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Affect of pouring temperature on volume deficit of US 413

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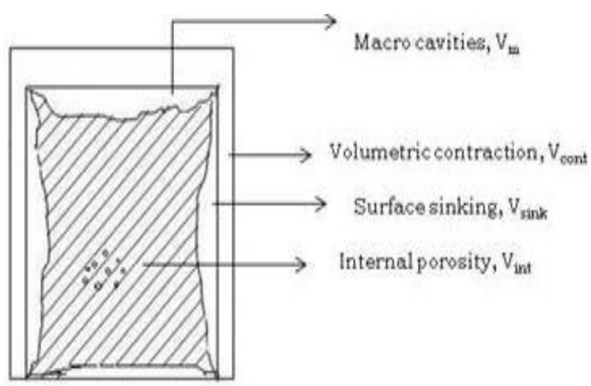
Abstract- US 413 (Al-12Si) alloy volume deficit characteristic has been studied in this paper. Influence of pouring temperature on volume deficit is studied and latter is addition of Macro cavities, Internal porosity, Surface sink and Volumetric contraction. The decrease in definite volume of molten metal leads to volume deficit in castings, and it can be envisaged as a casting defect. Volume deficit of a casting depends on casting material and casting conditions. Influence of pouring temperature and casting shape on the volume deficit characteristics are studied in this paper. Increase in pouring temperature lowers the rate of heat extraction by the mould thereby reducing volume deficit.

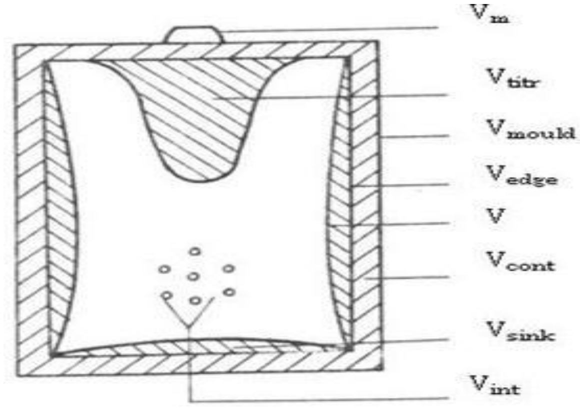
Key Words : Volume deficit, pouring temperature, Macro cavities, Internal porosity, Surface sinks, Volumetric contraction, Al-Si alloy

1. INTRODUCTION

Sand casting technique is the most cost effective and design flexible in foundry [1,2]. Cast Aluminium alloys (mostly Al-Si alloys) have wonderful combination of properties like excellent castability, mechanical properties, corrosion resistance, machinability, hot tearing resistance, fluidity and weldability resulting in a wide range of applications in automobile, aerospace and engineering industries [3]. Alloy 413 is an Al-Si eutectic alloy which solidifies at the narrowest range among all cast aluminium alloys. Castings produced from these alloys are usually pressure tight. The parameters which affect the volume deficit and shrinkage are [4, 5] Pouring temperature, Casting shape, Presence of chills, Alloy composition, Mould coat, Pouring time and Mould sand. The main technical factor which affects the size of a shrinkage cavity in a casting is the temperature of liquid metal poured into a mould [5]. The volume deficit classification and description has been given in Figure.1. Patterson and Engler [5] have classified the technical volume deficit into four types, namely macro cavities (Vm); internal porosity (Vint); Surface sinks (Vsink) and volumetric contraction, (Vcont). The main factor which affects the size of a shrinkage cavity in a casting is the temperature of liquid metal poured into a mould [6].Therefore, volume shrinkage changes when the temperature of liquid metal is changed in a relatively small range. Generally macro cavity takes the conical shape and is the last portion to be solidified in the casting [7]. The theoretically volumetric contraction is calculated as the sum of change in lengths of the casting in all directions [8]. Surface sinking in the casting occurs due to the variation in pressure between atmosphere and solidifying liquid metal in the casting. The microporosity forms due to poor mass feeding, difficulties in interdendritic feeding, low pore nucleation energy, low atmospheric pressure and high gas content or low gas solubility in the solid [9].



a. Classification of volume deficit



b. Categorization of volume deficit
Figure 1: Volume deficit

II. EXPERIMENTAL STUDIES

For the present study the process parameters considered are **pouring temperature** and **casting shape** for calculating the volume deficit of the US 413 (Al-12Si) alloy. The main technical factor which affects the size of volume deficit and shrinkage porosity in a casting is the temperature of liquid metal poured into a mould [5,10] and shape and relevant wall thickness of a casting. Casting shapes considered for the present investigation are [5]: cube (82 x 82 x 82mm)and cylinder (∅90 x 90mm). Pouring temperature (T) and Pouring temperature T+50 are considered. 4 experiments have been conducted for the present study and details are presented in Table 1. Diagram for the volume deficit experiment for cube shape casting is given in Figure 1.

Table 1: Experimental plan for volume deficit

Exp No.	Alloy	Pouring temperature (^{0}C)	Casting shape
1	US 413	T+50	Cube
2	US 413	T	Cube
3	US 413	T+50	Cylinder
4	US 413	T	Cylinder

The overflow core is placed over the mould in order to ensure that a fixed quantity of metal only is poured each time into the mould. The assembled mould, overflow core, pouring basin and other details for this experiment are shown in Figure. 2. The moulds are provided with dowel pins for perfect matching of cope and drag. Moulds are prepared with slight ramming. The patterns have been stripped after 3 hours. Moulds are prepared using green sand process consisting of Bentonite (5%-6% of sand weight) and water (5%-8% of sand weight). The moisture level is adjusted in such a way that compatibility is maintained between 45% and 50%, permeability is maintained between 400 and 500 and green compression strength is in the range of 700-900g/cm^2.

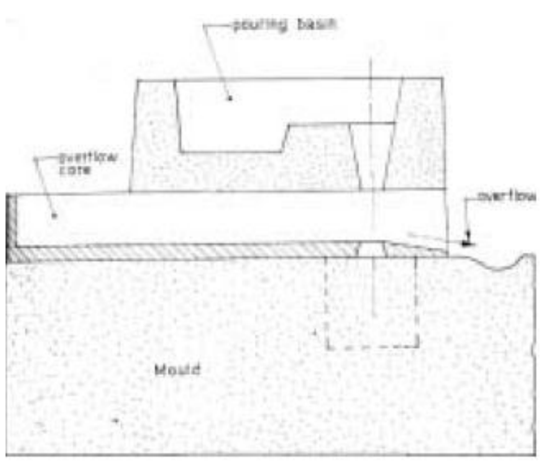


Figure 2: Diagram for the volume deficit experiment for cube shape casting

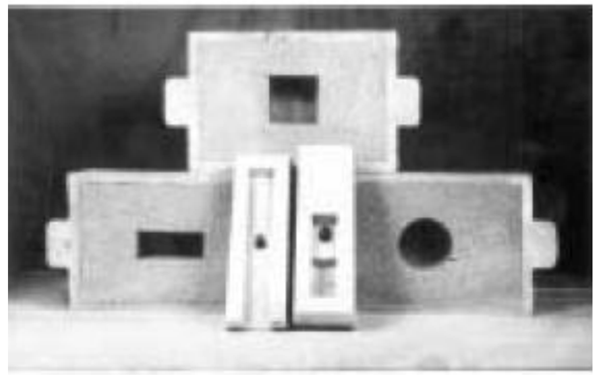


Figure 3: Details for experiment for volume deficit experiment

The mould hardness is in the range of 75-80 on B scale. The alloys are melted in an electric resistance furnace of capacity 20Kg provided with mild steel crucible. Temperature is measured with the help of a thermocouple. The furnace is put off and the crucible is lifted and put in a tilting device. The metal is tapped into a smaller crucible for pouring into the mould. The pouring height is maintained constant to avoid turbulence and difference in surface oxidation and oxide pick-up.

III. RESULTS

To minimise the casting defects information regarding the volume deficit and its distribution is critical. Test castings have been analysed to determine the volume deficit and its distribution by using the following procedure.

1. The test casting is taken out of the mould and the cone portion is cut off. The volume of the pipe is measured by keeping the casting under a burette and distilled water with wetting agent is dropped into the cavity till it is completely filled. The titration volume V_{titr} is read from the burette. The macrocavity, V_m is given by
   $$V_m = V_{cone} + V_{titr}$$
2. The average length, width and thickness of the test casting is measured using a vernier caliper
   $$V_{edge} = \text{length X width X thickness}$$
3. The weight of casting in air and water are determined using a sensitive balance of accuracy 0.001gm
   V = (weight in air – weight in water)
   The surface sink is given by $V_{sink} = V_{edge} - (V_m + V)$
4. The theoretical volume, V_{theor} is obtained as follows
   V_{theor} = Weight in air / Theoretical maximum density

is obtained from the chill specimen

The internal porosity V_{int} is computed as

$V_{int} = V - V_{theor}$

5. The volumetric contraction V_{cont} is calculated as

$$V_{cont} = V_{mould} - V_{edge}$$

V_{mould} is the volume of the mould which has been calculated before pouring.

6. The volume deficit is given by

$$\Delta V = \frac{V_m + V_{\sin k} + V_{cont} + V_{\text{int}}}{V_{mould}}$$

The volume deficit is calculated using the above formulae and given in table 2.

Table 2: Volume deficit values - US 413

Parameter, cc	**1**	**2**	**3**	**4**
Vshrink	21.46	26.56	30.609	34.65
Total volume deficit	0.0368	0.0455	0.05387	0.06
%Total volume deficit	3.67	4.55	5.39	6
%Vmacro	46.4	69	53.7	62.4
%Vint	1.9	1.9	0.8	1.6
%Vsink	6.8	6.9	3.2	4.1
%Vcont	44.75	24	40.14	33.4

3.1 Influence of pouring temperature

Additional pouring temperature or super heat increases the fluidity and considers the allowance for heat losses before they are in their final position in the mould. The influence of degree of superheat on the total volume deficit and its distribution is studied for pouring temperatures T and T+50°C. The volume deficit decreases with increase in pouring temperature as shown in Figure 4. The main factor which determines the size of a shrinkage cavity in a casting, is the temperature of metal poured into the mould. Pouring temperature has the biggest influence on porosity of a casting. With increasing pouring temperature the alloy remains in liquid state for longer duration due to higher heat content and hence the liquid metal is available to compensate the normal solidification shrinkage.

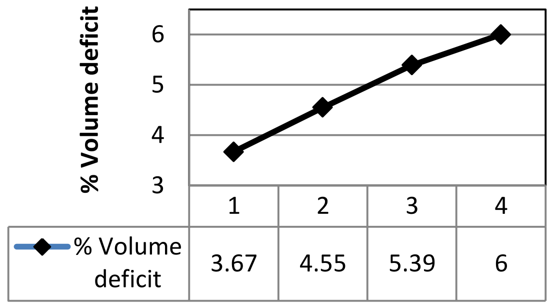


Figure 4: Influence of pouring temperature on volume deficit

The macro cavities V_m decrease with increase in pouring temperature for US 413 alloy as shown in Figure 5. With higher pouring temperature there is a lower rate of heat extraction by the mould and so the heat and feeding capacity of the molten metal increase there by influencing the freezing of the alloy. So the higher pouring temperature leads to decreased macrocavities. The pressure difference between the atmosphere and internal pressure in the interior of the casting is very low, which is the main cause for surface sinking [11,12]. The increase in pouring temperature increases the heat capacity of the molten metal, hence more quantity of liquid metal is available to fill the mould. The reduction in surface sinking is shown in table 2. The volumetric contraction increases with increase in pouring temperature. With higher pouring temperature the molten metal contraction in liquid state is more. This is due to the lower rate of heat extraction at the edges. Sinking surfaces draw the ends along with them, resulting in an evident decrease in the linear dimensions of the solidifying castings as shown in table 2.

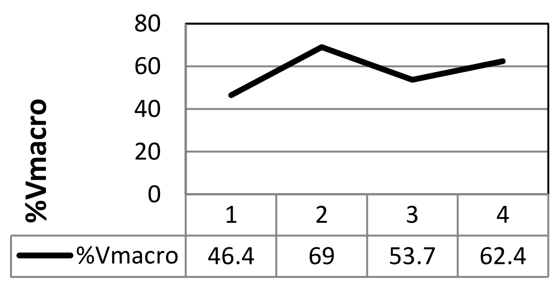


Figure 5: Influence of pouring temperature on macro cavities

IV. CONCLUSIONS

Increase in pouring temperature results in lower rate of heat extraction by the mould, there by liquid metal flows to solidifying leads to less amount of volume deficit. With increasing pouring temperature the alloy has high heat content, resulting in alloy being in liquid state for longer duration. So the liquid metal compensates the normal solidification shrinkage. Rate of heat extraction is lower at the edges and sinking surfaces draw the ends along with them resulting in an evident decrease in the linear dimensions of the solidifying castings.

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