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Effect of Die Geometry on Thermal Analysis of Aluminium Alloy (ADC12 Aluminium A383) using Pressure Die Casting Process

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ABSTRACT

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Dies for aluminium alloys die-casting fail because of a great number of different and simultaneously operating factors. Some of them may be controlled to some extent by the die-casting experts. In the process of the die-casting the primary source of loading is cyclic variation of the temperature; the influence of other loads is relatively insignificant. The replacement of a die is expensive in both: money and production time. The die design, the material selection and the process thermal stress which is the consequence of the working conditions, the inhomogeneous and to low initial temperature of the die, contribute to the cracks formation. The size and location of cooling channels relative to the surface of the die, which affect the thermal stresses of dies. This work focus on thermal analysis of Aluminium alloy pressure die casting process and analyses the effect of coolant channel location on temperature distribution using ANSYS Workbench 17.1 finite-element package.

Keywords : Aluminium alloys, Die-casting, Thermal, Temperature distribution.

I. INTRODUCTION

Die casting is a very cost-efficient method of forming thin walled and complex near net-shaped products with geometric tolerances and good surface finish. Low melting point alloys based on aluminium, zinc, magnesium and copper are frequently used. Many different types of products are manufactured by die casting such as engine blocks, cylinder head covers, valves, Pipe coupling etc. and other components for the automotive industry and for heating etc. In die casting, large numbers of identical products are produced using one die, which is necessary, since the die is very expensive. Any kind of tool failure that causes rejection of casting and extra tool maintenance increases the production costs. The overall aim of this work to development of better tool materials for die casting. Die Casting tools are exposed to thermal mechanical and chemical conditions during each casting cycle. Thermal cracking in die casting of aluminium alloy, since the temperature of the melt is high.

1.1 Die casting : Die casting process is that the liquid metal is forced by the application of pressure to flow with high velocity during injection and completely and rapidly fill an internally cooled mould, typically within the order of milliseconds. The high melt velocity during injection and the continuous internal cooling of the tool during the process allows production of thin-walled net-shaped cast products at high manufacturing rates. The complexity of the castings and the manufacturing rate are considerably beyond those provided by the permanent mould (gravity) casting process.

There are two principal types of die casting machines, either classified as hot chamber or cold chamber machines. In the hot chamber machine process, the liquid metal injection mechanism is submerged in the molten metal, and the cylinder is automatically filled with metal prior to each casting operation when the injection plunger rod is withdrawn. This process is typically applied for low melting point casting alloys, which cause the minimum of attack on the injection system material during the contact with the liquid metal. In the cold chamber machine process, the injection mechanism is separated from the molten metal, and the cylinder is filled with metal prior to each casting operation using a ladle. The cold chamber process minimises the liquid metal exposure of the injection system components, and it is normally applied for casting alloys with higher melting points, e.g. aluminium alloys.

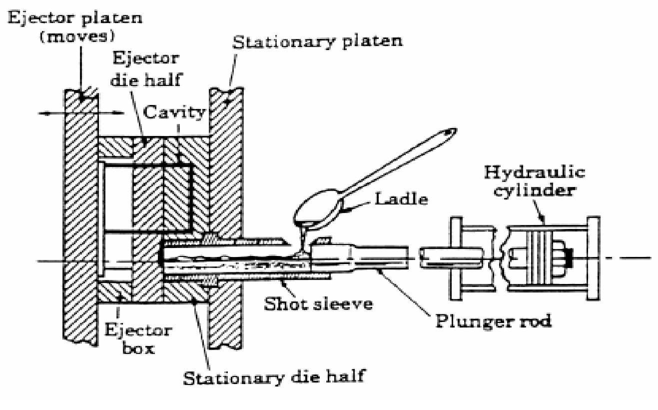


Fig.1.1: Cold-chamber die casting

1.2 Die-Casting failure mechanism : Aluminium alloys castings which are produced all through the world by the use of gravitational die casting or high pressure die casting is used in different automotive parts and consumer goods. One of the major concerns in die casting is the durability of die materials/surface when they are exposed to pressurised casting process during filling, high temperature molten aluminium flow, and solidification and die holding stages. In die casting process, the molten aluminium alloy is injected into die cavity at high speed of 30-100 m/s at temperatures between 670 – 710 ^{0}C and injection pressure of 50-80 MPa. Several failure modes appear on aluminium die casting surface such as soldering effects, washout gross-cracking and thermal cracking which happen in effect of heat checking. Die-casting dies are high mechanical and thermal loads. Thermal cracking of dies which is caused by thermal cycling might considerably reduce the die lifetime. Cracks reduce the surface quality of dies and consequently the surface of castings will decline. During the process cracks are identified and their size and location are measured. Thermal and mechanical loads produce high local stresses which make the surface to crack.

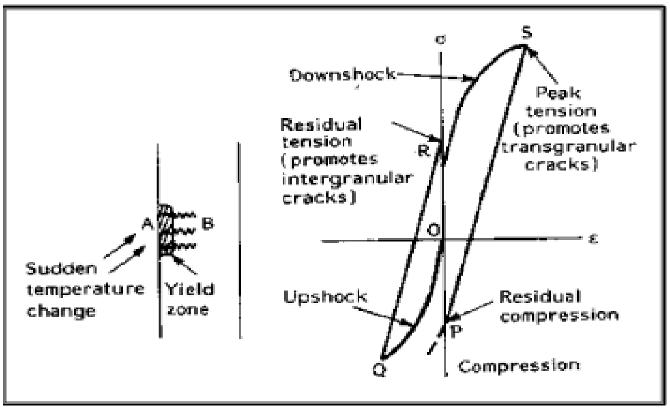


Fig.1.2: Hysteresis loop at the surface of a material subjected to cyclic heating cooling

1.3 Thermal in Die-Casting : The thermal resistance of aluminium alloy can be studied through high-pressure die-casting process. The mechanical properties of the material grow instable in result of heating the die material. The thermal stresses, which take place in the die, develop from the thermal gradient across the die area. The thermal gradient is made in the result of the heating and cooling of the surface during the injecting stages of the casting cycle. With an increase in the temperature, the yield strength of the material is lowered and the compressive strains might grow plastic. The surface temperature decline quickly once a flow of heat is conducted to the lower layers. When the casting is ejected, cooling the surrounding from the surface help to decrease the surface temperature. If the surface cools more than the interior, the compressive strain are released and tensile strains might be produced.

1.4 Thermal Stress in Dies-Casting: The thermal stresses, which take place in the die, develop from the thermal gradient across the die area. The thermal gradient is made of the heating and cooling of the surface during the ejecting, injecting stages of the casting cycle. When the molten aluminium is injected into the die, the die surface heats up as opposed to the cooler mass of the die. When the casting is ejected, cooling the surroundings from the surface, and further decreasethe surface temperature.

II. Material Properties

In our investigation work a complex analysis of a typical dies for die-casting of aluminium alloys (ADC12 ALUMINIUM A383). The material used in the object is high pressure die casting of aluminium alloys. Aluminium alloy (ADC12 ALUMINIUM A383)with the composition shown in table 2.1

Table 2.1: Chemical Composition of Aluminium Alloy (ADC12 ALUMINIUM A383)

Chemical Composition (%)	Al	Cu	Mn	Ni	Zn	Sn	Fe	Si
ADC12 ALUMINIUM A383	77.3-86.5	2.0-3.0	0.5	0.35	3.0	0.15	1.3	0.060

Table 2.2: Properties of Aluminium Alloy (ADC12 ALUMINIUM A383)

Density(g/cm^3)	2.74
Thermal Expansion	21.1
Latent Heat of Fusion (J/g)	71.016
Specific Heat capacity(J/kg K)	963
Thermal Conductivity(W/m.K)	96.2

III. Transient Thermal Analysis

3.1 Geometric modelling of die-casting: The discretization of the geometric model was carried out using ANSYS workbench 17.1 was discretize the CAD model with quadratic displacement behaviour is exhibited by the elements.

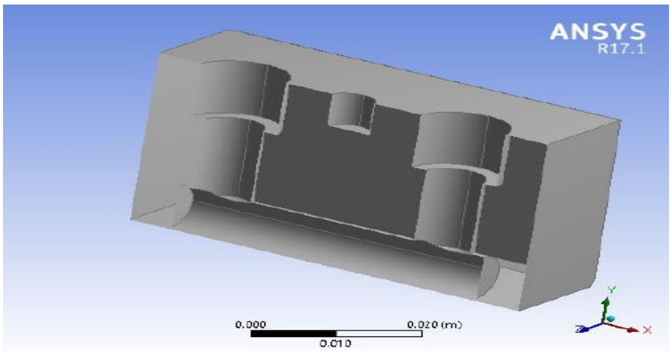


Fig.3.1 : Geometrical 3D CAD model

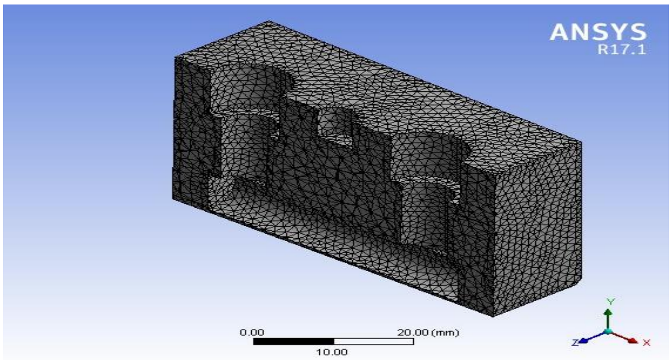
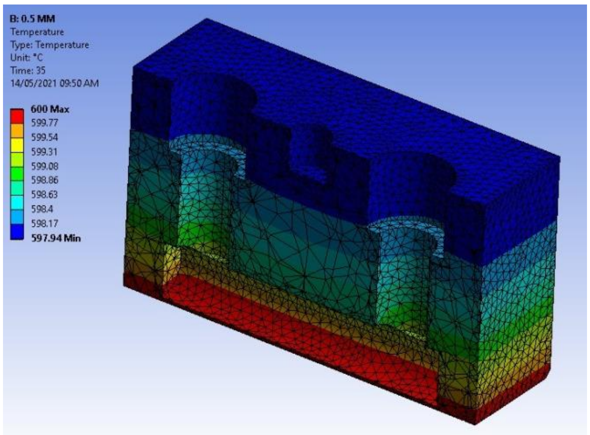
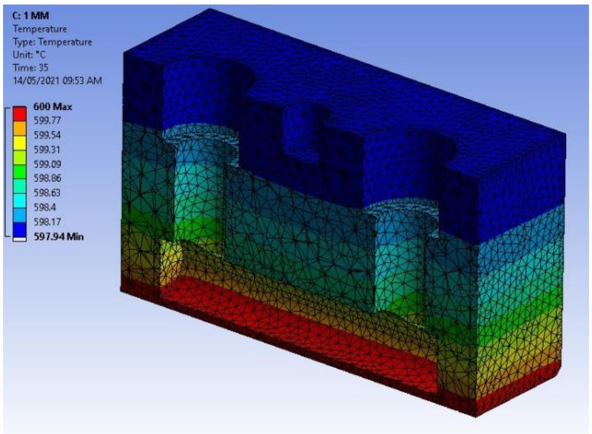


Fig.3.2 : Meshing of Die Geometry

3.2 Thermal Analysis of Aluminium Alloy (ADC12 ALUMINIUM A383) Die Casting

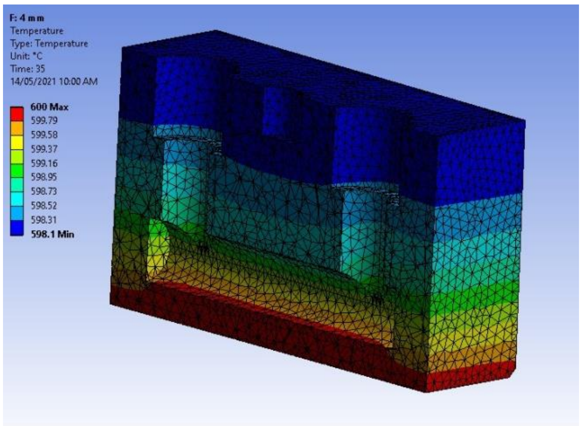


(a)

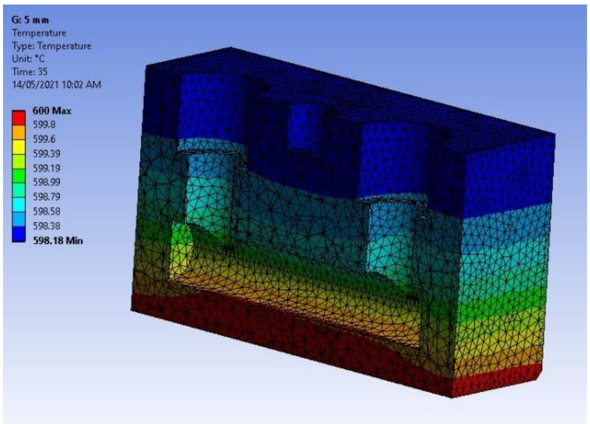


(b)

Fig.3.3 (a) Temperature Distribution for 0.5 mm base location (b) Temperature Distribution for 1 mm base location



(a)



(b)

Fig.3.4 (a) Temperature Distribution for 2 mm base location (b) Temperature Distribution for 3 mm base location

Table 3.1 : Results of thermal simulation test for Aluminium Alloy (ADC12 ALUMINIUM A383) Die Casting

Sr. No.	Coolant channel location from base (mm)	Temperature (^{0}C)
1	0.5	597.94
2	1	597.94
3	2	597.98
4	3	598.03
5	4	598.1
6	5	598.18

IV. RESULTS AND DISCUSSIONS

4.1 Effect of coolant channel position on temperature distribution: Figure 3.3(b) illustrates the temperature distribution of aluminium alloy (ADC12 ALUMINIUM A383)for the coolant channel location situated at 1 mm from the base and Figure 3.3(a)illustratestemperature distribution for varying coolant channel locations. The coolant channel location situated at 0.5 and 1 mm from the base experienced a temperature of 597.94 ^{0}C, whereas other positions at 2,3,4 and 5 mm from the base experienced 597.98, 598.03, 598.1 and 598.18 ^{0}C, respectively. The minimum temperature of the die that has to be maintained to reduce the thermal crack and the average tool temperature is usually kept at determined levels through internal cooling. Cooling channel close to the bottom surface increases the heat transfer rate through forced convection, resulting in less thermal expansion. From this, it is expected that the thermal cracks will appear at the specimen surface due to higher temperature and due to the decreased strength at elevated temperature. As the coolant channel location distance from the base increases, the surface temperature increases for aluminium alloy (ADC12 ALUMINIUM A383). Hence, it leads to expectation of crack initiation at higher distance from the coolant channel location.

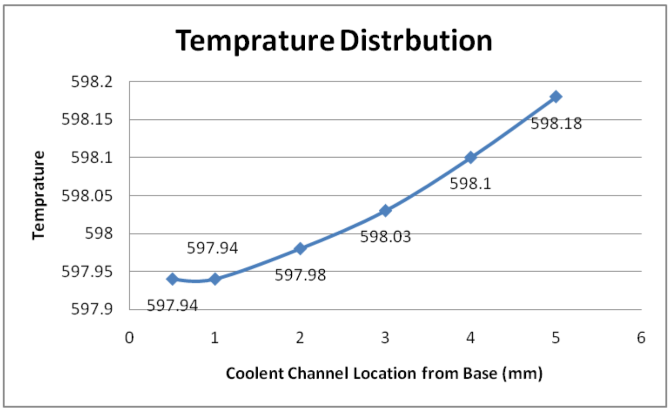


Fig. 3.6: Temperature distribution for aluminium alloy

V. CONCLUSION

The life of high-pressure die casting could be increased by using an effective cooling channel near the base and greater thermal stable of mechanical properties at operational temperature. Thermal analysis was carried out using Workbench 17.1 package in order to characterize temperature distribution. The results indicated that the coolant location at 2 mm from the base experiences the temperature of 597.98^{0}C However, coolant channel location at 0.5 and 1 mm from the base experiences minimum temperature 597.94^{0}C. This is considered to be the best among the coolant channel locations.

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