Modeling & Analysis of Injection Chamber of High Pressure Die Casting to Reduce Porosity

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Abstract— In this research work, thorough study has been done to decrease the porosity that arises during high pressure die casting. Ansys software has been used to reduce the defect of porosity. The reading, dimensions and specifications of the injection chamber have been taken from a manufacturing plant. The main objective is to reduce porosity from the end product which is a 100 watt LED light frame in this case. With the help of ansys, a CAE software, the change in the pressure of molten metal flow has been observed inside the injection chamber which has been modeled using ansys fluent. And it has been found that when the pressure of molten metal flow is reduced, porosity also tends to get reduced or completely vanished.

Key words: Porosity, High Pressure Die Casting, Injection Chamber

I. INTRODUCTION

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The mold cavity is basically related using two hardened tool steel dies, which undergo machining processes to get into its desired shape. Most die castings are usually made of some non-ferrous metals specifically zinc, copper, aluminum magnesium, lead, pewter and tin-based alloys. Depending on the type of metal being caste, a hot- or cold-chamber machine is used.

A casting defect is an undesired irregularity in a metal casting process. Some defects can be tolerated while others can be repaired, otherwise they must be eliminated. They are broken down into five main categories: gas porosity, shrinkage defects, mold material defects, pouring metal defects, and metallurgical defects.

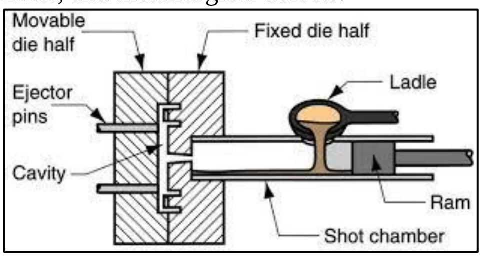

Fig. 1: High Pressure Die Casting.

A major type of casting defect is gas porosity. Gas porosity is the formation of bubbles within the casting after it has cooled. This occurs because most liquid materials can hold a large amount of dissolved gas, but the solid form of the same material cannot, so the gas forms bubbles within the material as it cools. Gas porosity may present itself on the surface of the casting as porosity or the pore may be trapped inside the metal, which reduces strength in that vicinity. Nitrogen, oxygen and hydrogen are the most encountered gases in cases of gas porosity. In aluminum castings, hydrogen is the only gas that dissolves in significant quantity, which can result in hydrogen gas porosity. For casting with a few kilograms in weight, the pores are usually 0.01 to 0.5 mm (0.00039 to 0.01969 in) in size. In larger casting they can be up to a millimeter (0.040 in) in diameter. Some terminologies associated with high pressure die casting are described below-

A. Ram (Plunger)

A plunger is a type of positive displacement pump where the high-pressure seal is stationary and a smooth cylindrical plunger slides through the seal. This makes them different from piston pumps and allows them to be used at higher pressures.

B. Ladel

A ladle is a vessel used to transport and pour out molten metals. Ladles range in size from small hand carried vessels that resemble a kitchen ladle and hold 20 kilograms (44 lb) to large steel mill ladles that hold up to 300 tonnes (330 tons). Many non-ferrous foundries also use ceramic crucibles for transporting and pouring molten metal and will also refer to these as ladles.

C. Shot Chamber

A similar characteristic of either die casting process is the use of high pressure to force molten metal through a mold called a die. Many of the superior qualities of castings manufactured by die casting, (such as great surface detail), can be attributed to the use of pressure to ensure the flow of metal through the die. In hot chamber die casting manufacture, the supply of molten metal is attached to the die casting machine and is an integral part of the casting apparatus for this manufacturing operation.

D. Ejector Pins

Ejectors are mould and die components with which the casting is extracted from the cavity. Ejector places leave round, rectangular or similar clearly visible marks to the casting surface. For this reason, the side of the casting, from which the ejection takes place, should be non-visible in the final product. This sets some challenges.

II. PROBLEM DEFINITION

Porosity or void fraction is a measure of the void (i.e. "empty") spaces in a material, and is a fraction of the volume of voids over the total volume, between 0 and 1, or as a percentage between 0 and 100%. To reduce porosity from 100 watt LED light frame, we have prepared the model of an injection chamber on ansys fluent, and conducted the simulation while maintaining a variation in the pressure of molten metal flow. The injection chamber measures at a diameter of 580x580 mm, its plunger has a dimension of 60 mm, outlet diameter stands at 110mm and inlet diameter stands at 70mm. The injection chamber is made of cast iron. The values of pressure of molten metal flow taken for the experimentation are 1400 kgf/cm^2, 500 kgf/cm^ 350 kgf/cm^2.

III. COMPUTATIONAL MODEL & MESH GENERATION

The model of the injection chamber has been prepared using the dimensions and specifications obtained from the casting plant with the help of ansys geometry modeler. A figure has been show below.

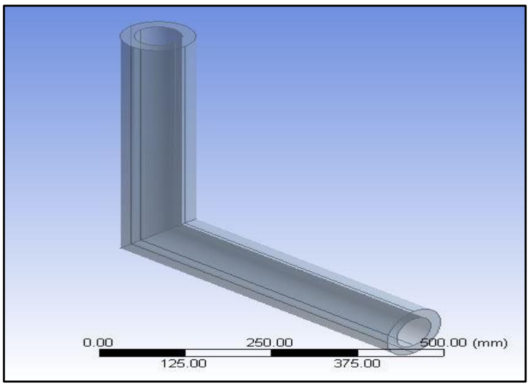

Fig. 2: Geometry of L shaped injection chamber

Generation of mesh is the procedure of creating a polygonal or polyhedral mesh that usually approximates a geometric domain. Typical uses are for rendering to a computer screen or for physical simulation such as finite element analysis (FEA) or computational fluid dynamics (CFD). For the analysis of the flow of fluid, the domains are needed to split into smaller sub domains and mesh accuracy of the domain increases as we go towards the shape. The governing equations are then discretized and solved inside each of these sub domains. The generated portion of mesh of the injection chamber is shown in the two figures below.

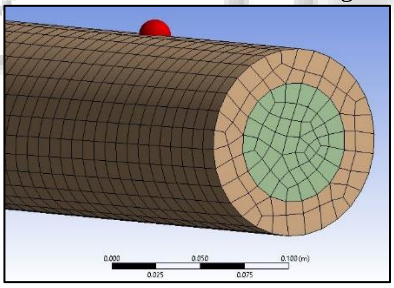

Fig. 3: Meshing Process

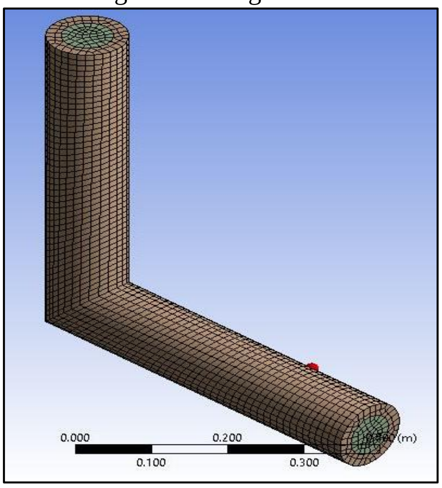

Fig. 4: Meshing Process of L shaped injection chamber

IV. DEFINING THE BOUNDARY CONDITIONS

The main part of any CFD problem is the definition of its boundary conditions. The problem for the said injection chamber considers flow of molten metal with a variation in its pressure. To conduct the simulation, boundary conditions for the problem and some initial inputs are taken, and it is shown in the table below-

A. For Fluid Material

Sl. No	Input	Value
1	Material Name	Aluminum (Molten)
2	Material Type	Fluid
3	Density	2542 (kg/m^3)
4	Cp (Specific Heat)	871 (j/kg-k)
5	Thermal Conductivity	0.0242 (w/m-k)
6	Viscosity	0.00296 (kg/m-s)

Table1: Fluid Material Properties

B. For Solid Material

Sl. No	Input	Value
1	Material Name	Cast Iron
2	Material Type	Solid
3	Density	7200 kg/m^3)
4	Cp (Specific Heat)	871 (j/kg-k)
5	Thermal Conductivity	202.4 (w/m-k)

Table 2: Solid Material Properties

V. SIMULATION RESULTS & DISCUSSION

A. Contour of Pressure at 1400 kgf/cm^2 Overall Pressure

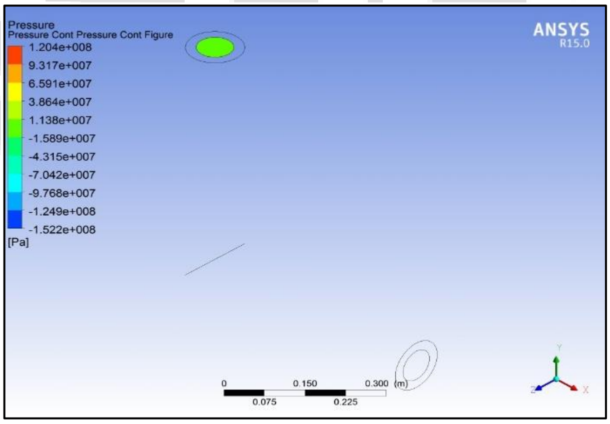

Fig. 5: Pressure Contour at Outlet

B. Contour of streamline velocity at 1400 kgf/cm^2 Overall Pressure

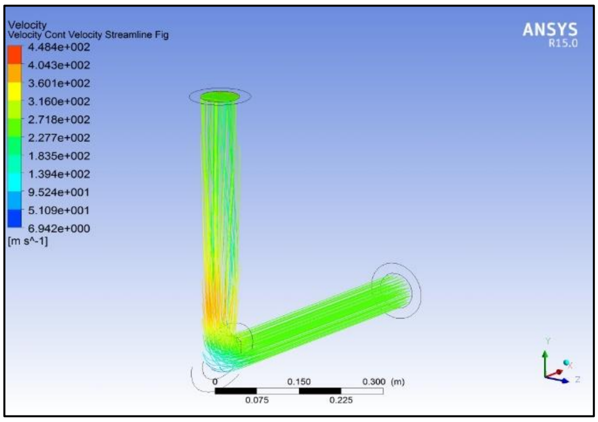

Fig. 6: Streamline velocity contour

C. Contour of Pressure at 500 kgf/cm^2 Overall Pressure

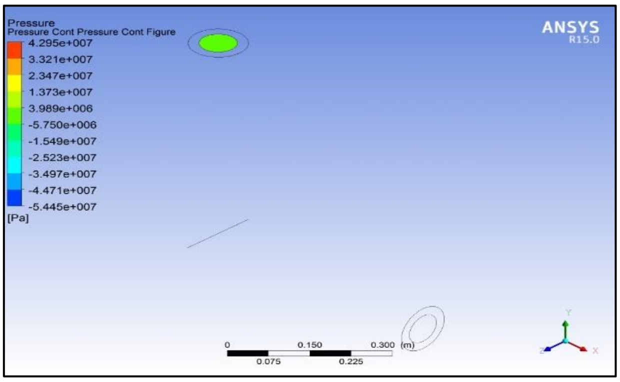

Fig. 7: Pressure contour at Outlet

D. Contour of streamline velocity at 500 kgf/cm^2 Overall Pressure

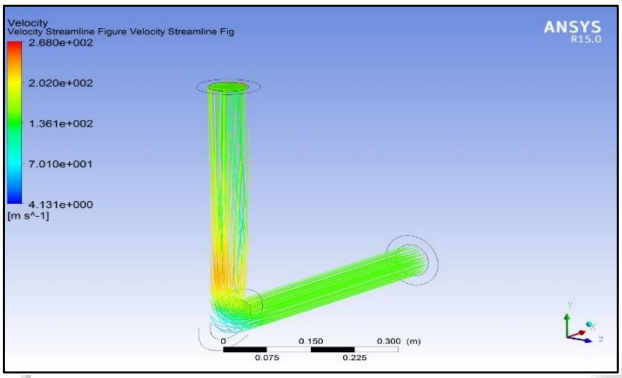

Fig. 8: Streamline velocity contour

E. Contour of Pressure at 350 kgf/cm^2 Overall Pressure

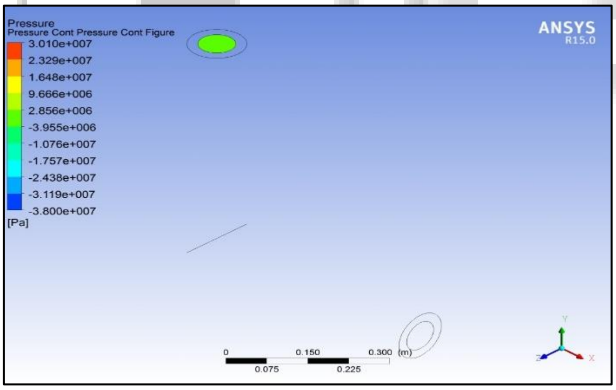

Fig. 9: Pressure Contour at Outlet

F. Contour of streamline velocity at 350 kgf/cm^2 Overall Pressure

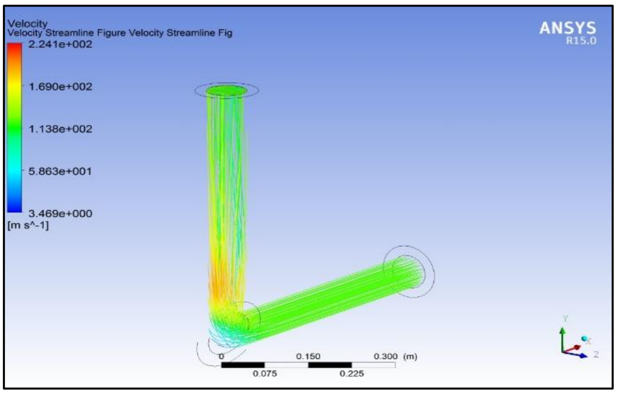

Fig. 10: Streamline velocity contour

G. Velocity chart with 100 iterations at 350 kgf/cm^2 Overall Pressure

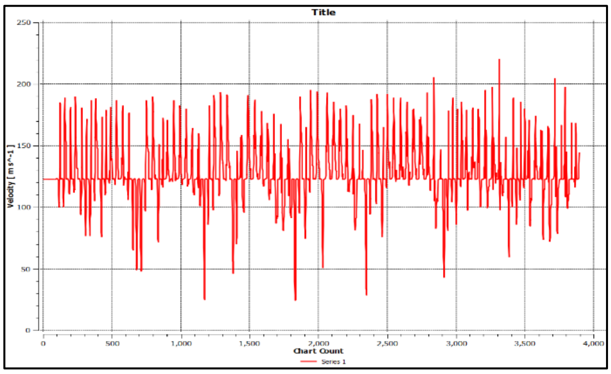

Fig. 11: Velocity chart

The simulation has been carried out for three times by changing the value of overall pressure of molten metal flow.

When the pressure was kept at 1400 kgf/cm^2, the pattern of flow particles was getting disturbed at the turning point.

When the pressure was changed to 500 kgf/cm^2, the pattern of flow particles was still getting disturbed, but it was a little less comparing to earlier time.

When the pressure was changed to 350 kgf/cm^2, it was observed that the flow particles of molten metal were flowing in a straight path, and thus, there was no formation of bubbles within the casting after the molten metal has cooled. As a result, porosity is being reduced.

VI. CONCLUSION

Gas porosity is one of the main issues of high pressure die casting. It occurs because most molten metals hold a large amount of dissolved gas, but when the molten metal solidifies, the solid form of the same material cannot, so the gas forms bubbles within the material as it cools. Maximum velocity inside this injection chamber for an overall pressure of 350 kgf/cm^2 stands at 2.241e+002. And when the pressure is kept at 350 kgf/cm^2, there are no or negligible formation of bubbles, which ultimately results in zero porosity in the end product. But if we increase the pressure of molten metal flow, the porosity appears as usual.

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