Developing an Effective Die for aluminium alloy Casting Solidification

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Abstract: Aluminium metal matrix composites have encountered a massive development due to the wide range of application for its high mechanical properties, high corrosion resistances and low density. Several manufacturing methods have been used to fabricate them such as ex-situ and in-situ. One of the most widely used ex-situ method is Stir casting. This method has the advantages of obtaining uniform density, fine grain size, clear interface and thermodynamic stable of reinforcements as compared with other fabricating process. During the fabrication of aluminium alloy composite by stir casting method cooling of molten metal is very difficult to control because thermal characteristic of the die affect the properties of casting material. In this study an attempt is made to design a die for aluminium alloy casting to achieve best properties of casting metals.

Index Terms— *Aluminium alloy, stir casting, die, cooling rate*
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1 INTRODUCTION

Particle reinforeced aluminium alloys matrix have become very attractive for automotive and aerospace application. Particulate form of reinforcement present in the composite exhibits excellent mechanical properties, wear resistance, corroosive resistance and high heat stability [1-2]. Commonly reinforcement particles such as carbides or nitrides are used to improve the mechanical properties and structural properties of the alumninium alloys composite materials. The reinforcement particles reacted with material alloying ingredient and particle dispersion make the composites thermodynamically and chemically stable [3-4].

Aluminium matrix composite material manufactured by different process such as powder metallurgy, ball milling, squeeze casting, spray casting, stir casting and friction stir processing, depending upon the nature, size and morphology of reinforcement particles. In the casting process the reinforcement particles are reinforced in the melt of aluminium matrix under atmospheric pressure or inert gas environment with the help of a mechanical stirrer. In case of powder metallurgy, uniform mixture of reinforcement particles and metal matrix powder are compacted in a punch die assembly, after that subjected to sintering. In ball milling process a homogeneous material is obtained by mixing the matrix powder and reinforcement particles powder in a vial with the help of grinding medium such as ceramic balls or hardened steel balls. Friction stir processing used to refine the microstructure; in this, the composites are manufactured when the metal matrix is in a solid state condition . Among these conventional stir casting is one of the most commonly used processes with advantage of low cost, wide range of material and processing conditions with better bonding of metal matrix with reinforcement particles because of stirring action [5-8].

In stir casting process, die play an important role to achieve the best properties of aluminium alloys composite materials. The die performs two basic functions in making the casting: It imparts shape and it removes heat. Heat removes is more difficult to control because the thermal characteristics of the die affect so many aspects of the process such as die surface must cool the metal rapidly, die temperatures should be fairly uniform and casting should eject with a relatively uniform temperature. Narayan et al [13] developed a model to compute the interfacial heat transfer coefficient using a model considering both conduction and radiation based on surface roughness characteristics of the casting and the mold. Griffiths [14] revealed that thermal stress produced during solidification deformed the initial skin of the casting.. Eduardo [15] performed experiments in a cylindrical stainless steel chill to understand the behaviour of casting-mold heat transfer coefficient. Incropera [16] showed that increasing contact pressure or reducing the surface roughness can lead to greater contact area thereby reducing the contact resistance. Stavros [17] made comparison between effect of air and helium on heat transfer at casting mold interface. The aim of this study to design a die for aluminium alloys casting in order to maintain uniform temperature and to enhance mechanical properties of casting composite. We use finite element method to calculate steady die temperature. Finite element method provides a powerful analytis for a large class of die casting and permanent mold processes.

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2 THEORTICAL ANALYSIS

In this approach, first we select size of our composite sample to formulate the general heat conduction problem for steady state die casting. Heat conduction is generally defined as the determination of heat flux from measured transient temperature inside a heat conducting. We consider three-dimensional region in the die cavity as shown in figure1. The boundaries of the die components are divided into two surfaces: the *cavity surface*, where the die is in contact with the molted metal and outer surface of die which is exposed in atmosphere. The temperature at any point in the cavity surface is taken as 650° for aluminium alloy casting and outer surface temperature is 25°.

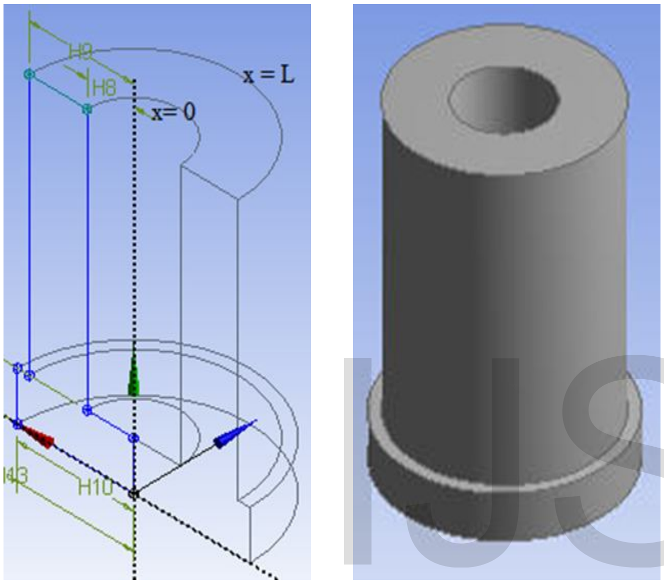


Figure1: schematic diagram of die

3 METHODOLOGY

The heat conduction problem in the casting and transient surface layers is formulated by generalizing equation of heat transfer. The material used for die material is stainless steel because it has good properties to heat transfer and retain its mechanical properties at high temperature. Thermal conductivity of steel is designated by k_s, mass density by ρ_s, heat capacity by c_s, and thermal diffusivity by $a_s = k_s / \rho_s c_s$.

$$\frac{\partial}{\partial x}\left(k_s \frac{\partial T}{\partial t}\right) = \rho_s c_s \frac{\partial T}{\partial t} in\ 0 < x < L for t > 0$$

$$-k_s \frac{\partial T}{\partial t} = f(t) at x = 0 \qquad for t > 0$$

$$T = T_L \qquad at\ x = 0 \qquad for\ t > 0$$

$$T = F(x) \qquad for\ t = 0 \qquad in\ 0<x<L$$

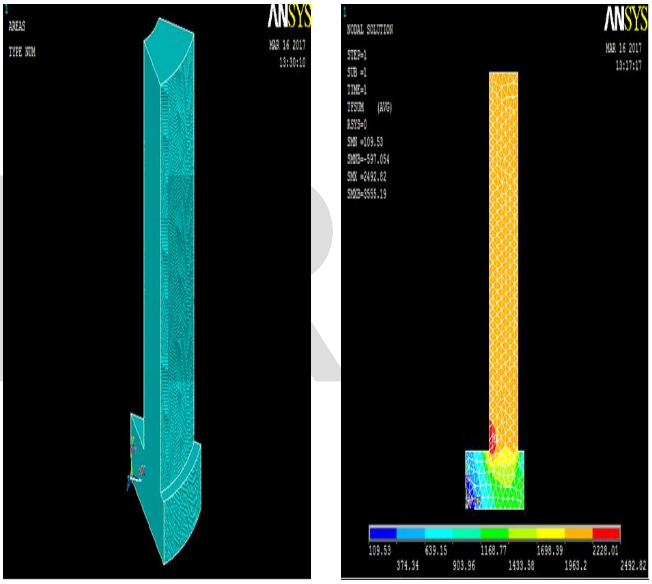
The heat conduction problems in the casting and the die are governed by the fundamentally differential equation. Heat transfer at the casting mold interface can be calculated by the finite element method by using ANSYS 14.0 tool. For simplification firstly we consider quadric element of die casting as shown in gfigure 2.

TABLE 1

UNITS FOR MAGENTIC PROPERTIES

Mesh Data	
Material	Stainless steel
Total number of nodes	7801
Total number of element	4879
Bodies	2

Initial condition	
Melt temperature	650°C
Initial temperature	22°C
Mold	Adiabatic

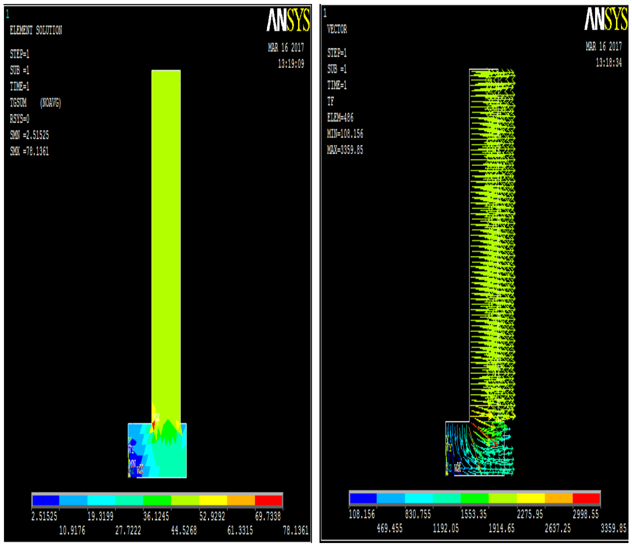


Geometry (b). Meshed form

Figure 2: Quadric element of die

4 RESULTS AND DISCUSSION

Figure 3 shows the simulated temperature distribution and total heat flux flow of die element. Note that the color contours are different at inner surface and same color at the outer surface. The analysis revealed that the surface temperature accurately simulates and maintain the uniform temperature of die during the pouring of aluminium alloys composite molten metal.



(a). Temperature Variation **(b). flux flow**

Figure 3: temperature distribution and flux flow of die element

Figure 4 shows the simulated flux and total heat flux flow of the die. The analysis showed that flux and total flux vary with the area of the die and become more uniform at outer surface of the die. The value of flux and total flux vary from 1.553 ×107 to 1.725 ×106 W/m2 and 1.052×107 to 1.170×106 W/m2 respectively.

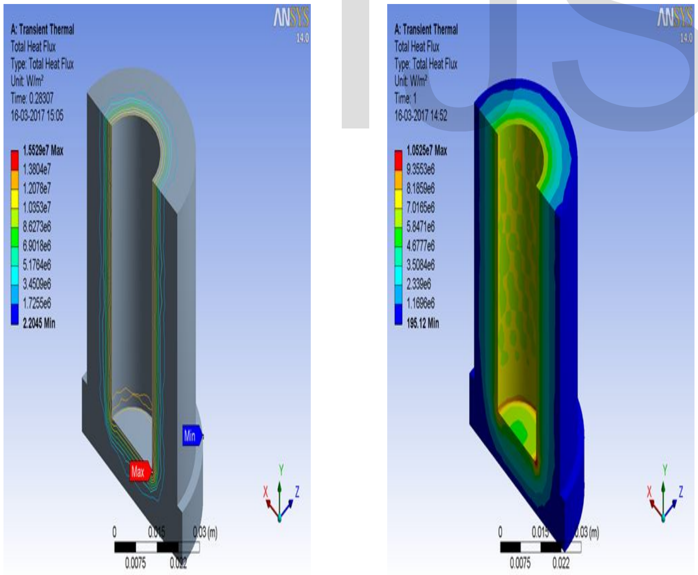


Figure 4: flux and total heat flux flow in die

Figure 5 shows the graphs heat flux and total heat flux values with respect to time. It was observed that the values of heat flux and total heat flux decreased at rapidly rate and become constant with respect to time in a short interval period of time.

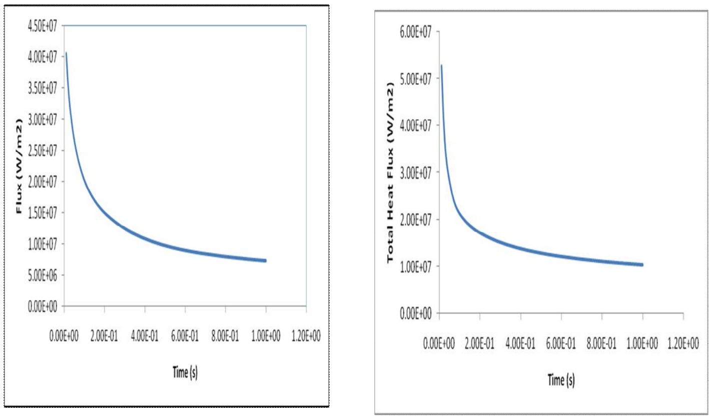


Figure 5: Graphs show flux flow and total heat flux flow with respect to time

Figure 6 shows variation of temperature of die with respect to time. It was revealed that the temperature of die varies rapidly when the molten metal is poured in the die and remains constant with respect to time. It was observed most of heat transfer take place at the pouring time and which heat up the die material. The die should be designed in such a way that it maintains the die temperature constant with short interval of time to enhance the mechanical properties of aluminium alloy material which was achieved as shown in graph. Figure 7 shows the thermal error variation with respect to time. It was observed that the thermal error decreased with respect to time.

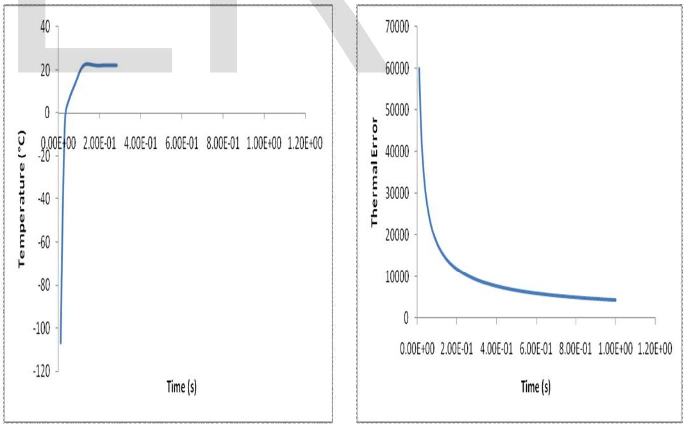


Figure 6 shows variation of temperature of die with respect to time.

4 CONCLUSION

In this paper the analysis was done by considering the cylindrical mould die for aluminium alloy casting. The die is designed in such a way as to maintain the uniform temperature gradient and achieve uniform cooling during the fabrication of composites material. The finite element method is applied for the analysis of design model. The analysis shows that die temperature remains uniform and constant in a short interval of time during the fabrication of composite.

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