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Design and Development of LM24 plate Casting using Solid Cast Simulation Technique

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Abstract: This research deals with the elimination of defects in aluminium alloy castings and enhancement in the casting yield and quality. The main intention of the work is to improve the quality of a cast component using Computer Aided Casting Simulation Software. SOLID Cast simulation software is used for simulating the solidification process of casting and visualizing outputs showing possible problematic areas or defects which may occur in the cast product. Plate Castings of aluminium alloy - LM 24 are produced with different designs of gating systems and tested for defects like porosity using Archimedes immersion Technique and also Radiographic testing is used to check the quality of the castings. The produced castings are observed to be sound, and the results obtained are in agreement with the simulation results. Hence it is verified that solidification simulation helps in improving the quality of castings without any shop-floor trails. Casting yield and percentage porosity values are determined for 12 castings produced with different gating systems. The best results are observed to be produced by the castings having a 1-Ingate system in horizontal or lateral positions.
Keywords: Sand casting, Casting optimization, Casting parameters, Casting defects.

I. INTRODUCTION

Sand casting is a manufacturing process for making intricate shapes of metal materials in large production. There are two main consecutive stages, the filling process and the solidification process, in casting production. in the filling process gating system composed of a pouring cup, runner, sprue well and ingate, is designed to guide liquid metal filling. Riser system is used to compensate for shrinkage caused by casting solidification. It is unavoidable that many different defects occur in the casting process, such as porosity and incomplete filling. how to improve the casting quality becomes important. Casting quality is heavily dependent on the success of gating/riser system design, which currently is conducted mainly relying on technicians' experience. Therefore, there is a need for the improvement of a computer-aided sand casting process design tool with CAD, simulation or analysis, and optimization functions to ensure the quality of the casting.

II. LITERATURE REVIEW

1) SachinL. Nimbulkar et al. Sand casting is a manufacturing process to make different shapes of metal materials; many researchers reported that 90 per cent of the defects obtained in casting are only because of improper design of the feeding and gating system. The main objective was to study the existing design of the feeding and gating system, to improve the feeding and gating system using Auto CAST X1 sand casting simulation software to prepare the mould and cast the part, to compare the experimental result and simulated results, and to reduce the rejection rate.
2) Swaroop S.Magdum et al. - This study deals with the process of casting various intricate shapes manufactured and that involves creating a hollow cavity inside a sand mould and then pouring the liquid metal directly into the sand mould cavity. Having a proper gating system is very important in the sand casting process for quality, defects-free sand casting and higher yield. The sand casting process is very uncertain even in a completely controlled process defects are found which challenging to find the causes of sand casting defects. In the simulation or analysis technique, the gating system is designed numerically and by that dimensions, the 3Dimension model of the gating and cavity is modelled and the optimized gating system is finalized.
3) Sanni Dev et al. This study deals with an endeavour to synthesize a hybrid metal matrix composite by taking Al piston alloy (LM 26) as base material and Porcelain ceramic particles as reinforcement. The hybrid metal matrix composites were fabricated with 2 weight % 4 weight % 6 weight % and 8 weight % porcelain-filled LM26 AL alloy, through a cost-effective liquid metallurgy course i.e. The void fraction decreases from 0.58% to 0.36% by increasing weight % of porcelain from 0 weight % to 6 weight % and then increase to 0.65% for 8 weight % addition of porcelain in a matrix material. The microhardness increased by 10% by adding 8 weight % porcelain to LM26 master alloy. Similarly, the tensile strength was increased by 20%

for 6 weight % addition of porcelain. All the tested physical and mechanical properties of fabricated composites were superior compared to the LM 26 master alloy.

A. Gaps in Literature Review

From the literature survey, it has been observed that little amount of work is available on the design of castings for the aluminium LM24 alloy sand mould casting process. No work is available on the effect of different gating systems on the quality, %porosity and yield of castings.

Hence an effort is made to design different gating systems for LM24 material and study the effect of different gating systems on the quality of casted components.

III. MATERIAL AND METHODS

The properties of aluminium-silicon alloys have been used for sand casting. It is seen that an increase in the (SI) silicon content of the aluminium-silicon cast alloy causes a decrease in casting density. The chemical composition of the aluminium alloys is given in Table 1

Table 1: Alloy composition

Alloy	Cu	Mg	Si	Fe	Ni	Al
LM24	3.4-4.0	0.3 max	7.5-9.5	1.2 max	0.5 max	Remainder

The objective of this paper is to optimizing the defects in casting including optimum levels. The 12 experiment/simulation. The procedure for 12 experiment/simulation is as follows:

Table 2: Experimental Plan

Case 1	1Runner 2Gate Horizontal
Case 2	1Runner 2Gate Lateral
Case 3	2Runner 2Gate Horizontal
Case 4	2Runner 2Gate Lateral
Case 5	1Runner 3Gate Lateral
Case 6	1Runner 3Gate Horizontal
Case 7	2Runner 3Gate Horizontal
Case 8	2Runner 3Gate Lateral
Case 9	2Runner 2Gate Lateral (Inclined)
Case 10	2Runner 3Gate Lateral (Inclined)
Case 11	1Gate Horizontal
Case 12	1Gate Lateral

IV. DESIGN CALCULATIONS

Step-1:Calculating the total Weight of the Casting:

$$W = \rho \,.\, V$$

Where, W = total weight of casting, ρ = density, V = total volume of casting.

W = 2.79 x 532 = 1425.76g = 1.48423Kg.

Step-2: Calculating Pouring Rate:

Pouring Rate for non-ferrous gating:

$R = b\sqrt{W}$, Where R – Pouring Rate, b – is a constant depends upon wall thickness (For < 6mm thickness, b = 0.99)

$R = 0.87\sqrt{1.48423}$ = 1.059 Kg/sec.

Step-3: Calculating effective sprue height:
Effective height of metal Head,
For Top gating; H= h, h= 100mm, Therefore, For Bottom gating, H = h - $\frac{c}{2}$
H = 100mm, c = 10mm Therefore, H = 100$-\frac{10}{2}$ = 95mm
Where H = Effective height of metal Head, h = height of the sprue , C = Total height of mould cavity

Step-4: Calculating cross-sectional area of the choke:
Flow rate equation (from Bernoulli's Theorem),

$$A = \frac{W}{\rho t C\sqrt{2gH}}$$

Where, A = Choke area, mm^2; W = weight of casting, Kg; t = pouring time, sec;
ρ =density of molten metal, kg/mm^2 = 0.9 x Solid density = 0.9 x 2.79 = 2.511 g/cc
g= acceleration due to gravity = 9800 $mm/s^{2,}$ C= efficiency factor which is a function of Gating system used,
= 0.85 to 0.90 for tapered sprue in gating system.
For Top gating,

$$A = \frac{1.48423}{2.511\times10^{-6}\times1.191\times0.85\times\sqrt{(2\times9800\times100)}} = 417.057\,mm^2$$

$$\frac{\pi}{4}\times D_1^2 = 417.057\,mm^{2} = D_1 = 23.04mm \approx 23mm.$$

For Bottom gating,

$$A = \frac{1.48423}{2.511\times10^{-6}\times1.191\times0.85\times\sqrt{(2\times9800\times95)}} = 427.891\,mm^2$$

$$\frac{\pi}{4}\times D_2^2 = 437.08\,mm^2 = D_2 = 23.34mm \approx 24mm \text{ again.}$$

Step-5: Calculating Sprue inlet area:
Considering sprue exit area as choke area, from law of continuity, $A_1V_1=A_2V_2$, and $V = \sqrt{2gh}$
Where A_1 = Area of sprue entrance, A_2 = Area of sprue exit, h_1 = Level of liquid metal above sprue entrance, h_2 = Level of liquid metal above sprue exit, and V = Velocity of metal flow.

$$\frac{A1}{341.39} = \sqrt{\frac{80}{20}}$$

A_1 = 834.114mm^2; D_1 = 32.5mm≈33mm

Step-6: Calculating cross-sectional area of Runner:
For aluminium alloy castings, considering the gating ratio of A_c:A_r: A_g = 1:1.2: 2 (Non-pressurized gating system)
Where; Gating Ratio = Cross-sectional areas of Choke: Runner: Ingates
A_c:A_r: A_g = 417.057:834.114:834.114
Total Runner Area = 834.114 mm^2 = w x d
Considering width of runner is twice that of its depth; w = 2d; where w = width & d = depth of runner
D = 20.42 ≈ 20mm; and w = 2×20= 40mm

Step-7: Calculating cross-sectional area of Ingates:
Similarly, from gating ratio, Total Ingate Area = 834.114 mm^2 = w x d
Considering width of Ingate as four times as its depth; w = 4d; where, w = width & d = depth of Ingate.
d = 14mm; and w = 56mm.
Step-8: Calculating Pouring Time: $t = k\sqrt{G}$
Where G = Total weight of casting = $W_C + W_{GS} + W_{RS}$;

Or G = Total weight of metal poured = 2.5 × W = 2.5 ×1.48423 = 3.710 Kg and k = Shape factor = 8 for (Al alloy thin castings).

$$t = 8\sqrt{3.710} = 15.40 \text{ sec.}$$

V. CAD MODELLING AND SOLID CAST SIMULATIONS

A. Modelling in Solid works

Part modelling and assembling are carried out using Solid Works. It is one of the world's most advanced and highly integrated CAD/CAM/CAE products. Solid Works delivers great value to enterprises of all sizes by covering the entire range of product development. It improves the design process by simplifying various product designs.

B. Simulations in SOLID Cast

SOLID Cast is a casting simulation software program which can simulate thermal changes and heat transfer in the solidification process of casting. It assists the user in visualizing the solidification process of a particular casting. The program offers functions to help guide a user in producing gating and riser designs and also has functions which produce visual outputs showing possible problem areas and defects which may occur in a casting. therefore SOLID Cast can help reduce the lead time and reduce the loss in the trial-sand casting stage**.**

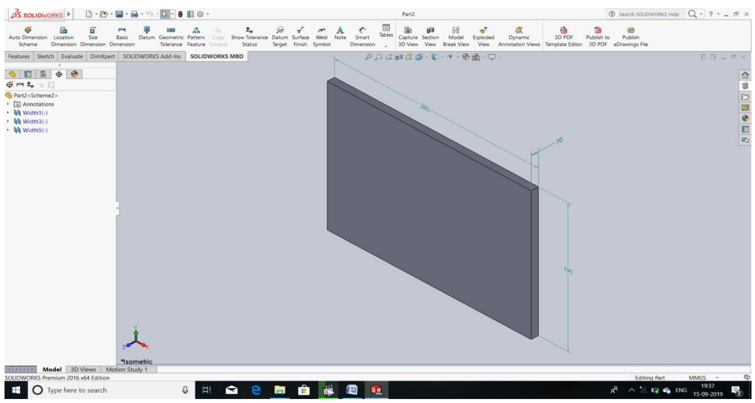
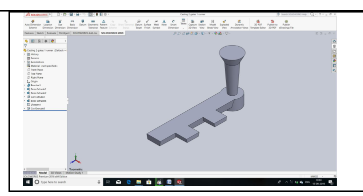
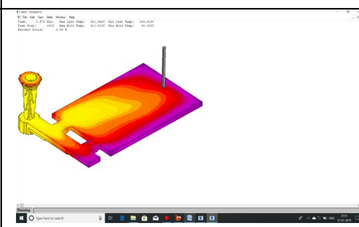
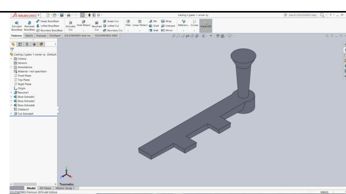
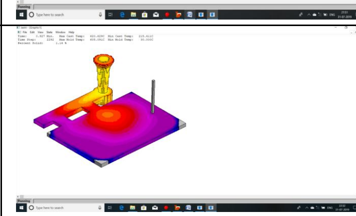
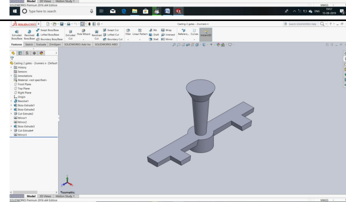
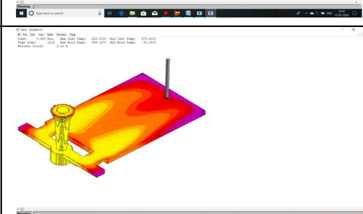
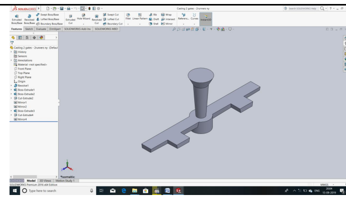
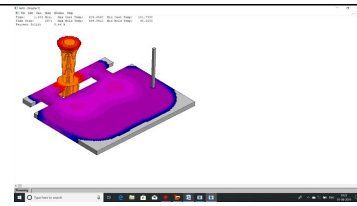
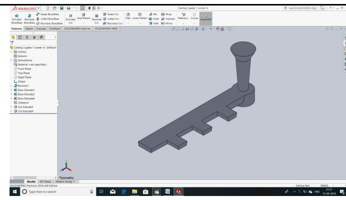
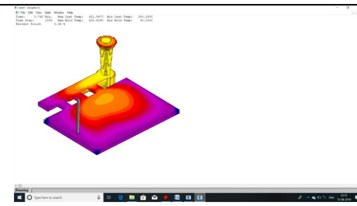
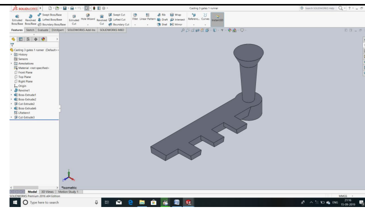
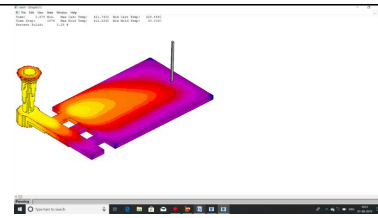
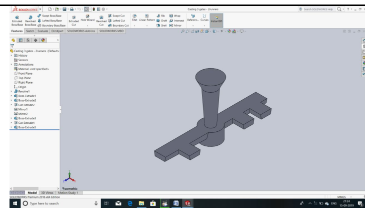
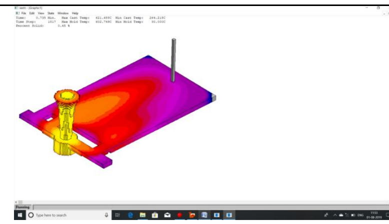
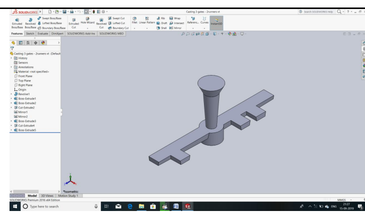
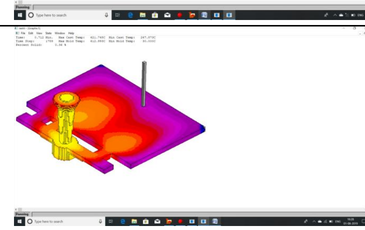
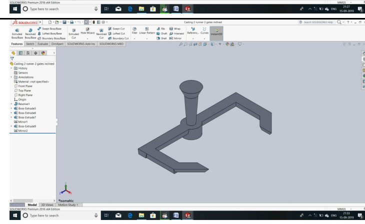
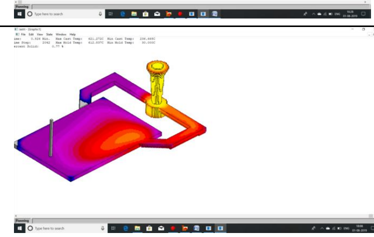
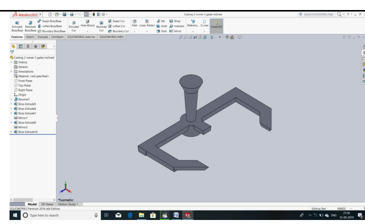
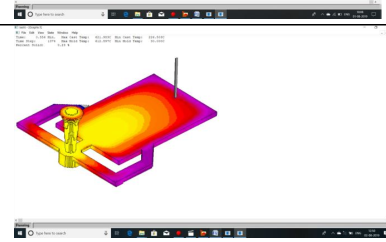
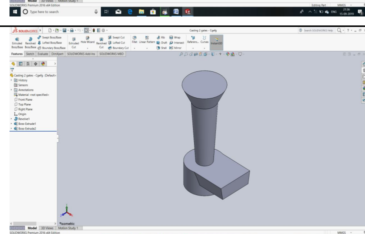
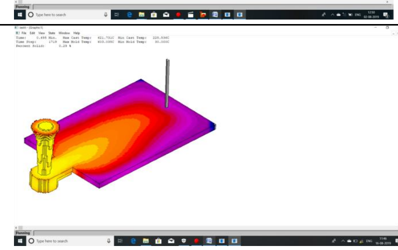
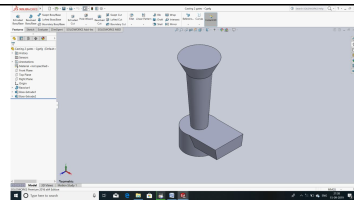
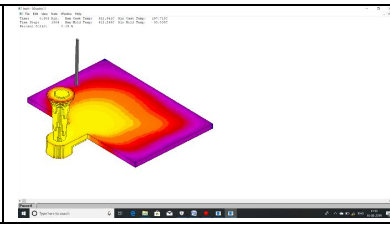


Figure 1: plate casting 280×190×10mm

EXP	DESCRIPTION	SOLID MODELING	SOLID CAST SIMULATION
Case 1	1Runner 2Gate Horizontal		
Case 2	1Runner 2Gate Lateral		
Case 3	2Runner 2Gate Horizontal		

Case 4	2Runner 2Gate Lateral		
Case 5	1Runner 3Gate Lateral		
Case 6	1Runner 3Gate Horizontal		
Case 7	2Runner 3Gate Horizontal		
Case 8	2Runner 3Gate Lateral		
Case 9	2Runner 2Gate Lateral (Inclined)		
Case 10	2Runner 3Gate Lateral (Inclined)		
Case 11	1Gate Horizontal		

Case 12	1Gate Lateral		

VI. EXPERIMENTAL WORK

A. *Mould Making Procedure*

1) The first step in making mould is placing the pattern on the moulding board Then the drag is placed on the board.
2) Dry-facing sand is sprinkled over the board and the pattern to provide a non-sticky layer.
3) Moulding sand is then riddled to cover the pattern with the fingers; then only the drag is filled.
4) The sand is then firmly packed in the drag utilizing hand rammers. The ramming must be done properly. Here, it must either be too hard or soft.
5) After the ramming is over, the excess sand is levelled off with a straight bar known as a strike rod.
6) With the help of a vent rod, vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during the pouring and solidification process.
7) The finished drag flask is now rolled over to the bottom board thereby exposing the pattern.
8) The cope half of the pattern is then placed over the drag pattern with the help of locating pins. The cope flask on the drag is located aligning it again with the help of pins.
9) The dry parting sand is sprinkled all over the drag and also on the pattern.
10) A sprue pin for making the sprue passage is located at a small distance from the pattern. If a riser pin is required, it can be placed in an appropriate place.
11) The sprue and riser pins are removed first and a pouring basin is scooped out at the top to pour the liquid metal.
12) Then, the pattern from the cope and drag is removed and facing sand in the form of paste is applied all over the mould cavity and runners which would eventually give the finished casting a good surface finish.
13) Ultimately the mould is assembled and ready for pouring.

Figure 2: Solidification of casting

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VII. RESULT

Table 3: Simulation casting

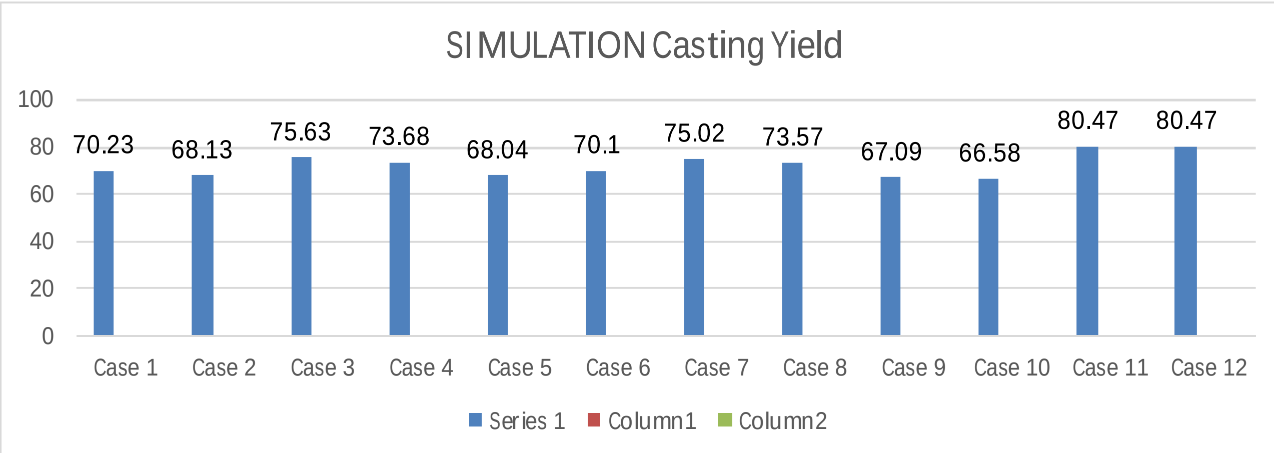


Table 4: Experimental casting yield

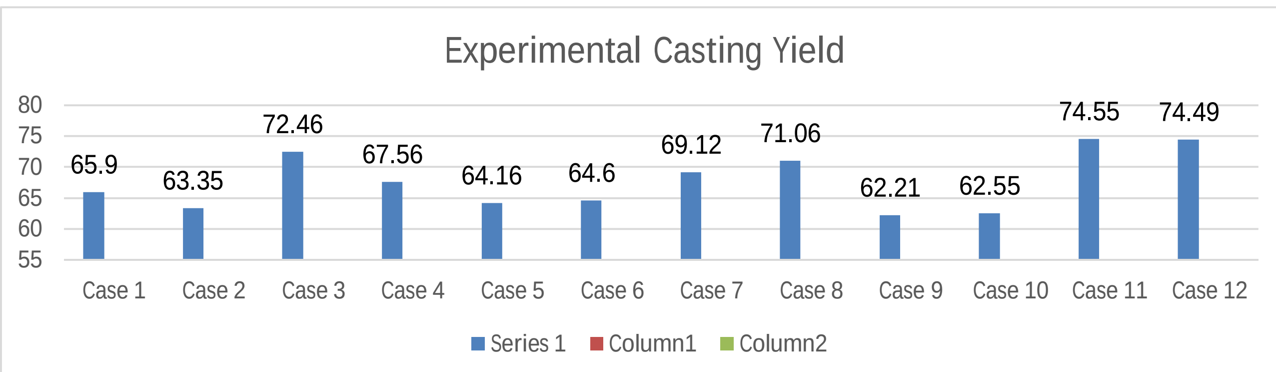
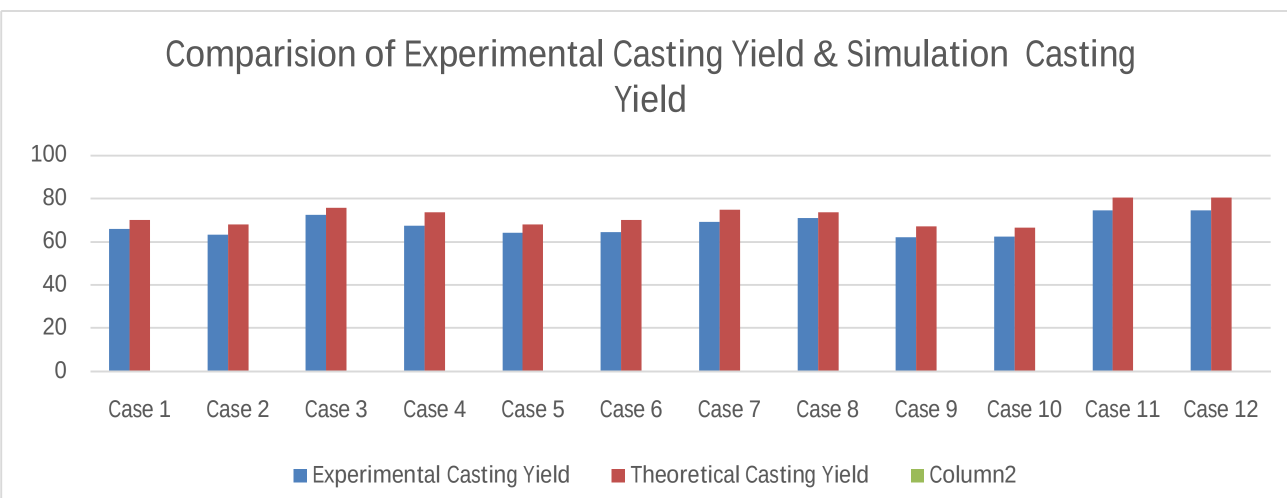


Table 5: Comparison of Simulation& Experimental Casting Yield:



VIII. RADIOGRAPHIC TESTING RESULTS:

Table 6. Radiographic testing results

S.No	Identification	Thickness	Film size	Observations	Remarks
1	Case-6	10mm	15”x12”	Isolated blow holes	Acceptable
2	Case-11	10mm	15”x12”	Cluster blow holes	Acceptable

IX. CONCLUSION

The results of simulation are in good accordance with that of experimentation. The defects like solidification shrinkage, cracks, unfilled riser and incomplete mould cavity are completely eliminated from the casting.

The X-ray radiograph of the plates taken, shows that there were no major defects in the castings. The result obtained from this experiment shows that gating system design is one of the essential factors to produce good quality of casting product.

From the experimental results, it is concluded that among all the casting designs, design of Experiment no. -11 i.e. 1-Gate (in horizontal position) is the best design as it gives the highest casting yield of 74.55% and the least percentage porosity of 3.17.

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