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AN ANALYSIS OF VOLUME FLOW RATE AND MASS FLOW RATE IN MULTI-MATERIAL CASTING OF Al-Zn ALLOYS

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Abstract-The casting is the process of manufacturing in which the metal is brought in the liquid state and poured into the mold cavity then allowed to solidify. It takes the shape required for the particular material. Now a days research have been reached to a step where the demand of the complex properties are required under the affordable budget. The multi-material casting is one of the process that have been introduced here in this paper to get the various complex properties in a single object by using two or more materials. Typically such combinations of dissimilar materials provide desired properties in various areas of the single part. The volume flow rate and mass flow rate is the parameter that have not yet been studied for Al-Zn alloy. So the purpose of this paper is to bring the study of Volume flow rate and mass flow rate

***Keywords*- Mould filling time, Multi-material casting , Aluminium-Zinc alloys, Volume flow rate**

I. INTRODUCTION

The multi-material casting is the process in which two or more materials are mixed in a proportion so that they get mixed well and to produce the specific and complex properties . Nowadays, in industries it is very important to save time and money in manufacturing product, because there is competition in industrial sector. Vehicle construction and aerospace in particular demand solutions which save as much weight as possible while fulfilling identical or even greater requirements with regard to component properties, and which can be produced at low cost. Mould and pouring temperature is calculated by analysis of

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variance technique, this work shows that the selected technique is an effective tool for analyzing sand casting process [1]. In addition to saving weight, it has the added advantage of reducing bonding processes.
From above explanation we can identify the following needs of the multi-material casting:

- Light weight construction of the equipments.
- To satisfy more than single demand for any kind of application.
- To produce different mechanical properties in a single part of a machine.

The mould filling time is one of the important factor that plays an important role in the casting process. If the mould filling time will be predefined by some specific formulae then it will become easier to make calculation for the total time that may take to complete the process of casting. That may lead to find the manpower required. This can also be implemented in the automation if the specific formula isdefined . The mould filling time is used to calculate the mass flow rate and volume flow rate. Then the graph will be plotted for both the parameters for Al-Zn alloys. So that The process can be carried out to evaluate the same or other parameters for the same materials.

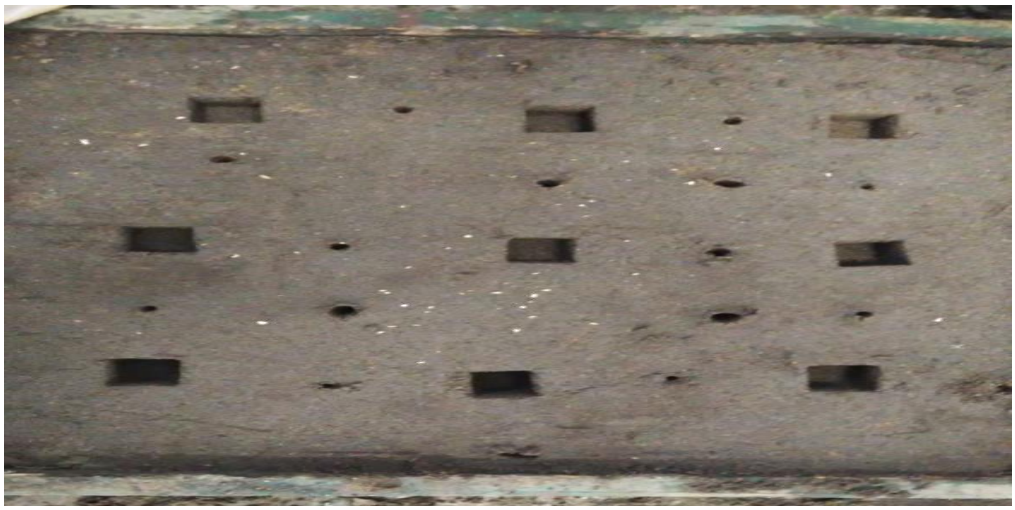

Figure 1 Sand mould cavity

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II. Methodology

The process involved in the multi-material casting is described that gives the complete steps that needs to accomplish the above process. Before applying this method we need to take a great care of the material that we are going to use for any of the specific purpose. The properties of the materials play a vital role in to produce a desired effect in the application defined.

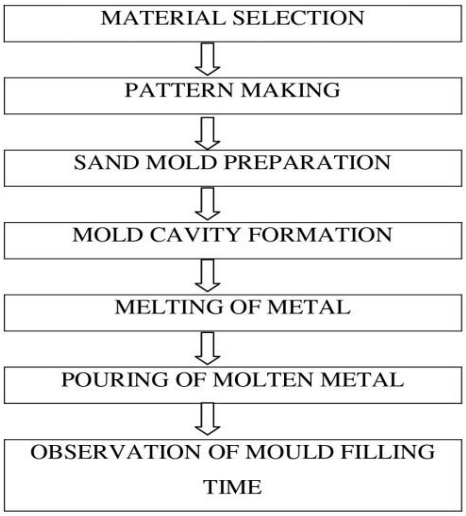

Figure 2 Multi-material casting process.

A. Material selection

Material selection is a one of the challenging task in the multi-material casting process. It arises numbers of question in the actual practice. Because the combination of any of two or more material need a deep study for its physical , chemical and mechanical properties.

The material used here by studying theproperties is given in table 1 and 2 for Al and Zn respectively. Aluminium is the most common element in the earth crust and exists as aluminium oxide. It possesses some peculiar properties such as high resistance to corrosion, ease of fabrication, high thermal and electrical conductivity, low weight and bright colour. Aluminum alloy casting has melting temperature of 660°C and its pouring temperature range is between 649°C to -750°C. The knowledge of melting temperature of metals and alloys is necessary to estimate their corresponding pouring temperature.

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Table I Properties and Specification of Aluminium

Sr. No.	Properties of Material	Material Specification
1	Density	2700 kg/m^3
2	Strength	310 MPa
3	Corrosion Resistance	High Resistance
4	Thermal Conductivity	237 W/Mk
5	Melting Point	660^{0}C

Table II Properties and Specification of Zinc

S.No.	Properties of Material	Material Specification
1	Density	7100 Kg/m^3
2	Strength	200 MPa
3	Corrosion Resistance	High Resistance
4	Thermal Conductivity	115 W/mK
5	Melting Point	419.58^{0}C

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B. Pattern making

The pattern is the principal tool during the casting process. It is the replica of the object to be made by the casting process. The figure shows the replica of the casting to be produced.

Figure 3 Pattern

C. Preparation of sand moulding

First of all moulding sand was produced when the sand of known specification is mixed with water to foundry. Mould boxes were produced using wood as shown in figure 4. The drag was placed on a flat wooden board and then a cylindrical pattern placed on the board. The moulding sand was added to the pattern and rammed, properly. When properly rammed, the mould box containing the pattern was turned upside down and the parting sand was applied. The cope was place on the drag and care was taken to ensure proper alignment.

Figure 4 Mould box

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1) Green sand mould

Green sand is also known as tempered or natural sand which is a just prepared mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous. Green sand is damp, when squeezed in the hand and it retains the shape and the impression to give to it under pressure as shown in figure 5. Molds prepared by this sand are not requiring backing and hence are known as green sand molds.

Figure 5 Green sand mould

D. Mould cavity formation

Green sand mixture is filled into the mould box then it is pressed using mechanical tools . Thereafter when it becomes very smooth surface ,the pattern is pressed into the mould then the replica of the pattern is formed . The same process is being repeated and the small holes are produced to create vents into the mould to keep the smooth surface inside the mould cavity as shown in figure 1.

E. Melting of metal

The various combination of the metals in the specific proportion by weight is taken into a crucible and it is placed in the furnace The furnace gives the higher temperature as required by burning the cokes inside. The process includes melting the charge, refining the melt, adjusting the melt chemistry and tapping into a transport vessel.

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Figure 6 Furnace

Figure 7 Melting of metal

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F. Pouring of molten metal

When the metal is melted completely it comes into the liquid state .The molten metal from the crucible is put into the vessel having circular cross section so that constant flow rate can be maintained. Pouring can be accomplished with gravity, or it may be assisted with a vacuum or pressurized gas.

Figure 8 Pouring of molten metal

G. Observation of the mould filling time

The volume flow rate of the molten metal can be calculated by taking theobservation of the time for complete filling of the mould cavity for specified volume. Here the volume of the cavity is 15.625 cm^3 and time that took to fill the cavity is given in the table III.Now again preparing the table for the volume flow rate by using the data mentioned above for filling time of specified volume.

III. CALCULATIONS

The calculation for the desired parameters is made by using the 21 samples of different composition of aluminium and zinc in their alloy. Starting from 100% Al & 0% Zn , 95% Al & 5% Zn ……till 0% Al & 100% Zn. The mould filling time has been studied carefully and is described by tables ,figures, curves etc. Then final conclusion is analysed to obtain a unique output.

The formula for volume flow rate and mass flow rate are-

1. Volume flow rate = volume of the mould cavity / time taken to fill the mould

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2. Mass flow rate = mass of the material in the cavity / time taken to fill the mould

Table 3 Volume flow rate and mass flow rate of Al-Zn alloy

S. No.	Percentage Amount (in %)		Average Mould Filling Time (T_{avg}) in Sec	Volume of the mould cavity in cm^3	Volume Flow Rate of molten metal in cm^3/s	Weight of the product (in gm)	Mass Flow rate Of molten metal (in gm/sec)
	Al	Zn					
1	100	0	4.76	15.625	45	3.282	0.689
2	95	5	4.66	15.625	46	3.353	0.719
3	90	10	4.46	15.625	48	3.503	0.785
4	85	15	4.43	15.625	50	3.527	0.796
5	80	20	4.26	15.625	51	3.667	0.860
6	75	25	4.03	15.625	53	3.877	0.962
7	70	30	3.9	15.625	55	4.006	1.027
8	65	35	3.8	15.625	56	4.111	1.081
9	60	40	3.65	15.625	58	4.280	1.172
10	55	45	3.45	15.625	60	4.528	1.312
11	50	50	3.26	15.625	63	4.792	1.469
12	45	55	3.03	15.625	65	5.156	1.701
13	40	60	2.81	15.625	69	5.560	1.978
14	35	65	2.81	15.625	72	5.560	1.978
15	30	70	2.75	15.625	76	6.681	2.429
16	25	75	2.55	15.625	86	6.127	2.402
17	20	80	2.49	15.625	89	6.275	2.520
18	15	85	2.41	15.625	93	6.483	2.690
19	10	90	2.28	15.625	99	6.853	3.005
20	5	95	2.07	15.625	104	7.548	3.646
21	0	100	1.85	15.625	110	8.446	4.565

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IV. RESULTS AND DISCUSSIONS

The table 3 indicates the mould filling time of the mixture of Zn and Al by varying percentage .From the above data we observe that the average pouring time is decreasing with increase in % of Zn in Al-Zn alloy. The curve is drawn below by using the above data of pouring time.

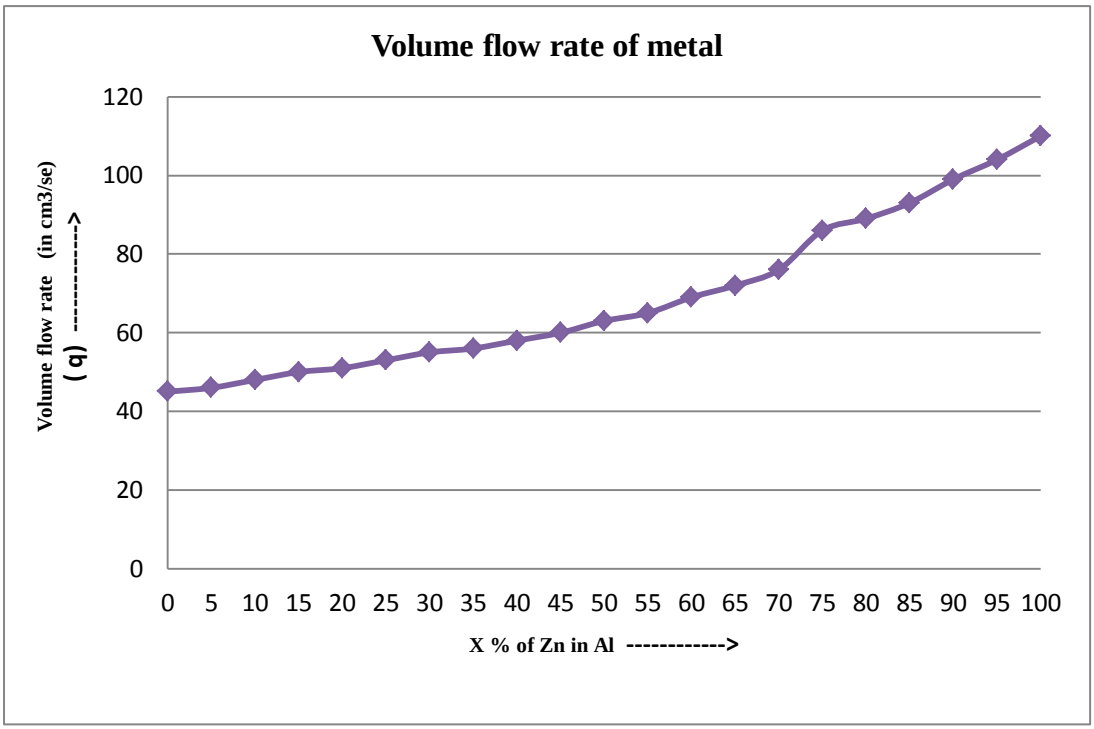

Figure 9 Volume flow rate of the material

The equation of curve is obtained by the graph traced in the figure 9 This equation can be used to obtain the volume flow rate for each sample of Zn and Al alloy. The same process can be used to establish the equation for other combination of material

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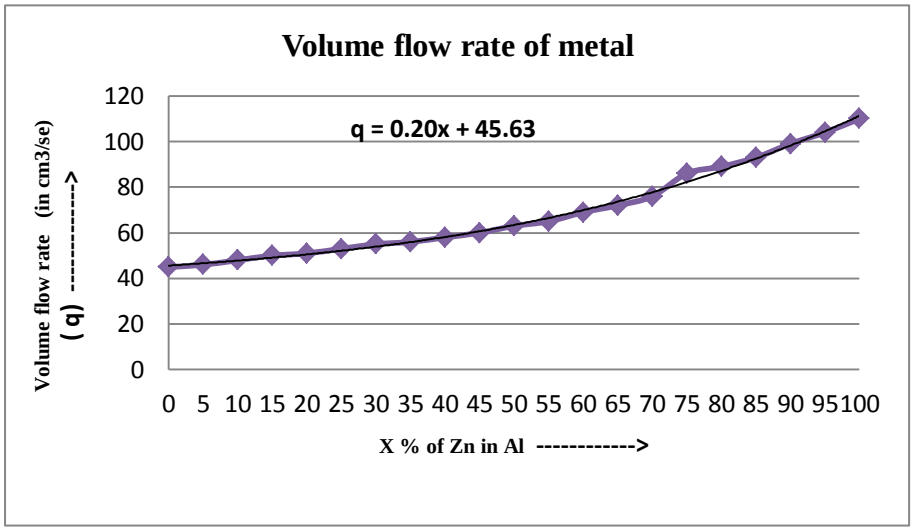

Figure 10 Equation of curve for volume flow rate of the material

The curve drawn above here the curve is drawn between the mould filling time denoted by (t) which is indicated in vertical axis and percentage of Zn in Al-Zn alloy

Volume flow rate q = 0.20x + 45.63

Figure 11 Mass flow rate of the material

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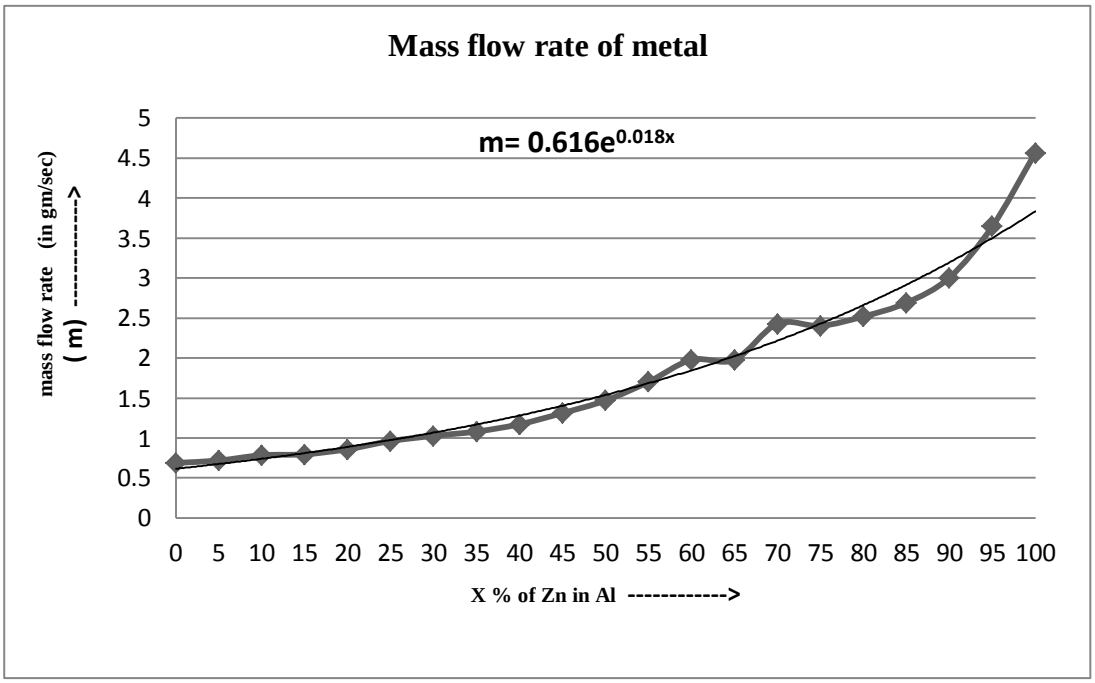

The equation generated from the graph is given below and this equation will help to estimate the mass flow rate for any sample for any percentage of zinc in Al –Zn alloy.

Mass flow rate of the material (m) = $0.616e^{0.018x}$
Where x is the percentage of zn in Al alloy

This kind of equation can be generated for other combination of material.

V. CONCLUSION AND FUTURE WORK

It is performed the experimental analysis on casting of Al-Zn alloy .By varying the percentage of Zn in alloy the following parameters have been studied and reached to the conclusion that may lead to enhance the properties of material to fulfill the desired requirement .

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- Volume flow rate – When the amount of Zinc in the aluminium-zinc alloy increases then the volume flow rate of the material also increases. The following equation can be used to find the volume flow rate for any sample.

Volume flow rate q = 0.20x + 45.63

- Mass flow rate – When the amount of Zinc in the aluminium-zinc alloy increases then the mass flow rate of the material also increases. The following equation can be used to find the volume flow rate for any sample.

Mass flow rate of the material $\mathbf{m = 0.616e^{0.018x}}$

Future work- The Desired property can be produced as per design requirement in multi- material casting by using two or more material that the single material can not produce which may fulfill exact need. So further the numbers of materials can be taken to get the specific desirable properties in a single object. Other materials can be used for obtaining the basic parameters such as mould filling time , solidification time , volume flow rate , mass flow rate etc. in multi-material casting.

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