratios (S/N), which are log functions of desired output, serve as the objective functions for optimization, help in data analysis and the prediction of the optimum results. The controlling factors for this research was squeezing pressure, squeezing time and the melting temperature. Each factor tends to have three levels. According to Taguchi method, if three factors and three levels were fixed, L9 orthogonal array should have been employed for the experimentation[21].

In order to find the main factors effect on output with a small number of experimental trials, a special standard experimental design required, hence orthogonal arrays were employed.

In Taguchi parametric design, S/N ratio was adopted to help the experimenters and designers to evaluate the effect of change in design variables on the outcome of the product or process. Signal to noise (S/N)ratio was a quality indicator in the Taguchi parametric design. S/N ratio of each experimental run was calculated for hardness and wear rate using equations 1 & 2 respectively[26].

$$S/N_{\text{larger then better}} = -10\times\log\left(\frac{\sum(1/Y^2)}{n}\right) \quad (1)$$

$$S/N_{\text{smaller then better}} = -10\times\log\left(\frac{\sum(Y^2)}{n}\right) \quad (2)$$

Where,

S/N = Signal to noise ratio

Y = Response for the given factor level combination

n = number of responses in the factor level combination

2.4 Optimization software

Minitab software has been used for framing the design of experiments (DOE) and finding out the optimal results in this research work. Generally, Minitab software was user friendly and finds the optimum results accurately with the minimum elapses of time and the way in which getting confirmation results were also accurate in nature. This software helps to derive the experiments with statistical and combinational theory. Finding the most desirable factor settings for multiple responses simultaneously.

2.5 Experimental work

The LM25 alloy which was fabricated by introducing the material into the furnace and materials began to melt. When the metal was melted, the molten alloy was made to pour into the die. The piston arrangement areused to apply the pressure on the cast and made to wait for a certain period of time. After the solidification of cast, the piston was removed.The samples were fabricated by varying the process variables[19].

The cast samples thus produced were taken for mechanical properties determination, wear analysisand followed by microstructure analysis. The required dimensions of microhardness and wear analysis were produced from the cast samples. Micro hardness was determined through the indentation which was produced from the indenter using Vickers hardness test(ASTM E92–17)[20].Micro hardness testing samples shown in figure1.

Figure1.Micro hardness testing samples

Dry sliding wear behaviour of the alloy was performed using pin on disc wear test machine according to ASTM G99-95 standards. The EN32 steel having hardness of 65 HRC was used as the disc. Strain gauged friction detecting arm holds and loads the pin specimen vertically into a rotating hardened steel disc.After the specimens slides over the hardened disc for the specified time, then wear debris were collected and the samples were taken to find its weight[21,22]. The difference in weight measured before and after the test would give the wear of the specimen. Wear testing samples shown in figure 2.

Figure 2. Wear testing samples

The microstructure of the alloy has been taken in the inverted microscope. The sample has been polished with various grades of abrasive paper forobtaining the optimum microstructure from the samples. The micrograph of the worn surface of the sample has also been taken to analyse the mechanism with which the wear occurred[23-25].Morphological microstructure image analysis samples shown in figure 3.

Figure 3. Morphological microstructure image analysis sample

3. Result and Discussion

3.1Microhardness

The sample thus produced from this method would results high in compact, enhanced mechanical properties compared with the other casting techniques. The hardness of the localized region of the samples, i.e., hardness of the grain of the samples has been found in this method. The grain hardness further characterize the hardness of the entire sample and its compactness.The micro hardness value found to be maximum of about 164.8 HV from the sample produced at the condition 675˚ C, 100MPa, 10 minutes squeezing time. The micro hardness results for the various samples has been tabulated in the table 3.

Table 3.Micro hardness results

S. No	Melting temperature	Squeeze pressure	Squeeze time	Micro hardness	SNRA
	˚C	MPa	minutes	HV	
1.	675	50	5	129.8	42.2655
2.	675	100	10	164.8	44.3391
3.	675	150	15	123.1	41.8052
4.	700	50	10	112.6	41.0308
5.	700	100	15	155.2	43.8178
6.	700	150	5	128.1	42.1510
7.	725	50	15	129.8	42.2655
8.	725	100	5	139.9	42.9164
9.	725	150	10	122.3	41.7485

3.2 Wear Analysis

Wear rate primarily may producedusing the weight loss method.Wear specimen length 30 mm, diameter 10 mm then the wear test was carried out at the constant condition such as room temperature 30˚C, humidity 60-65% at a constant parameter sliding speed of 500rpm under 19.62 N applied load, sliding distance 942.47 m and track diameter 60 mm. The sample has been weighed before and after the wear test for each run.The wear test results and wear graph for the various samples has been tabulated in the table 4 and shown in the figure 4 and figure 5. The wear rate found to be minimum from the sample produced at the condition 675˚ C, 150MPa, 15 minutes squeezing time.

Figure 4. Minimum wear rate 88 µm

Figure 5.Maximum wear rate 319 µm

Table 4.Wear results

S. No	Load (kg)	Speed (rpm)	Time (min)	Initial weight (gm)	Final weight (gm)	Change in weight (gm)	Wear rate (µm)	SNRA
1	2	500	10	6.213	5.744	0.469	319	-50.0758
2	2	500	10	6.571	6.246	0.325	155	-43.8066
3	2	500	10	6.712	6.496	0.225	88	-38.8897
4	2	500	10	6.115	5.818	0.297	123	-41.7981
5	2	500	10	5.221	4.911	0.310	148	-43.4052
6	2	500	10	7.235	6.947	0.288	178	-45.0084
7	2	500	10	6.650	6.370	0.280	112	-40.9844
8	2	500	10	6.421	6.042	0.379	226	-47.0822
9	2	500	10	6.312	6.049	0.263	100	-40.0000

3.3Microstructure

The microstructure for the various samples has been taken before and after the wear analysis. The micrograph of the various samples before and after the wear test has been shown in the figure6 and figure 7. The micrograph of the sample revealedthat grains were finely arranged and closely packed. More the pressure applied, finer would be the grain size of the sample. The micrograph of the worn surface has been taken. From the micrograph of the worn surface it would be revealed that adhesive wear mechanism has been occurred in this wear test.

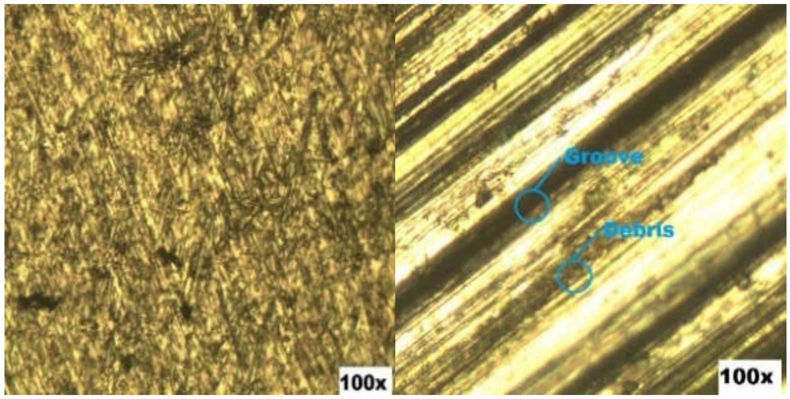

Figure 6. Microstructure of minimum wear rate samplebefore wear and after wear

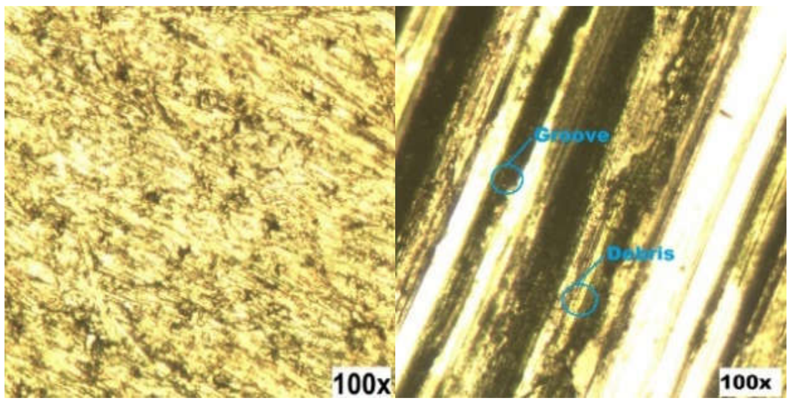

Figure 7. Microstructure of maximum wear rate samplebefore wear and after wear

3.4 Optimization of process parameter

Once the necessary data has been collected, the data has been analysed by calculating sound to noise ratio (S/N).As per the experiments conducted in this research work, two distinct S/N ratio confirmation analysis has been made. In Micro hardness test, better signal was obtained when noise is smaller, so larger S/N ratio yields better final results. On converse, better signal was obtained when noise is higher for the wear analysis, so smaller S/N ratio yields better final result. Response table for the micro hardness test and wear test has been tabulated in the table5 and table 6. The S/N ratio curve for the micro hardness and the wear test was shown in figure8 and figure9.

Table 5.Response table for signal to noise ratios for micro hardness test

Level	Melting Temperature	Squeeze Pressure	Squeeze Time
	˚C	MPa	Minutes
1	42.80	41.85	42.44
2	42.33	43.69	42.37
3	42.31	41.90	42.63
Delta	0.49	1.84	0.26
Rank	2	1	3

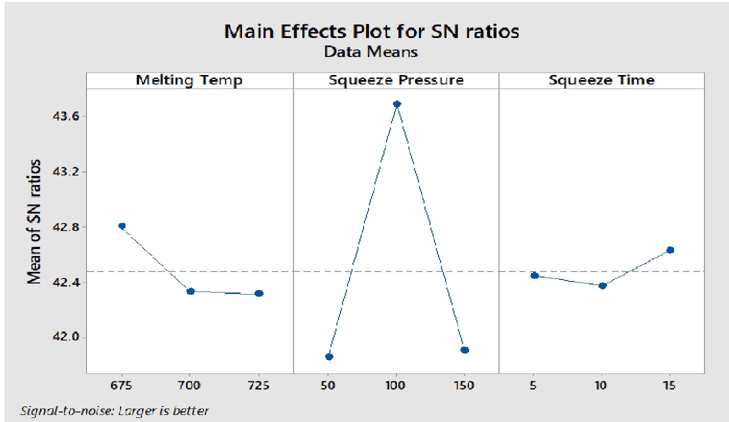

Figure 8. Optimized result of micro hardness test

The larger then better optimized process parameters are melting temperature 675˚ C, squeeze pressure 100 MPa, squeeze time 15 minutes.

Table 6. Response table for signal to noise ratios for wear test

Level	Melting Temperature	Squeeze Pressure	Squeeze Time
	˚C	MPa	Minutes
1	-44.26	-44.29	-47.39
2	-43.40	-44.76	-41.87
3	-42.69	-41.30	-41.09
Delta	1.57	3.47	6.30
Rank	3	2	1

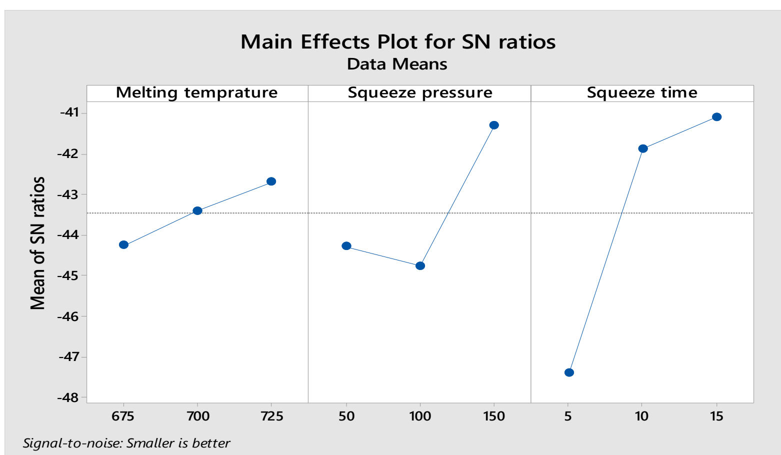

Figure 9. Optimized result of wear test

The smaller then better optimized process parameters are melting temperature 675˚ C, squeeze pressure 100 MPa, squeeze time 5 minutes.\

3.5 Confirmation results

In this research work Confirmation test for the processparameter were conducted at the optimum settings. Hence from the two separate confirmation test, it can be could conclude the parameteric setting for the maximum hardness and minimum wear rate. The optimized result for micro hardness and wear was tabulated in the table7.

Table 7. Optimized values for micro hardness and wear

S. NO	Melting temperature	Squeeze pressure	Squeeze time	Micro hardness	Wear
	˚C	MPa	Minutes	HV	µm
1.	675	100	15	187.5	99
2.	675	100	5	139.4	76

4. Conclusion

The following results were obtained in this work on squeeze casting of aluminium LM25 alloy:

- Optimized process parameters for higher hardness are melting temperature 675˚ C, squeeze pressure 100 MPa and squeeze time 15 minutes.
- Optimized process parameters for minimum wear rate are melting temperature 675˚ C, squeeze pressure 100 MPa and squeeze time 5 minutes.
- Increasing the applied pressure results is smaller grain size and improved hardness.
- Hardness of the sample increases with increasing in applied pressure resulted in elimination of gases and shrinkage occurrence when compare to stirring casting process.
- The minimum wear rate of the sample occurs at squeeze pressure of 100 MPa for 5 minutes.

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