ISSN : 0974 - 7486 Volume 11 Issue 4

Materials Science

An Indian Journal

Full Paper

MSAIJ, 11(4), 2014 [135-141]

Effects of gating geometry on casting solidification using computer simulation tools

K.K.Pathak[1]*, Vijay Verma[2], Pankaj Pawar[3], Geeta Agnihotri[2]

[1]Department of Civil & Env. Engg, NITTTR Bhopal (MP) 462002, (INDIA)

[2]Department of Mech. and Production & Industrial Engg. MANIT Bhopal (MP) 462007, (INDIA)

[3]CSD Center AMPRI (CSIR) Bhopal (MP) 462064, (INDIA)

E-mail : kkpathak1@rediffmail.com

ABSTRACT

In this study, gravity sand casting simulations are carried out considering four gate sections. Viz. triangular, square, circular and half hexagon. Simulation results are critically examined in terms of shrinkage porosity, fill time, solidification time and velocity. Based on simulation results a comparatives study of all the section has been made and some design guidelines are proposed.

KEYWORDS

Metal casting;
Simulation;
Shrinkage;
Solidification.

INTRODUCTION

Casting is the oldest known process to produce metallic components. The first metal casting was done using stone and metal moulds during the period of 4000–3000 BC. Since then, various casting processes have been developed. In casting, the liquid material is poured into a cavity (die or mould) corresponding to the desired geometry. The shape obtained in the liquid material is stabilized, usually by solidification, and can be removed from the cavity as a solid component. In past casting processes were designed based on trial and error approach. Such approaches were prone to casting defects and were uneconomical due to enlarged design period.

In modern days computer simulation is widely used for casting process design. Some of the prominent literature on casting simulation is as follows:

Advances in modeling of casting processes using smoothed particle hydrodynamics (SPH) are described by[1]. Three-dimensional simulations of high pressure die casting were presented for two realistic dies. The design of gating and risering, or rigging systems as they are sometimes referred to, has been very important task in the manufacture of cast components. This paper presented by[3], is a compilation of common rules of thumb used by foundry experts and guidelines suggested by researchers for better quality castings. The L-shaped junctions in running and gating systems used in aluminum gravity casting were investigated by[4]. Using computational modeling, a guideline for constructing two geometries of L-junctions was developed[5]. used various analytical FEM, FDM tools for flow process analysis including die casting. A design guideline was induced by[6], while investigating resin flow patterns considering depending on several gate positions obtained by numerical analyses of a simple strip with a hinge. [7]described the simulation and experimental results of thermal analysis in sand casting process. Simulation model of 2-ingate mould and 3-ingate mould of sand casting are developed. The effects of gating systems, number of runner, and their locations, in the Lost Foam Casting (LFC) of Aluminum alloy (A.413.0) were investigated by[8]. Finite element analysis in heat transfer can be program for finite element modeling of casting Venkatesana et. al. (2005) developed finite element software for casting solidification analysis.

In this study, computer simulations of sand casting process considering different gate cross section have been studied. Four different cross sections of gate are Triangular, Square, Circular, and Half Hexagon. The effect of the gating system on the casting is analyzed in terms of shrinkage porosity, fill time, solidification time and velocity.

GEOMETRICAL AND MATERIAL PARAMETERS

The geometrical parameters used in this study are as follows:

- The cross sectional area of Gating system for all section (triangular, square, circular & half hexagon) = 176 mm^2. Dimension of these sections are shown in Figure 1.

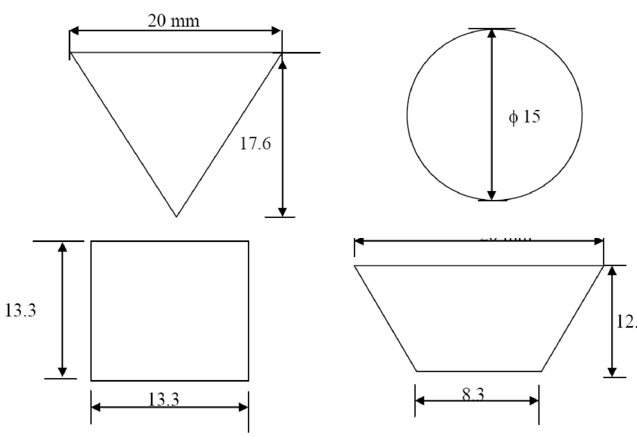


Figure 1 : Different Gate cross sections

- Runner diameter = 12 mm
- Diameter of pouring basin is = 20 mm
- Height of pouring basin =10 mm.
- Dimensions of mold cavity = 100 x 100 x 100 mm^3
- Dimension of the mold box = 190 x 120 x 130 mm^3

Material properties are as follows:

- Pouring material = Al-201
- Pouring temperature = 700 ÚC
- Moulding material = Silica sand
- Heat transfer coefficient = 100
- Flow rate 1Kg/sec
- Gravity 9.8 m/sec^2

The thermal properties for these materials are taken from the library of ProCAST software (Ref.10).

CAD Modeling and simulation

First step of computer simulation is to make the CAD model of the all casting elements. CAD model elaborating mould box and basin sprue is shown in Figure 2(a) & (b). CAD models shown different gate cross sections are shown in Figure 3(a), (b), (c) & (d). After making the model on I-deas software (Ref.9), this file is stored in. xmt format exported to MeshCAST, which is the next module of the ProCAST software where finite element mesh is developed. In MeshCAST tetrahedral elements are used for meshing of the casting. There are 37747 elements and 8315 nodes in the finite element model. The finite element model for triangular section is shown in Figure 4. After meshing material properties and boundaries conditions mentioned above is imposed and simulation are carried out.

RESULT AND DISCUSSION:

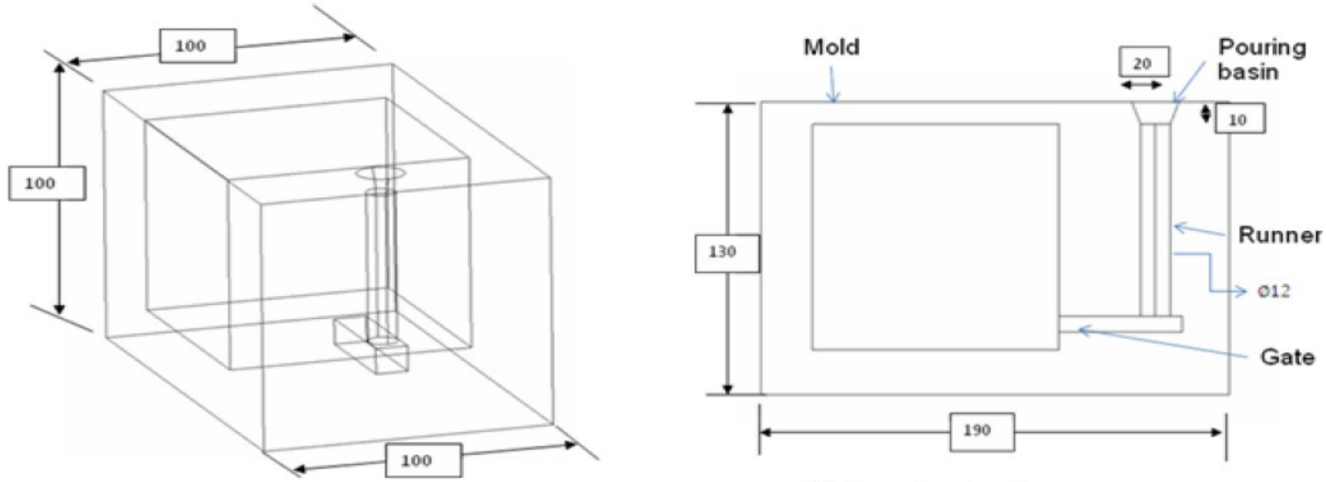
The summary of simulation results are given in TABLE 1 can be critically examined under following heads:

Shrinkage porosity

Shrinkage porosity is minimum in case of half hexagon section hence half hexagon section is best among the four section, In case of square section shrinkage porosity is maximum. Bar chart for shrinkage porosity is shown in Figure 9. Shrinkage porosity contour for different gating section are shown in Figure 5(a), 6 (a), 7(a), and 8(a).

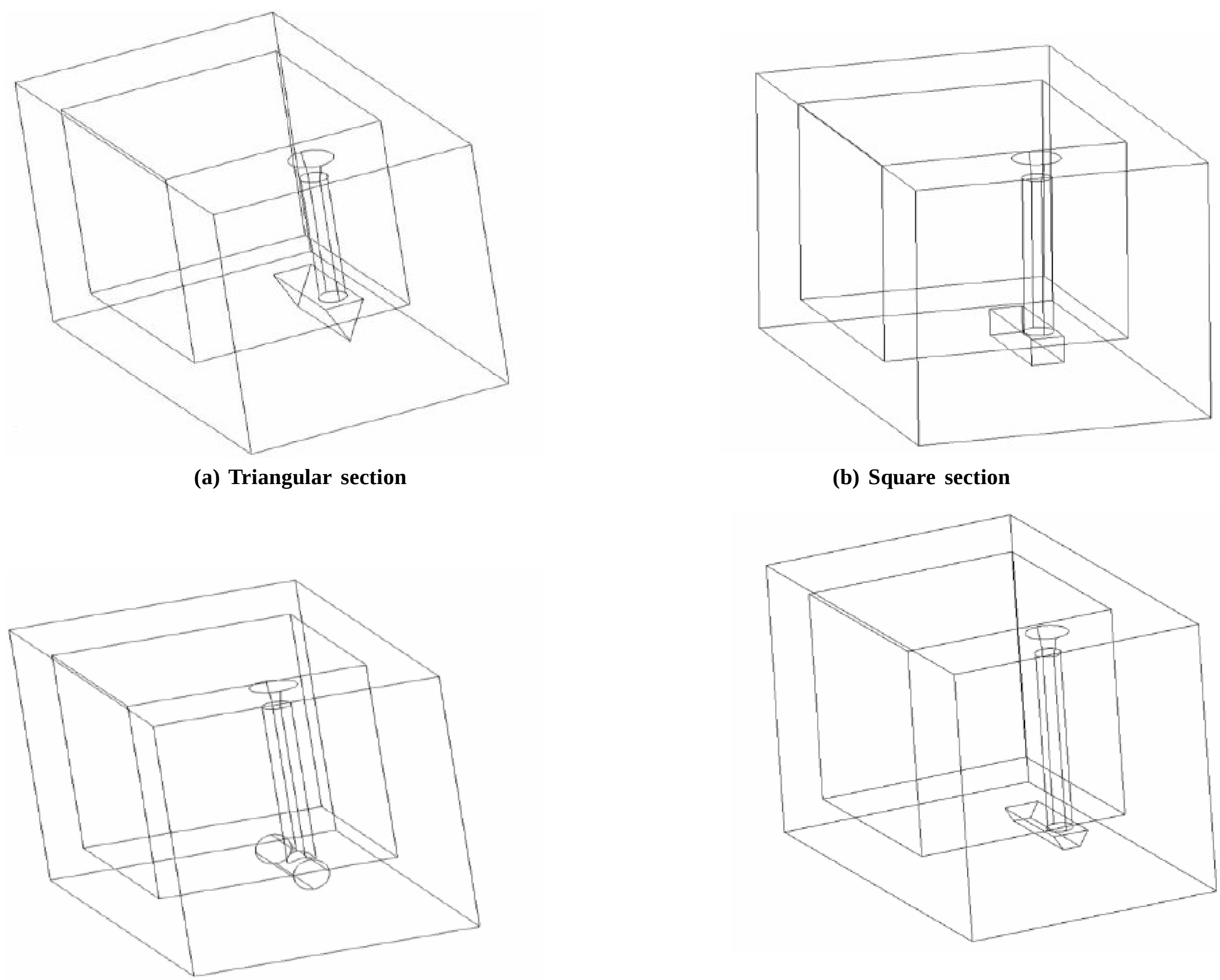
Filling time

Triangular section takes more time to fill the mold. While in case square section filling time is minimum. Bar chart for filling time is shown in Figure 8. Filling time contour for different gating system is shown in Figure 5(b), 6 (b), 7(b), and 8(b).



(a) Mould box (b) Pouring basin

Figure 2 : Mould box, Pouring basin



(a) Triangular section (b) Square section

(c) Circular section (d) Half hexagon section

Figure 3 : CAD Models for different cross section

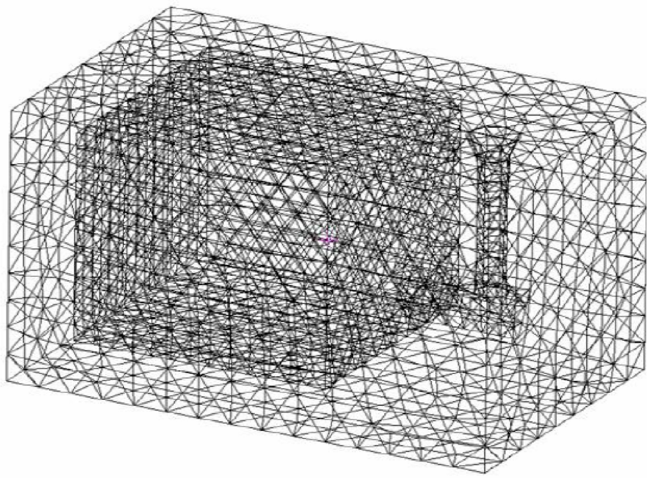


Figure 4 : Meshed model of Triangular section mold

Velocity

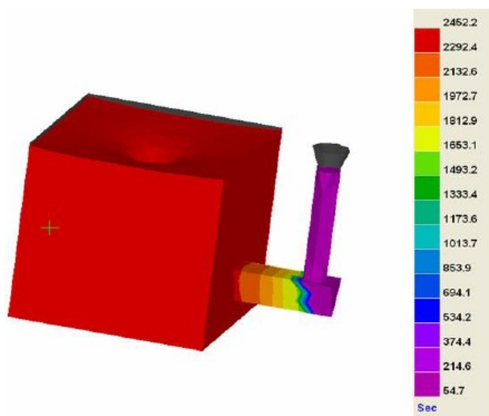
Velocity in case of circular section is maximum while in case of triangular section is minimum. Bar chart for velocity is shown in Figure 9. Velocity contour for different gating system are shown in Figure 5(c), 6 (c), 7(c), & 8(c).

Solidification time

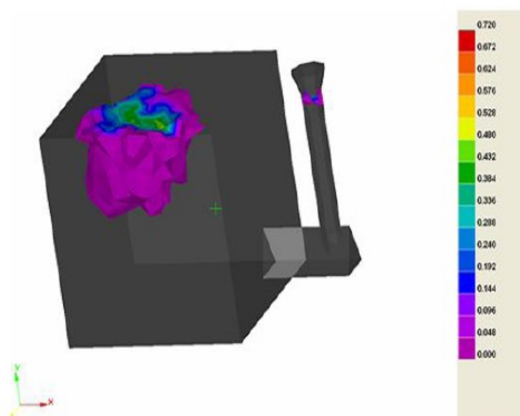
Half hexagon section takes maximum time for solidification and in case of triangular section solidification time is minimum. Grains in case of triangular gate will be finer than the other sections. Bar chart for solidification time is shown in Figure 10. Solidification time contour for different gating system are shown in Figure

TABLE 1 : Simulation Results

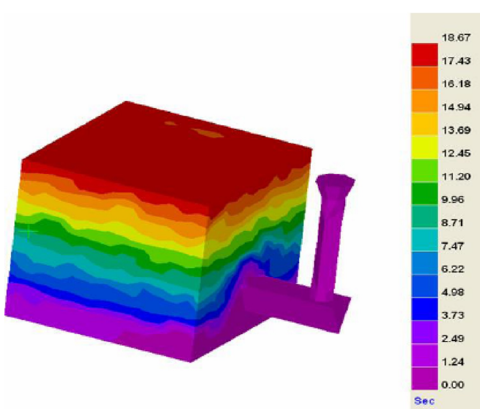
S.N.	Model	Shrinkage porosity	Fill time in sec	Velocity in m/sec	Solidification time in sec
1	Triangular	0.72	18.67	0.981	2452
2	Square	0.73	18.52	0.997	2777
3	Circular	0.724	18.58	1.049	2912
4	Half hexagon	0.718	18.54	1.003	2928



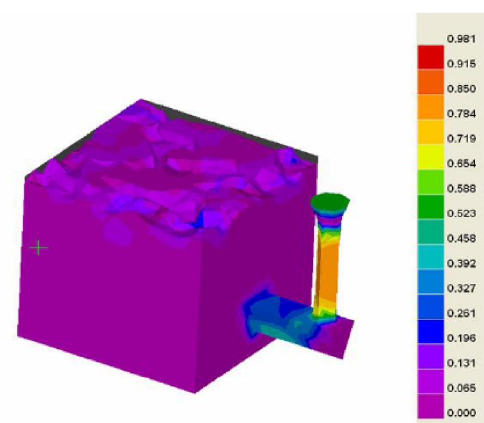
(a) Solidification time



(b) Shrinkage porosity

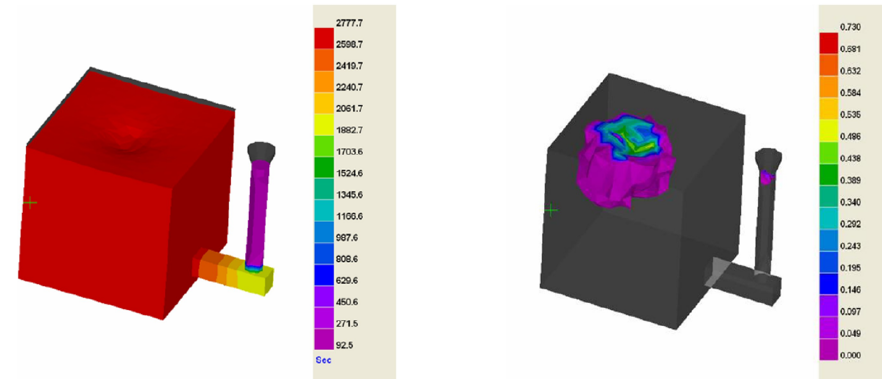


(c) Filling time

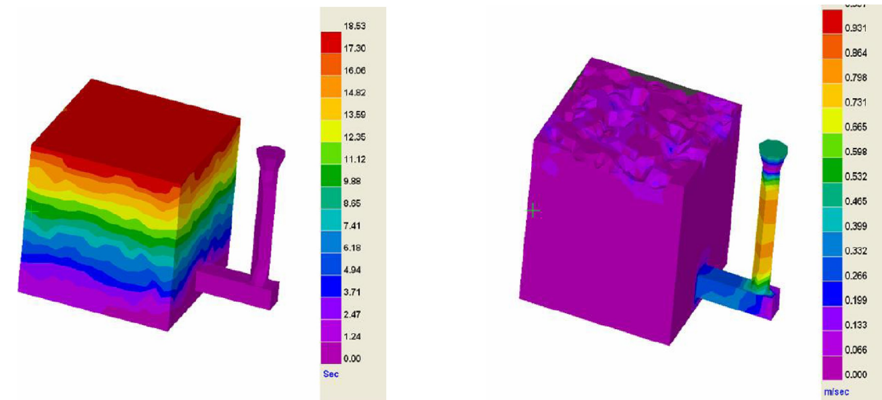


(d) Velocity

Figure 5 : Simulation of triangular section

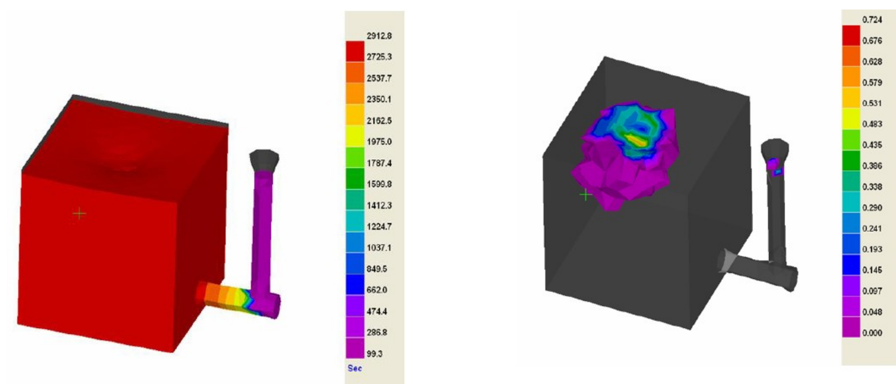


(a) Solidification time **(b) Shrinkage porosity**

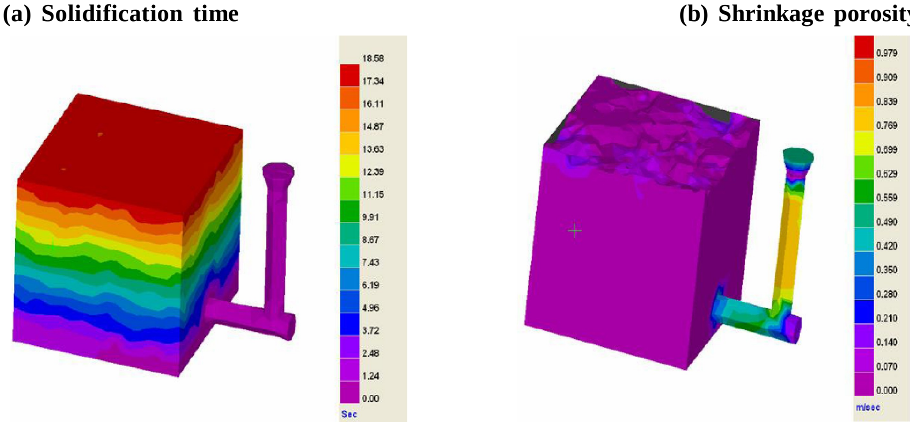


(c) Filling time **(d) Velocity**

Figure 6 : Simulation of square section

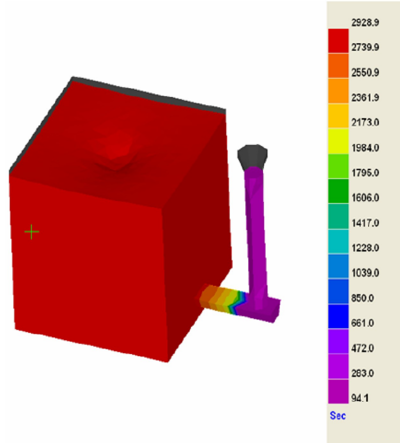


(a) Solidification time **(b) Shrinkage porosity**

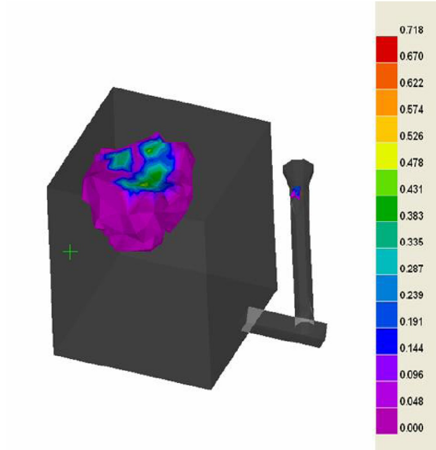


(c) Filling time **(d) Velocity**

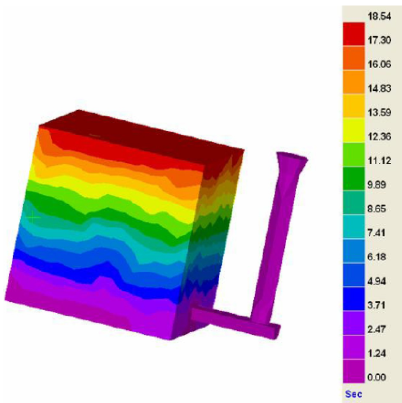
Figure 7 : Simulation of circular section



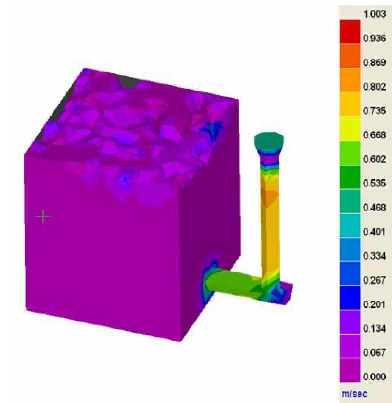
(a) Solidification time



(b) Shrinkage porosity



(c) Filling time



(d) Velocity

Figure 8 : Simulation of half hexagon section

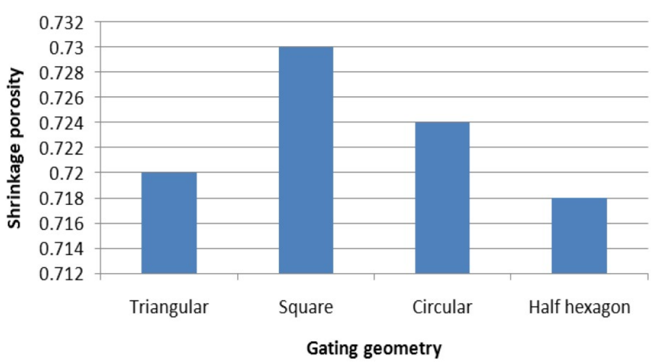


Figure 9 : Bar chart for shrinkage porosity

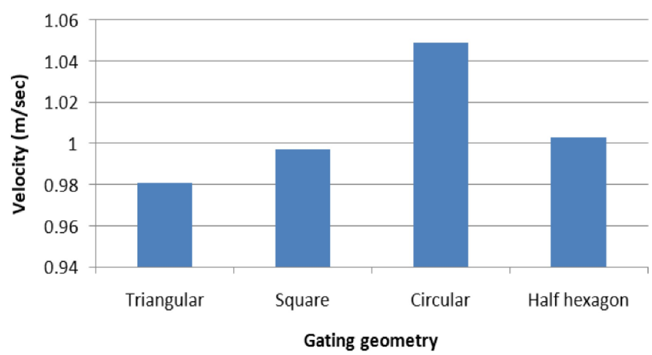


Figure 11 : Bar chart for velocity

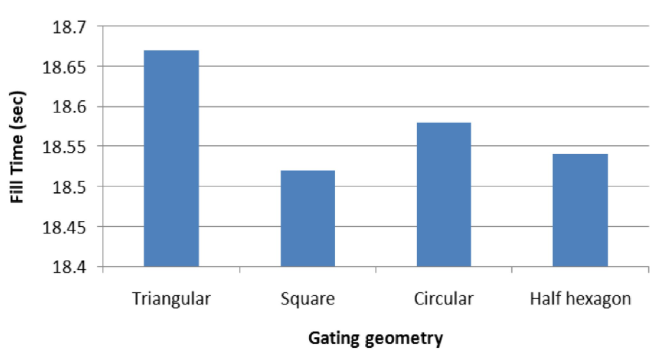


Figure 10 : Bar chart for Fill time

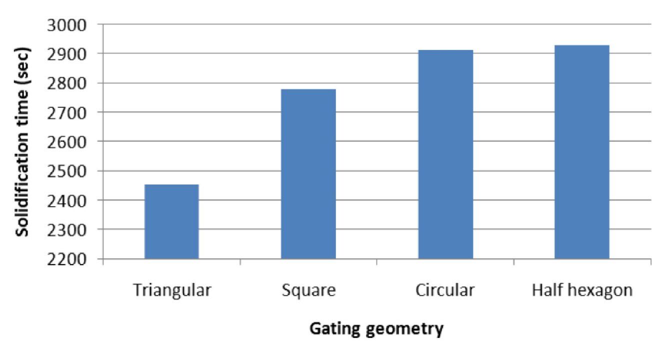


Figure 12 : Bar chart for Solidification time

5(d), 6 (d), 7(d), 8(d).

CONCLUSION

With the help of simulation result obtained for aluminum alloys (Al-201) we can conclude that:

1. Triangular section takes minimum solidification time and half hexagon section takes maximum time for solidification.
2. Shrinkage porosity is minimum in case of half hexagon section hence half hexagon section is best among the four section, while in case of square section shrinkage porosity is maximum therefore it is not good.
3. Triangular section takes more time to fill the mold and square section takes minimum time to fill the mold.
4. Velocity is maximum in circular section and minimum in triangular section.

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