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Parameter optimization of aluminium alloy centrifugal casting using simulation technique

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Abstract:
Centrifugal casting is a metal casting process in which molten metal is poured into a rotating mould at a specific temperature. The mould will generate a centrifugal force that will affect the outcome of the casting. The centrifugal casting method is suitable for manufacturing of hallow cylindrical part to obtain better results.This paper deals with improving the quality of aluminium alloy castingsusing Simulation Software. SOLIDWORKS FLOW simulation software is used for simulating the density of casting and visualizing outputs of the cast product.Cylindrical castings of different aluminium alloys are simulated with variable mould rotation, pouring temperature, preheating temperature and tested for defect like porosity.Taguchi design of experiments is designed and employed to optimize the centrifugal casting process parameters such as material, pouring temperature, preheat temperatures, and mould rotation, each with three different levels to obtain the minimum porosity. The optimum results obtained are found to be material = LM24, mould rotation = 1500 rpm, pouringtemperature =750°C, preheating temperature = 300 °C. It is found that metal pouring temperature is the most significant parameter affecting the quality of centrifugal casting component.
***Key Word**:Centrifugal casting,Optimization, Mould rotation, Flow simulation, Aluminium alloys.*

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I. Introduction

The centrifugal casting is a metal casting process that was developed after the turn of the 20^{th} century to meet the need for hallows section parts. In the centrifugal casting process, centrifugal force is used for getting the final shape of the casting. The centrifugal force is created where a body rotates about an axis. In this process, the mould is rotated at very high speed concerning horizontal plane and molten metal is poured into the mould. Thus, the molten metal is thrown to the surface of the cavity due to centrifugal force. Therefore, a final casting is made by solidifying it as hallow cylinder.Centrifugal casting techniques have two distinct methods, the horizontal and vertical centrifugal casting where horizontal and vertical defines the placement of axis of rotation of the mould. The horizontal centrifugal casting is used for parts which have a length of the castingis more compare to diameter,on the other hand vertical centrifugal casting is used for the parts where the diameter of casting is more compare to length. The thickness of the object is determined by the volume of liquid that is poured into the mould. Thus, the yield is above those of the gravity casting process.

The purpose of the paper is to study the effect of process parameters on the quality of aluminium casting produced by centrifugal casting process, to design the experiment using Taguchi orthogonal array and to simulate the process using SOLIDWORKS flow simulation and optimize process parameter to minimize porosity and improve quality of the casting.

II. Literature Review

[1]. P.Shailesh,S.Sundarrajan and M.Komaraiah they Fabricated (Al-Si) 4600 Aluminum alloy cylinder through the centrifugal casting process and stated that the increase in pouring temperature reduces the mechanical properties while the increase in mould speed increases mechanical properties and density. They use the Taguchi method of design of experiments was experiment was conducted to optimize the process parameters and increases mechanical properties

[2].P. G. Mukunda, ShaileshRao and ShrikanthaRao they prepare AL-2si by centrifugal casting method with various mould rotational speed, In this experiment, they investigated an optimum speed for reducing the defect in the final casting and they found a uniform cylinder at an optimum speed which is 800 rpm, at this optimum speed the mechanical properties were enhanced and wear rate was decreased.

[3]. Madhusudhan, Narendranath and G.C Mohan Kumar they prepare a set of three dies of different wall thickness and castings are obtained at three different speeds, 200 rpm, 400 rpm and 800 rpm and concluded

that as the grain size is directly proportional to the rate of solidification of the casting that is if the rate of solidification increases grain size also increases, observation on suggested that based on grain size the rate of solidification of the centrifugal casting can be determined. Grain size has been measured for the convectional castings at varying cooling rates and using this result rate of freezing of the centrifugal castings have been determined which are created at varying mould rotation speeds.

[4].Kevin Cook and Raman Reddy has created a mathematical model which states that thermal energy transfers between aluminium alloy and mould play an important role in the surface quality of cast cylinder and the uniformity of cylinder thickness and the model results also show why preheating and regular coating could not significantly improve the quality and uniform thickness of the cast cylinder.

[5].AakankshaSuryawanshi, SweenaKashyap and AlokkumarVerma they fabricated a hallow pipe through the centrifugal casting machine and then investigated the influence of process parameters on its microstructures, the grey fuzzy method is applied for optimizing the process parameters and to reduces the defects which leads to enhance the mechanical properties of the cast alloy and concluded that mechanical properties of casting were found to be enhanced for mould speed of 500 and 550 rpm.

[6]. M. A. El-Sayedthis paper focused on the effect of the mould rotational speed of the centrifugal casting process. The hollow casting was fabricated through the horizontal centrifugal casting process. From this experiment, author concluded that uniform cylindrical casting is obtained at a speed of 1300 rpm and metal disturbs its position at speed below and above the observed speed. 1300 rpm is also known as optimized speed because at this speed the mechanical properties of casting were found to be enhanced which was mainly because of the flow of molten metal inside the mould.

III. MATERIAL AND METHODS

As the properties of aluminium-silicon alloys have been used for Centrifugal casting. It is seen that an increase of the (SI) silicon content of the aluminium-silicon cast alloy causes a decrease of casting density. The chemical composition of the aluminium alloys is given in Table 1. The mould of centrifugal castings is in the form of a cylinder with two lidscovering both the end(approximately inner diameter of 127 mm and length 356.90 mm with a thickness of 12.7mm) using three different mould rotation speeds 500, 1000 and 1500 rpm, three pouring temperature 690, 720 and 750 °C and three preheating temperature 200, 300 and 400 °C. As in this case taking nine combinations of the simulation input parameter and check the defect like porosity in casting.The current simulation investigation deals with the analysis of the density.

Table no 1: Alloy Composition

Alloy	Cu	Mg	Si	Fe	Ni	Al
LM6	0.1	0.1	10-13	0.6 max.	0.1	Remainder
LM24	3.4-4.0	0.3 max	7.5-9.5	1.2 max	0.5 max	Remainder
LM25	0.2	0.2-6	6.5-7.5	0.5 max	0.3	Remainder

II. Methodology

The objective of this paper is on optimizing the process parameter of centrifugal casting including optimum levels. The Taguchi DoE method can be applied by using nine experiment/simulation.

The procedure for DoE is as follows:

1. Identification of response parameter.
2. Identification of process parameter which affects thecentrifugal casting process.
3. Determination of accurate level for the specified parameter.
4. Selecting the right orthogonal array.
5. Achieving simulation test according to the orthogonal array table.
6. Analyzing the results and selecting the optimal process parameter.

Among the all centrifugal casting parameter, material, pouring temperature, mouldrotation, pre-heating temperature are considered as four effective operational parameters which may affect the porosity during thecentrifugal casting process.Three different levels and four parameters were considered for the centrifugal casting process according to table 2.

Table no 2: Process parameters

Description	Units	Level 1	Level 2	Level 3
Material	Alloy	LM6	LM24	LM25
Mould rotation	RPM	500	1000	1500
Pouring temperature	°C	690	720	750
Preheating temperature	°C	200	300	400

Underthe full factorial method, the number of simulation/experiment to be performed was 3^4=81; usingTaguchi L9 (3^4) the number of simulation/experiment was reduce to nine. These nine experiments to conduct is shown in table 3.

To determine theinfluence of process parameters on aresponse, the signal to noise ratio has to be calculated for nine simulation/experiment. Taguchi method defines three categories of quality characteristics: smaller is better, nominal is best and lager is better. For the present study porosity is selected as a response, comes under the category of smaller is better quality characteristics. The objective function is to be minimized by using a signal to noise ratio as given in equation (1).

$$\eta = -10 \log \frac{1}{n} \sum_{i=1}^{n} y_i^2 \qquad \text{………………................} \quad (1)$$

Where n is the number of trails and y is the selected response.

Table no 3: Orthogonal Array L9 (3^4) with response

Run	Material	Mould rotation	Pouring temperature	Preheating temperature	Response	Signal to noise ratio
1	1	1	1	1	Y_1	S/N (1)
2	1	2	2	2	Y_2	S/N (2)
3	1	3	3	3	Y_3	S/N (3)
4	2	1	2	3	Y_4	S/N (4)
5	2	2	3	1	Y_5	S/N (5)
6	2	3	1	2	Y_6	S/N (6)
7	3	1	3	2	Y_7	S/N (7)
8	3	2	1	3	Y_8	S/N (8)
9	3	3	2	1	Y_9	S/N (9)

Flow Simulation

Solid works flow simulation is a multipurpose fluidflow andthermal transfer simulation tool build with solid works 3D CAD. It allows true engineering simulation and brings the important impact of fluid flow analysis.

The main input to a flow simulation program is the solid worksCAD model of themould cavitywith aninner diameter of 127 mm and length of 356.90mm, but it has to be modified by adding lids so that the metal is being prevented from spillage. Other inputs to the program include process parameter (the type of material, mould rotation, pouring temperature, preheating temperature). The main output of the simulation program includes visualization of the density of the fluid, thus the simulation shows density distribution inside the mould, which is used for calculating percentage porosity based on a mathematical formula.

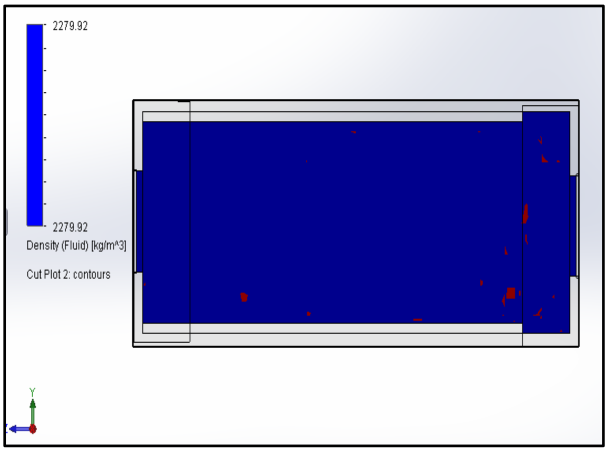

Figure 3a. Density distribution at run 1

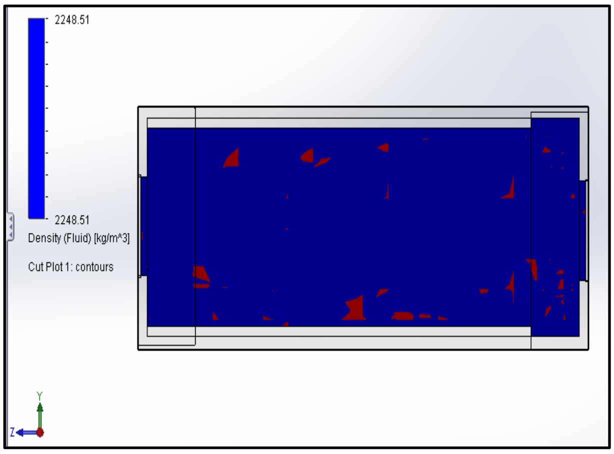

Figure 3b. Density distribution at run 2

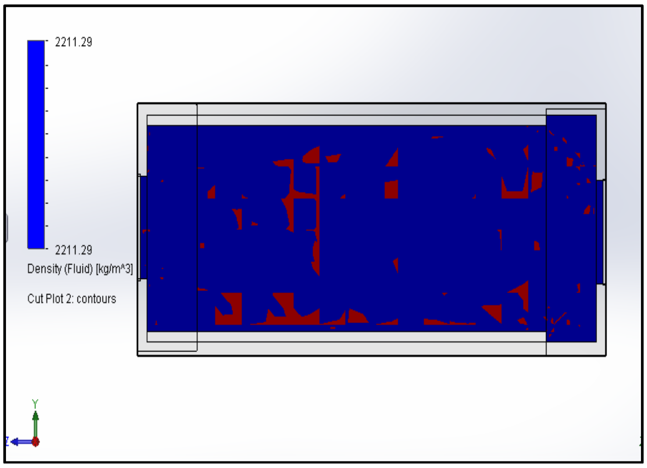

Figure 3c. Density distribution at run 3

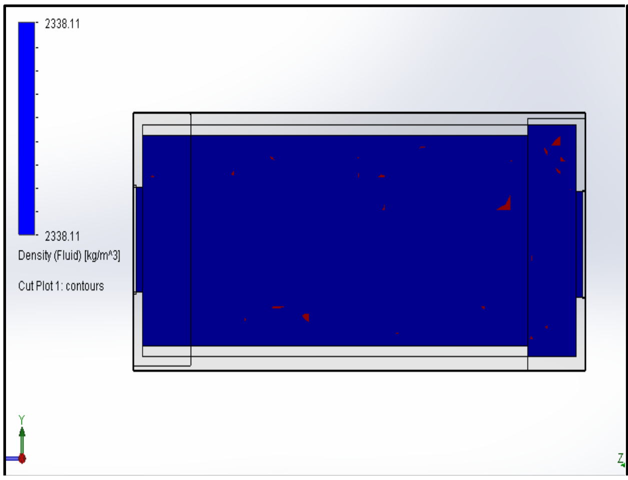

Figure 3d. Density distribution at run 4

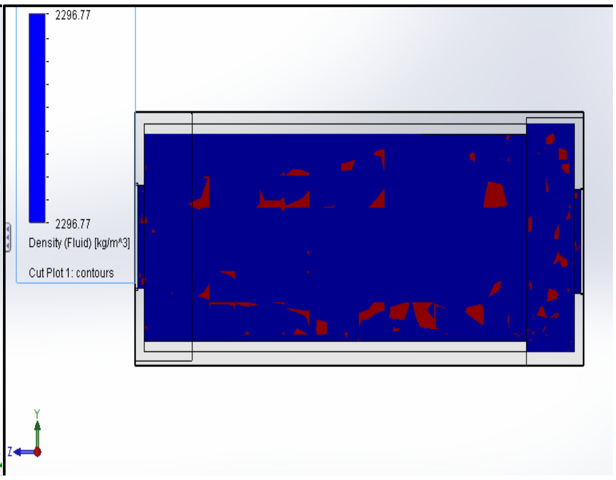

Figure 3e. Density distribution at run 5

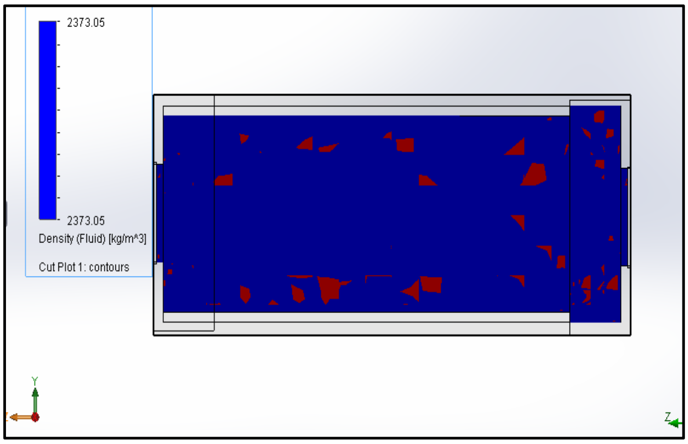

Figure 3f. Density distribution at run 6

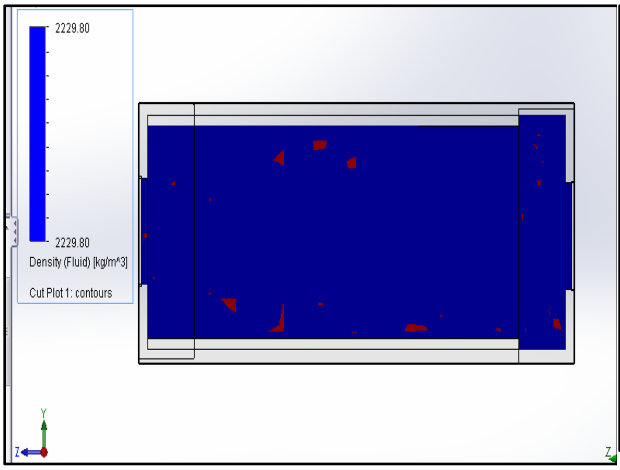

Figure 3g. Density distribution at run 7

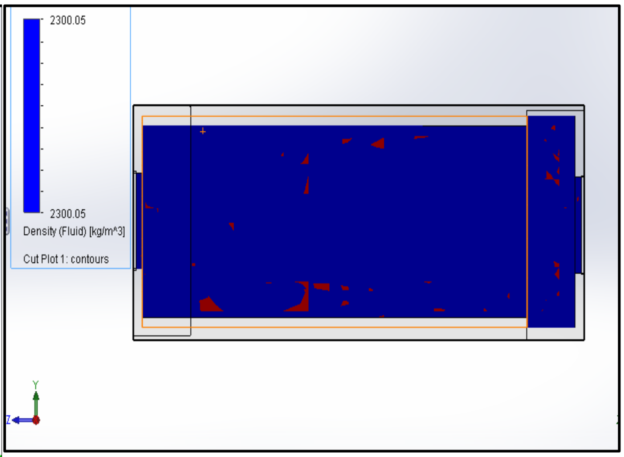

Figure 3h. Density distribution at run 8

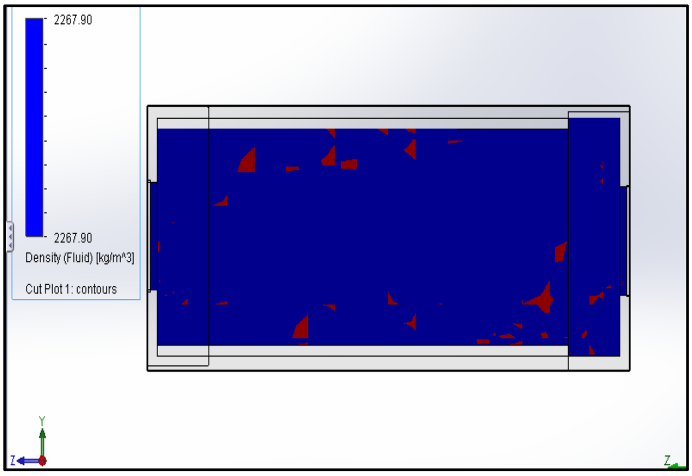

Figure 3i. Density distribution at run 9

Percentage porosity calculation

The percentage porosity of casting is determined by using the expression given in equation 2, where the true density of LM6, LM24, and LM25 Al alloys are 2650 kg/m^3, 2796 kg/m^3, 2680 kg/m^3 respectively.

$$\% \text{ Porosity} = \left[\frac{\text{True density} - \text{Apparent density}}{\text{True density}}\right] x\ 100 \quad (2)$$

IV. Result

Table no 4:Result of simulation and Response variables S/N data

Run	Material	Mould rotation	Pouring temperature	Preheating temperature	Response % Porosity	Signal to noise ratio (S/N)
1	LM6	500	690	200	13.99	-22.91
2	LM6	1000	720	300	15.15	.23.60
3	LM6	1500	750	400	16.55	-24.37
4	LM24	500	720	400	16.37	-24.28
5	LM24	1000	750	200	17.85	-25.03
6	LM24	1500	690	300	15.12	-23.59
7	LM25	500	750	300	16.79	-24.50
8	LM25	1000	690	400	14.17	-23.02
9	LM25	1500	720	200	15.41	-23.75

Using a signal to noise ratio as given in the equation (1), the objective function is to be minimized. The response obtained is presented in table 4.

Average signal to noise (S/N) ratio for factor 1at level 1 = $S/N1_1 = (Y_1+Y_2+Y_3) / 3$
Similarly, the average S/N values for each process parameter and each level are calculated for responses % porosity tabulated as shown in Table 4.

From the S/N ratio response table, the response curves are drawn for % porosity represented below in figure 3.

Table no 5: Signal to noise ratio response table for porosity

Level	Material	Mould rotation	Pouring temperature	Preheating temperature
1	-23.63	-23.90	-23.18	-23.90
2	-24.30	-23.89	-23.88	-23.90
3	-23.76	-23.91	-24.64	-23.89
Delta	0.67	0.02	1.46	0.01
Rank	2	3	1	4

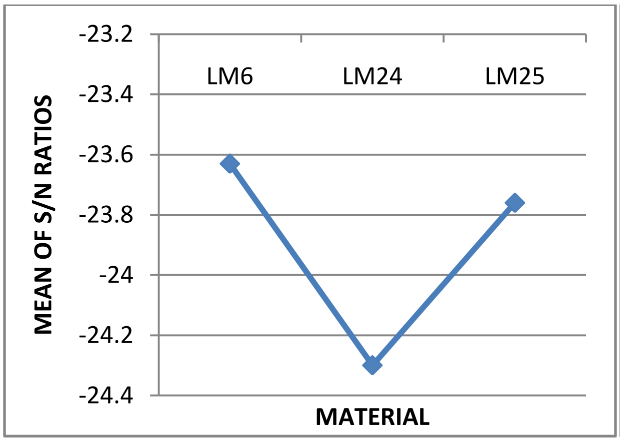

Figure 4a. Material response curve for porosity

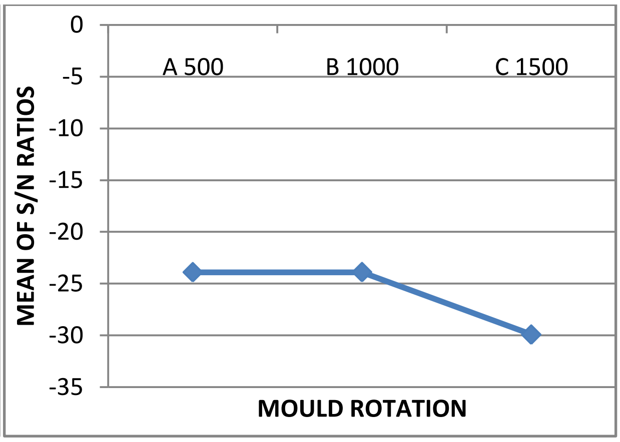

Figure 4b. Mould Rotation response curve for porosity

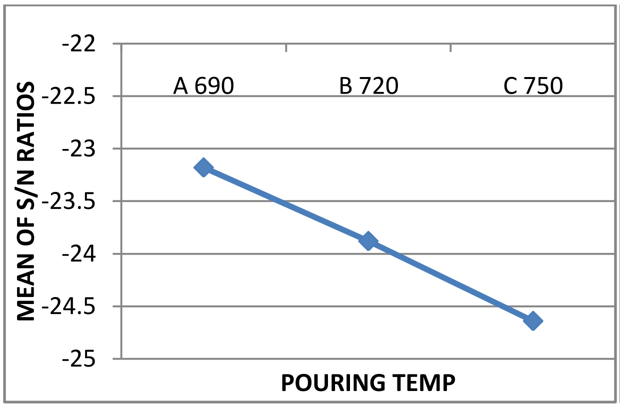

Figure 4c. Pouring temp response curve for porosity

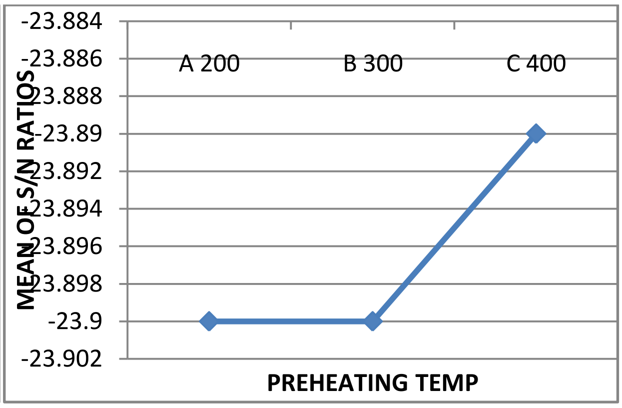

Figure 4d. Pouring temp response curve for porosity

It is clear from signal to noise ratio (S/N) The optimum levels for process parameters are material-LM24,mould rotation- 1500 rpm, pouring temperature – 750°cand preheating temperature – 300 °c

V. Conclusion

(1) In this study, the process parameters selected have a significant influence on the porosity of centrifugal casting. The optimum levels for process parameters are material - LM24, mould rotation - 1500 rpm, pouring temperature - 750°C, and preheating temperature - 300 °C.

(2) Casting defects mostlyoccurs because optimum conditions were not selected during the process. By this study, it is concluded that the data obtained can be applied to set the parameters at the optimum level. This will lead to enhance density and minimize porosity defect which improvesthe quality of produced aluminium alloy centrifugal castings.

(3) It is observed that the most significant parameters in the order are pouring temperature, material, preheating temperature and mould rotation which are affecting the quality of cast products.

(4) The best results are expected with LM24 alloy at a pouring temperature of 750°C.

References

[1]. Shailesh P, Sundarrajan S, Komaraiah M. Optimization of process parameters of Al-Si alloy by centrifugal casting technique using Taguchi design of experiments. Procedia materials science. 2014 Jan 1;6:812-20

[2]. Mukunda PG, Shailesh RA, Rao SS. Influence of rotational speed of centrifugal casting process on appearance, microstructure, and sliding wear behaviour of Al-2Si cast alloy. Metals and Materials international. 2010 Feb 1; 16(1):137-43.

[3]. Madhusudhan NS, Kumar GM. Experimental study on cooling rate of centrifugal casting based on grain size. International Journal of scientific & engineering research. 2012;3(1):1-3.

[4]. Cook K, Wu B, Reddy RG. Modeling of Centrifugal Casting of Aluminum Alloy Components. Journal for Manufacturing Science and Production. 2006; 7(1):49-60.

[5]. Suryawanshi A, Chandra SS. Optimization to improve the quality of centrifugal casting by grey fuzzy method. International journal of advanced engineering research and Studies. 2015:164-6.

[6]. El-Sayed MA. Effect of the Mould Rotational Speed on the Quality of Centrifugal Castings. International Journal of Applied Engineering Research. 2014;9(21):11575-82.

[7]. MukeshSahu, HemantSahu, A K Khandelwal.Parameters Optimization of Centrifugal Casting byMultiobjective Technique.Journal Of Scientific Research in Allied Sciences.2017 Nov; 6 (3):423-428

[8]. Mohiuddin MV, Krishnaiah A, Hussainy SF, Laxminarayana P. Influence of process parameters on quality of Al7SiMg alloy casting using statistical techniques. Materials Today: Proceedings. 2016 Jan 1; 3(10):3726-33.
[9]. Hussainy SF, Mohiuddin MV, Laxminarayana P, Sundarrajan S, Krishnaiah A. Analysis of Shrinkage Characteristics of Aluminium Silicon Alloy. Journal for Manufacturing Science and Production. 2016 Sep 1; 16(3):163-71.
[10]. Gondkar VS, Inamdar KH. Optimization of casting process parameters through simulation. International Journal of Application or Innovation in Engineering & Management. 2014 Jun;3(6):276-84.
[11]. Ravi B. Casting simulation and optimisation: benefits, bottlenecks and best practices. Indian Foundry Journal. 2008 Jan; 54(1):47.
[12]. Aneesh Kumar J, Krishnakumar K, Savithri S. Computer Simulation of Centrifugal Casting Process Using FLOW-3D. In Materials Science Forum 2015 (Vol. 830, pp. 53-56)..
[13]. Ebhota WS, Karun AS, Inambao FL. Centrifugal casting technique baseline knowledge, applications, and processing parameters: overview. International Journal of Materials Research. 2016 Oct 14; 107(10):960-9.
[14]. Pandey S, Jha SK. Casting Defects and its Optimization Method in Centrifugal Casting Process: A Review. InInternational Conference on Advances in Materials and Manufacturing (ICAMM '17) 2017 Jan 19.

M.Viquar Mohiuddin, et. al. "Parameter optimization of aluminium alloy centrifugal casting using simulation technique." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 17(5), 2020, pp. 13-20.