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AN ANALYSIS OF SOLIDIFICATION TIME IN MULTI-MATERIAL CASTING OF Al-Zn ALLOYS

Vijay Kumar Nishad[1], Lokesh singh[2], Sushil Kumar Maurya[3]

[1]*GD Rungta College of engineering and Technology Bhilai ,Chhattisgarh ,India*

[2]*GD Rungta College of engineering and Technology Bhilai ,Chhattisgarh ,India*

[3]*Modern Institute of Technology & Research Centre,Alwar,Rajasthan ,India*

[1]*vjy.nishad@gmail.com;* [2]*lokeshsingh25@gmail.com;* [3]*mauryasushil86@gmail.com*

***Abstract*-Casting is a suitable economical manufacturing process for various components. The multi-material casting is the process in which two or more material are mixed in a proportion to get some specific properties. Whenever a single material does not satisfy the demands of a specific application, multi-material casting may generate a solution. Especially in light weight construction, a multi-material-mix can provide ideal specific properties that are suitable for the conditions to which a part is subjected. Typically such combinations of dissimilar materials provide desired properties in various areas of the single part. The solidification time is the parameter that have not yet been studied for Zn-Al alloy as per research paper found. The time from the pouring to the completion of solidification is known as the total solidification time. The purpose of this paper is to make analysis on the solidification time in multi-material casting of the Al-Zn alloys. The result obtained can be used for analyzing the solidification time for such another alloy**

Keywords: **Solidification time, Multi-material casting, Aluminium-Zinc alloys.**

I. INTRODUCTION

Casting is one of the oldest manufacturing processes, and even today is the first step in manufacturing most products in industries. The lightweight construction philosophy is based on the principle of making the best possible use of the material.[2] The multi-material process involves the mixing of two or more materials to produce desired mechanical properties so as to make it utilize in the place where the use of expensive material can be minimized. 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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Vol.6 Issue.9,
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Pg: -126-137

variance technique, this work shows that the selected technique is an effective tool for analyzing sand casting process [5]. In this paper The solidification time is going to be calculated in which the time from the pouring to the Phase change i.e. liquid to solid needs to be noted. 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 increase in the mould and pouring temperature increases ultimate strength ,hardness and elongation.[4]. In previous research it is found that for multi-material cast product in Mg –Al alloy have been performed for the non-destructive tests such as X-ray diffraction, optical microscope etc. This paper deals with the solidification time for the Al-Zn alloy.

Figure 1 Sand mould cavities and solidified Al-Zn alloy

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Vol.6 Issue.9,
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Pg: -126-137

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.

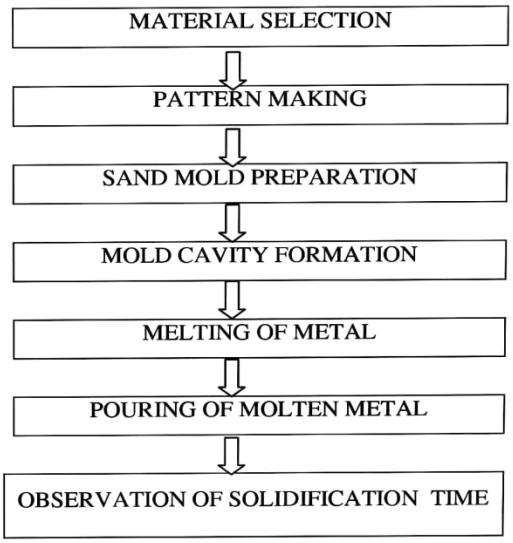

Figure 2 Multi-material casting process

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 the properties 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

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.

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Vol.6 Issue.9,
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Pg: -126-137

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.

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Vol.6 Issue.9,
September 2018
Pg: -126-137

Figure 4 Mould box

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.

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Vol.6 Issue.9,
September 2018
Pg: -126-137

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.

Figure 6 Furnace

Figure 7 Melting of metal

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Vol.6 Issue.9,
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Pg: -126-137

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 mould filling time is the time taken to fill the mould cavity from the constant cross –section provided in the discharge vessel. The mould filling time can also be termed as the pouring time. The stop watch is used to count the time .This time is being noted down for getting mass flow rate and volume flow rate etc.

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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.

Table III Solidification time for Al-Zn Alloy

S. No.	Percentage Amount (in %)		Solidification Time (T_1) in Sec	Solidification Time(T_2) in Sec	Solidification Time(T_3) in sec	Average Solidification Time, (T_f)avg (in sec)
	Al	Zn				
1	100	0	2min. 41 sec	2min. 40 sec	2min. 41 sec	2min. 40.6 sec
2	95	5	2min. 42 sec	2min. 42 sec	2min. 42 sec	2min. 42 sec
3	90	10	2min. 43 sec	2min. 42 sec	2min. 40 sec	2min. 41.6 sec
4	85	15	2min. 43 sec	2min. 41 sec	2min. 43 sec	2min. 42.3 sec
5	80	20	2min. 47 sec	2min. 43 sec	2min. 43 sec	2min. 44.3 sec
6	75	25	2min. 48 sec	2min. 46 sec	2min. 49 sec	2min. 47.6 sec
7	70	30	2min. 52 sec	2 min. 49 sec	2min. 46 sec	2min. 49 sec
8	65	35	2min. 57 sec	2 min. 53 sec	2min. 46 sec	2min. 52 sec
9	60	40	2min. 46 sec	3min. 0 sec.	2min. 59 sec	2min. 55 sec
10	55	45	3min. 5 sec	3min. 7 sec	3min. 2 sec	3min. 4.6 sec
11	50	50	3min. 4 sec	3min. 7 sec	3min. 4 sec	3min. 5 sec
12	45	55	3min. 4 sec	3min. 6 sec	3min. 7 sec	3min. 5.6 sec
13	40	60	3min. 4 sec	3min. 7 sec	3min. 9 sec	3min. 6.6 sec
14	35	65	3min. 5 sec	3min. 7 sec	3min. 10 sec	3min. 7.3 sec
15	30	70	3min. 5 sec	3min. 9 sec	3min. 9 sec	3min. 7.6 sec
16	25	75	3min. 7 sec	3min. 9 sec	3min. 9 sec	3min. 8.3 sec
17	20	80	3min. 7 sec	3min. 11 sec	3min. 9 sec	3min. 9 sec
18	15	85	3min. 9 sec	3min. 10 sec	3min. 9 sec	3min. 9.3 sec
19	10	90	3min. 9 sec	3min. 10 sec	3min. 10 sec	3min. 9.6 sec

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20	5	95	3min. 10 sec	3min. 11 sec	3min. 11 sec	3min. 10.6 sec
21	0	100	3min. 12 sec	3min. 11 sec	3min. 12 sec	3min. 11.6 sec

IV. RESULTS AND DISCUSSIONS

The curve gives the clear indication from figure 9 that while increasing the amount of Zn in Al –Zn alloy it will always raise the solidification time in case of this material.After the analysis of the solidification time the structure and the best mixing proportion is found .So that the concept of multi-material will help to obtain the desire properties in affordable economy. The study of mould filling time and solidification time together can be utilized to establish the relation between them.

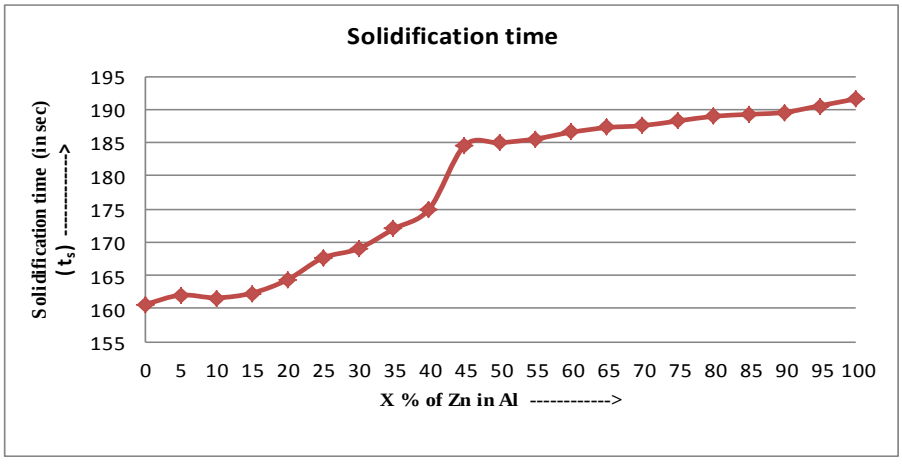

Figure 9 Solidification time curve

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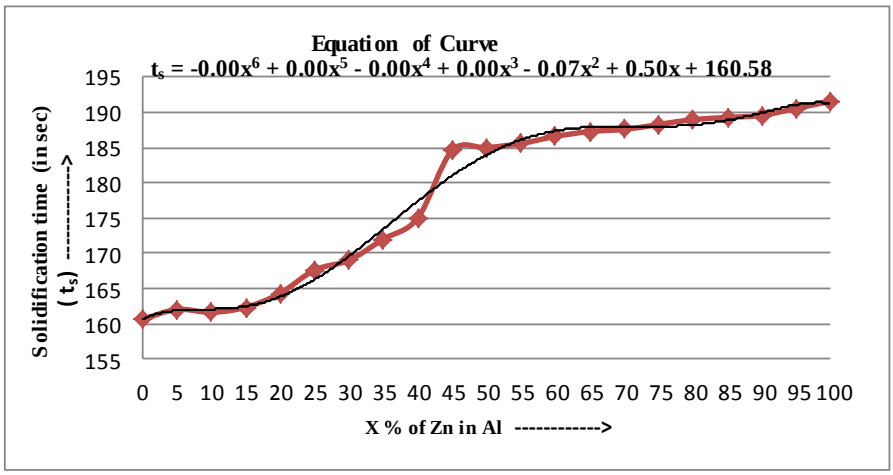

Figure 10 Solidification time curve equation

The graph obtained by using the data in table III gives the following equation

Solidification time, $t_s = -0.00x^6 + 0.00x^5 - 0.00x^4 + 0.00x^3 - 0.07x^2 + 0.50x + 160.58$

This equation can be written also be written as-

Solidification time, $t_s = -0.07x^2 + 0.50x + 160.58$

This is the polynomial equation of order 2 where x is the percentage of Zn in Al –Zn alloys .By using this equation the time for any percentage of Zn in Al-Zn alloy can be calculated.

V. CONCLUSION AND FUTURE WORK

Solidification time –It is found that When the percentage of Zn is increased in Al-Zn alloy the solidification time increases. Direct calculation of the solidification time can be obtained for all composition by the given equation below.

Solidification time ($t_{s)} = -0.07x^2 + 0.50x + 160.5$

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 Other materials can be used for obtaining the basic parameters such as solidification time, volume flow rate , mass flow rate etc. in multi-material casting for other materials.

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Vol.6 Issue.9,
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Pg: -126-137

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