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EXPERIMENTAL ANALYSIS OF CYLINDRICAL RISER DESIGN FOR LM6 ALUMINIUM ALLOY CASTINGS

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Abstract: Aim of the present work is to produce the defect free casting for optimised riser dimensions for a rectangular plate Aluminium alloy (Al-12%Si alloy) casting with insulating riser sleeve (plaster of paris) and chill (cast iron) by Experimental work.

In this work, previously found optimized riser dimensions three models are considered to conduct the experimental work for a double plate casting of size 240x150x 25 mm with cylindrical side riser having a hemispherical bottom of height (D/2) and diameter with H/D= 1.5. The first model is a riser without sleeve and chill, the second model is a riser with insulating sleeve and the third model is a riser with insulating sleeve and chill. The casting Specimen is prepared and the various tests are conducted to find the soundness of casting. It strongly shows, the optimum riser dimensions give better result. This work proves optimization of riser dimensions by ANSYS software reduces experimental work.

I.INTRODUCTION

Casting is one of the fundamental types of manufacturing any type of products. In response to consumer demands for increased performance and fuel economy, the use of aluminium in the automotive industry has grown dramatically in recent years

The volume of the cast aluminium components is projected to grow significantly during the next decade; according to one forecast by 2017 the amount of automotive cast aluminium is projected to rise from the current average of 85 kg per vehicle to over 105kg. So in order to produce a sound aluminium casting in the economical manner, a new approach in the riser design is needed.

1.1 CASTING PROCESS

Metal casting is one of the most ancient techniques used for manufacturing metal parts. Metal casting is the process of producing metal component parts of desired shapes by pouring the molten metal into the prepared mould(of that shape) and then allowing the metal to cool and solidify.

A. Applications of metal casting

1. Transportation vehicles, Turbine vanes
2. Air craft jet engine blades.
3. Machine tool structures (planner beds)
4. Agricultural parts

B. Casting Defects

Several types of defects like misruns, cold shuts, shrinkage cavities, pin hole porosity, hot tears, cracks and distortions may occur during casting. Increasing the total cost of the production, it is therefore important to understand the causes and remedies behind these defects. One of the defects that occur due to improper design of riser is shrinkage defect.

3. DESIGN OF RISER

A. Riser-Neck Dimensions

Riser-neck dimensions is important because it determines, first, how well the riser can feed the casting, and second, how readily the riser can be removed from the casting.

Riser-neck dimensions from [10], for side riser are given below

$H_N = (0.6 – 0.8)t$

Max. $L_N = D/3$; $W_N = 2.5L_N - 0.19\,D$

Where H_N = Height of the gate, L_N = Length of the gate, W_N = width of the gate
D= diameter of riser, t= plate thickness.

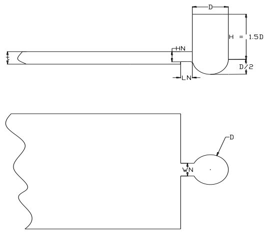


Fig.1 Riser Neck Portion and hemispherical bottom

Calculation
Riser diameter (D) = 60 mm
Neck Height (H_N) = 0.8 x 25 = 20 mm
Neck Length (L_N) = 60 / 3 =20mm
Neck Width (W_N) = 2.5 x 20 - 0.18 x 60=40mm

B. The basic requirements of a risering system for a casting

i. The riser should be thermally adequate

The solidification time of metal in riser must be greater than the solidification time of metal in mould. So that it can feed enough metal to the casting to compensate volume shrinkage during solidification.

According to **Chvorinov's equation,**

Freeze time t = K $[V/SA]^2$
Where, t = freeze time of casting (Sec)
V= volume of casting (mm^3)
SA = surface area of casting (mm^2)
K=solidification constant (Sec/mm^2)

ii. The riser should be volumetrically adequate

The feed metal supplied by the riser to the casting at least equal to the volumetric contraction of casting during solidification.

According to [5]
Feed metal of riser = 1/6 volume riser
According to [7]
Feeding capacity of riser = 16% for conventional riser
Feeding capacity of riser = 67% for insulated riser

So, the solidification time of riser metal can be increased by using insulated riser sleeve. Plaster of Paris is an insulating material and it can be used as a riser sleeve in metal casting process.

C. Riser Shape

According to Chvorinov's equation

Solidification time (t) α $[\text{Volume / Surface Area}]^2$

It does indicate that, for a riser to have a solidification time equal to or greater than that of the casting, the minimum riser size would be obtained from a sphere. Sphere are usually difficult to mould, and would present feeding problem as well, since the last metal to freeze would be near the center of the sphere, where it could not be used to feed a casting.

Practicalities dictate the use of cylinders for most risers. So the cylindrical riser with hemispherical base is used to provide the smallest possible surface area – volume ratio.

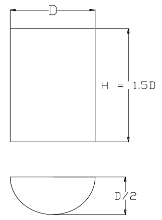


Fig.2 Hemispherical bottom of riser

A cylindrical riser with a hemispherical bottom is used in this project since the hemispherical bottom consumes 16-17% less metal than the standard cylindrical side riser as evaluated by [8] for Aluminum alloys.

D. Location of the Riser

Extensive use of top risers is made use on aluminum castings. Maximum benefit of metallostatic pressure in risers can be obtained with top risers. However, side risers must be often used. Whenever possible these “hot” risers; i.e, metal flows from gate into the riser and then into the castings. Side riser has some advantage over top riser. They act as bubble trap and easy to chip off from the casting. So the side riser is prepared in this paper.

E. Calculation of Riser Dimensions

1.By using shape factor method

Shape factor = (L+W)/T =(250+150)/25 =16

L=Length of casting, W=width of the casting, T=Thickness of casting

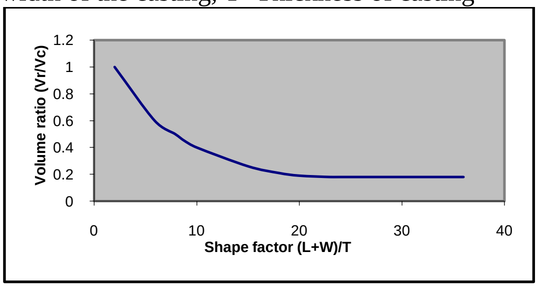


Fig.3 Riser volume to casting volume ratio as a function of the shape factor

2. Riser Dimension:

Riser volume /casting volume=V_R/Vc=0.35 (from figure)

Casting volume Vc=240x150x25 = 9×10^5 mm^3

Riser volume V_R = 0.35 Vc

= $0.35\times9\times10^5$ =315000 mm^3

$V_R = \Pi D^3/4 = 315000\ mm^3$; D=64.4 mm

3.Calculation of feed metal required

Volume of feed metal $V_F=\beta x Vc$

For LM6, β=3.7%

$V_F=0.037\times9\times10^5=33300\ mm^3$

4.Calculation of feeding capacity of riser

According to [5]

Volume of feed metal $V_F= \Pi D^3/24$

Theoretically, feeding capacity of riser =1/6 Volume of riser

Required volume of riser =6x V_F

V_R =6x33300=199800 mm^3 ; D=63.4 mm.

F. Plate Casting and Riser used

Cast metal : LM 6 Aluminium
Casting size : 240 x 150 x 25 mm
Casting volume : 90×10^4 mm^3
Surface area : 91500 mm^2
Casting modulus : 9.8 mm

A number of cylinders with hemispherical bottom and H/D ratio of 1.5 is used as risers for analysis. The dimensions of the riser ranged from 60 mm to 70 mm

G. Properties of lm 6 Aluminium alloy

CHEMICAL COMPOSITION

Copper	= 0.1 Max	Magnesium	=0.10 Max
Silicon	= 10 to 13 Max	Iron	=0.61 Max
Manganese	= 0.50 Max	Nickel	=0.12 Max
Zinc	= 0.12 Max	Lead	=0.15 Max
Tin	= 0.05 Max	Titanium	=0.20 Max
Aluminium	= 88.15 to 85.15 Max		

H. Riser dimensions calculations:

Model I:- Riser without Sleeve and Chill

i. Riser Dimensions:

Riser diameter (D)= 65 mm.
Riser height (H) = 1.5D= 1.5 X 65 = 97.5 mm
Riser hemispherical bottom = D / 2 = 65/2 = 32.5 mm

ii. Riser Neck Dimensions:

Height of the Neck (H_N) = (0.6 to 0.8) t
t - Plate thickness 25 mm (Constant)
H_N = 0.8 t
= 0.8 X 25 = 20 mm.
Length of the Neck (L_N) = D / 3
= 65 / 3
= 21.67 mm.
Width of the Neck (W_N)= 2.5 L_N – 0.18 D
= (2.5 X 21.67) – (0.18 X 65)
= 42.467 mm.

Model II :- Riser with Insulating Sleeve

i. Riser Dimensions:

Diameter of Riser (D) = 60 mm.
Height of the Riser (H)= 1.5 X D = 1.5 X 60 = 90 mm
Riser Hemispherical bottom = D / 2 = 60 / 2 =30 mm
Insulating sleeve thickness = 5 mm.

ii. Riser Neck Dimensions:

Height of the Neck (H_N)= (0.6 to 0.8) t
t - Plate thickness 25 mm (Constant)
H_N = 0.8 t = 0.8 X 25 = 20 mm.
Length of the Neck (L_N) = D / 3 = 60 / 3 = 20 mm.
Width of the Neck (W_N) =2.5L_N – 0.18D
= (2.5 X 20) – (0.18 X 60)=**39.2** mm.

Model III:- Riser with Insulating Sleeve & Chill

i. Riser Dimensions:

Diameter of Riser (D) = 50 mm.

Height of the Riser (H)= 1.5 X D = 1.5 X 50 = 75 mm

Riser Hemispherical bottom = D / 2 = 50 / 2 =25 mm

Insulating sleeve thickness = 5 mm.

ii. Riser Neck Dimensions:

Height of the Neck (H_N)= (0.6 to 0.8) t

t - Plate thickness 25 mm (Constant)

H_N = 0.8 t = 0.8 X 25 = 20 mm.

Length of the Neck (L_N) = D / 3

= 50 / 3 = 16.67 mm.

Width of the Neck (W_N) = 2.5 L_N – 0.18 D

= (2.5 X 16.67) – (0.18 X 50) = **32.67** mm.

The ratio of weight of plaster of paris powder to weight of water is called consistency ratio.

4 .EXPERIMENTAL PROCEDURE

4.1 MOULDING SAND

Silica sand moulds are prepared by sand mix with a composition of 10% bentonite, 5% moisture and 3% saw dust and coal powder are added.

4.2 MELTING AND POURING

The ingots of LM6 is melted in a crucible furnace. When it reaches a temperature of 745^{o}C, it is taken out and degassing is done. Then pouring the molten metal into the mould cavity at a temperature of 725^{o}C.

4.3 RISER SLEEVE

Specific quantity of dry Plaster of Paris is weighed and equal quantity of water (on weight basis) is taken in a beaker. The powder is added to the water and thoroughly mixed using a stirrer for 2 minutes to ensure intimate contact between them. The slurry is filled into the pattern and allowed to set as a solid mass. Then the sleeve is removed carefully from the pattern.

Presence of moisture in the Plaster of Paris of sleeve will react with molten metal during casting process. To remove the moisture content in the Plaster of Paris sleeve it is placed inside an oven and heated for 2 hours at the temperature of 150^o C.

4.4 CASTING EXPERIMENTAL SETUP

Size of 240 x 150 x 25 mm Plate is selected for the investigation. The test casting and runner and cylindrical riser with hemispherical bottom of H/D ratio = 1.5 are used.

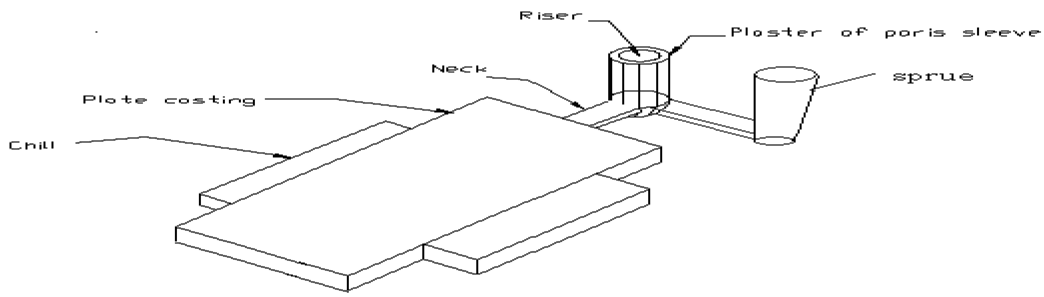
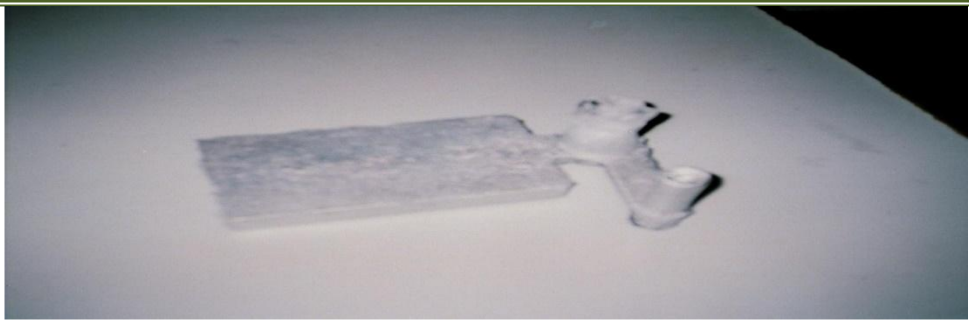


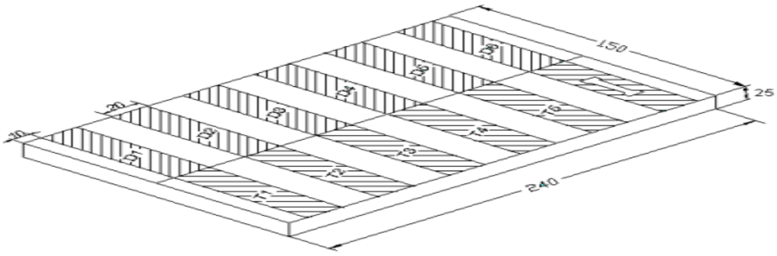
Fig. 4.Casting with Runner and Riser with Insulating Sleeve and Chill



Casting with Runner and Riser

5. SOUNDNESSMEASUREMENT

Soundness of Casting is assessed by UTS and porosity percentage. Porosity and mechanical properties of the castings can be determined by preparing test specimens pieces along the length of the casting, as shown in the Fig.5



ALL DIMENSIONS ARE IN mm

D - Density Test Specimen T - Tensile Test Specimen

Fig. 5 Plate Casting Sectioning Details

a. Density Measurement

The test blanks are marked as "D" in Fig.5 is determined by Archimedes principle,

Archimedes Principle:

$$\rho_m = \left[\frac{W_{m\text{-}a}}{W_{m\text{-}a} - W_{m\text{-}w}}\right] \times \rho_w$$

Where,

ρ_m – Casting Density (gm/cm^3),ρ_w – Density of water (gm/cm^3)

W_{m-}Casting Weight in air (gram), $W_{m\text{-}w}$ – casting Wt in water (gram)

b. Porosity Measurement

Porosity is calculated by,

$$P = \left[\frac{D_{MAX} - D}{D_{MAX}}\right] \times 100 \quad \%$$

Where, P = Porosity, $D_{MAX.}$ – Maximum Density (Theoretical Value).

D –Density by measurement (Experimental Value).

c. Tensometer specimen

To find out tensile strength, test specimen is prepared as shown in Fig. 6

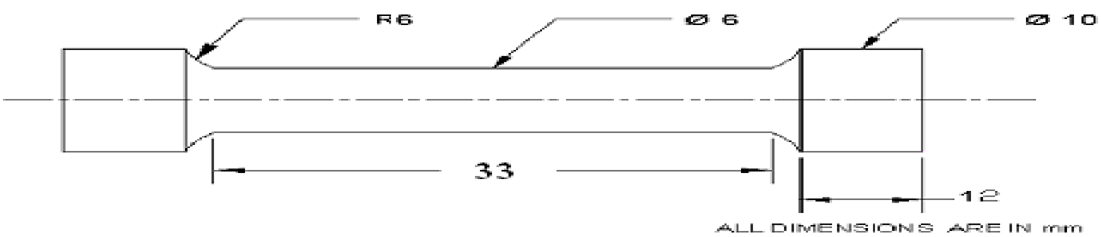
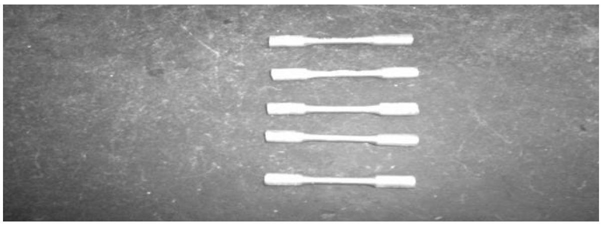


Fig.6 Specimen for tensile test

The minimum ultimate tensile strength and the maximum porosity of each piece are determined in order to decide whether the casting is sound and unsound.



Machined Tensometer specimens

6. RESULTS AND DISCUSSION

The experimental result are compared with the simulation results, in order to prove that the riser dimensions obtained from the computer simulation are optimal and produce sound casting.

Test castings are assessed for their soundness by conducted the following tests:

- Tensile test to determine the Ultimate Tensile Strength (UTS).
- Density measurement to calculate the percentage of porosity.
- Ultrasonic test to determine the soundness of casting.
- Microstructure Analysis.

TABLE1 MEASURED ULTIMATE TENSILE STRENGTH ALONG THE LENGTH OF THE CASTINGS

S.NO	Specimen-ID	UTS (kg/mm^2)	S.NO	Specimen-ID	UTS (kg/mm^2)
1	D50SC-T1	11.51	14	D65-T2	11.80
2	D50SC –T2	11.20	15	D65-T3	11.42
3	D50SC –T3	11.17	16	D65-T4	11.67
4	D50SC –T4	11.32	17	D65-T5	11.90
5	D50SC –T5	11.60	18	D65-T6	11.87
6	D50SC –T6	11.90	19	D63-T1	10.61
7	D60S-T1	11.87	20	D63-T2	10.70
8	D60S-T2	11.05	21	D63-T3	11.00
9	D60S-T3	11.38	22	D63-T4	10.61
10	D60S-T4	11.41	23	D63-T5	10.42
11	D60S-T5	11.67	24	D63-T6	10.90
12	D60S-T6	11.80	14	D65-T2	11.80
13	D65-T1	12.19	15	D65-T3	11.42

TABLE .2 MEASURED DENSITY AND POROSITY ALONG THE LENGTH OF THE CASTINGS

S.NO	Specimen-ID	W_{air}(gm)	W_{water}(gm)	D_{act}(gm/cc)	Porosity(%)
1	D50SC-D1	12.1084	7.4744	2.6129	1.398
2	D50SC -D2	12.1143	7.4805	2.6143	1.346
3	D50SC -D3	12.1180	7.4850	2.6159	1.287
4	D50SC -D4	12.3142	7.6120	2.6188	1.177
5	D50SC -D5	12.2067	7.5601	2.6270	0.867
6	D50SC -D6	12.1984	7.5500	2.6242	0.931
7	D60S-D1	11.5013	7.1101	2.6192	1.163
8	D60S-D2	11.4352	7.0480	2.6065	1.642
9	D60S-D3	11.3582	6.9982	2.6051	1.695
10	D60S-D4	11.4012	7.0114	2.5972	1.992
11	D60S-D5	11.3852	7.0109	2.6027	1.783
12	D60S-D6	11.3041	6.9812	2.6149	1.323
13	D65-D1	10.1264	6.2530	2.6143	1.345
14	D65-D2	10.0951	6.2163	2.6026	1.787
15	D65-D3	10.0849	6.2014	2.5969	2.005

16	D65-D4	10.0483	6.1812	2. 5984	1.947
17	D65-D5	10.1149	6.2211	2.5977	1.974
18	D65-D6	10.1287	6.2556	2.6151	1.315
19	D63-D1	10.1048	6.2102	2.5946	2.092
20	D63-D2	10.0755	6.1648	2.5764	2.772
21	D63-D3	10.0862	6.1752	2.5789	2.680
22	D63-D4	10.0851	6.1751	2.5793	2.667
23	D63-D5	10.1145	6.2090	2.5898	2.271
24	D63-D6	10.1052	6.2117	2.5954	2.061

 # T -Refer tensile test specimen **# D –**Refer density test specimen

6.1RISER LOCATION Vs MECHNICAL PROPERTIES

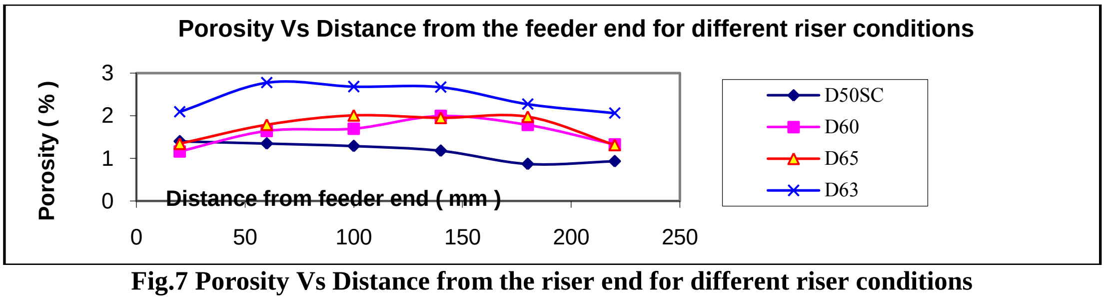


Fig.7 Porosity Vs Distance from the riser end for different riser conditions

In order to determine the soundness of the casting at different riser condition, the porosity percentage is plotted against the distance along the length of the casting for all the riser conditions (Fig.7).
The following observations are made from the results given in fig.7

- When the casting is inadequately fed, there exists a region in the middle of the casting where porosity is greater. On the other side of the casting the porosity is less.
- For a given end-chill-plate-Riser Sleeve combination, cast iron chill produces low porosity in the casting when compared to non-chilled casting.
- When the chill is used, the level of porosity along the length of the casting is lowered to some extent and the maximum porosity location shifts towards the riser. Because chill promotes good directional and progressive solidification.
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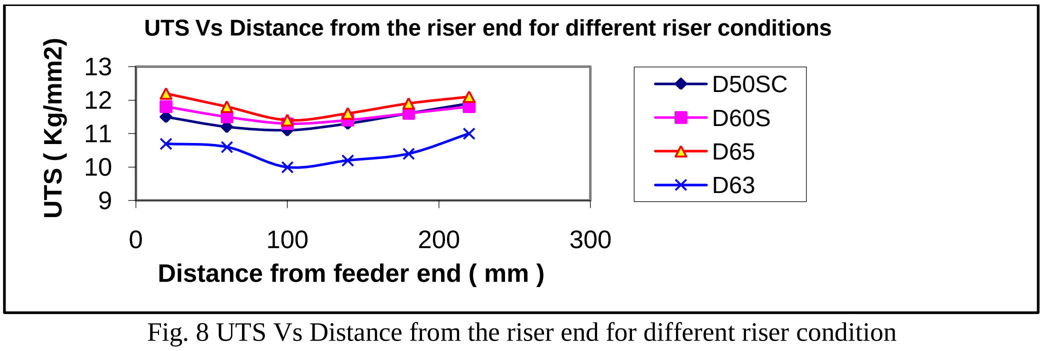
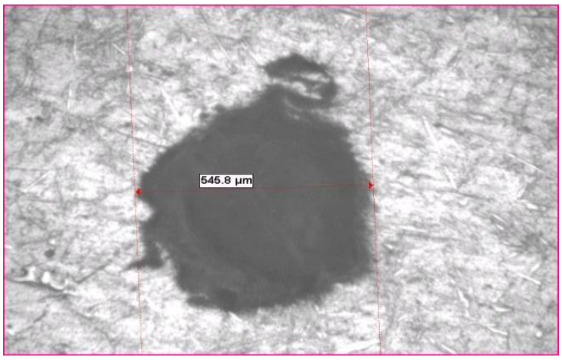


Fig. 8 UTS Vs Distance from the riser end for different riser condition

For all the castings, the UTS of a tensometer specimen was measured. It may be observed from these plots (Fig.8) the UTS values are less in the center of the castings and these values are high at both the end of the rectangular plate castings.

6.4 MICROSTRUCTURE ANALYSIS

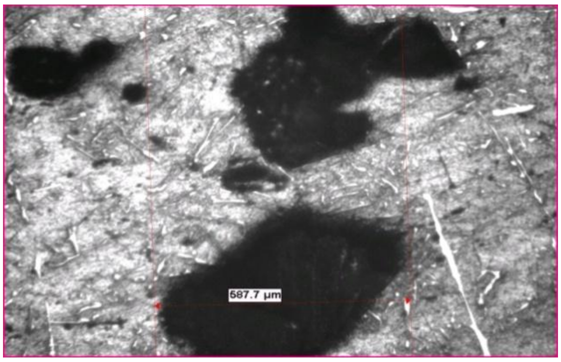
6.4.1 MICROSTRUCTURE OF D65 CASTING



50 X POROSITY

100X

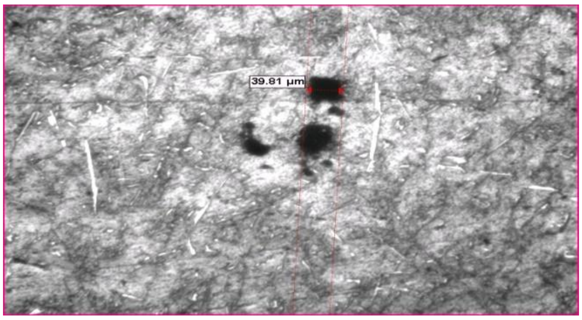
6.4.2 MICROSTRUCTURE OF D63 CASTING



50X POROSITY

100 X

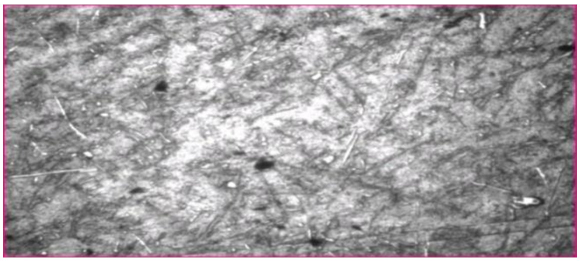
6.4.3 MICROSTRUCTURE OF D60S CASTING



50X POROSITY

100 X

6.4.4MICROSTRUCTURE OF D50SC CASTING



50 X POROSITY

100 X

6.4.5 POROSITY IN CASTING

When the riser condition is D65, it shows the limited porosity. Very fine pores are not seen which makes the casting sound. For D63, more porosity, Both dark and fine pores are seen which makes the casting unsound.

When the riser with insulating sleeve (D60S) is used, it shows significant reduction in porosity level as well as pore size (from 600 µm to 50 µm). Addition of sleeve has served to reduce porosity level and size.

When the riser with insulating sleeve and chill (D50SC) is used, pore size and porosity level have been reduced significantly.

Table 3 Soundness analysis for various combinations

Riser conditions	Riser diameter (mm)	Sound/Unsound In Experiment
Without insulating sleeve and chill	65	Sound
Without insulating sleeve and chill	63	Unsound
With insulating sleeve	60	Sound
With insulating sleeve and chill	50	Sound

7.CONCLUSION

- The optimized riser dimensions for a rectangular plate casting of size 240 x 150 x 25 mm with height of riser is H=1.5D for three conditions are
    - Without insulating sleeve and chill = **65mm**
    - With insulating sleeve = **60 mm**
    - With insulating sleeve and chill = **50mm**

  experimentally verified
- The obtained optimized riser dimensions from simulation results are verified experimentally for the soundness of the casting.
- When the insulating riser sleeve is used, the total volume of wastage is reduced by **19%** and when the insulating riser sleeve and chills are used, the total volume of wastage is reduced by **47%**. It is observed that the efficiency of the riser increases from **8%** to **17 %** for the rectangular double plate casting by using insulating sleeve and chill.
- When the chill is used, the level of porosity along the length of the casting is lowered to some extentand the location of maximum porosity shifts towards the riser. For the combination of chills and riser sleeve, it is observed that the riser volume is reduced by **52.5%** for this rectangular plate casting.
- From the experimental results it is proved that the ANSYS software can be utilized for identifying optimum riser dimensions.

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