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Research Article

Effect of Varying Gate Size on the Air Traps in Injection Molding

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Abstract

The Plastic and plastic products demand in present era is increasing at an increased pace. Plastic injection molding starts with component feasibility and then mold making considering various parameters. In mold designing, molded part is affected by ample factors. This paper focuses on the effects of different gate and its sizes on the component and molding parameters. Optimization plays a vital role in the manufacturing of plastic parts to increase the quality and efficiency of the process. Thus, Mold Flow analysis software is used to find the effects different gates and their gate sizes have on the component. This Paper describes the influence of different gate sizes of Film Gate and Submarine Gate to check air traps and various process parameters such as clamping force and fill time.

Keywords: *Injection Molding, Film Gate, Submarine Gate, Air Traps, Fill Time, Clamping Force*

1. Introduction

A plastic material can be from a wide range of semi-synthetic or synthetic organic solids that can be shaped. Plastics are usually organic polymers of high molecular mass, but they often comprise of other constituents. They are generally synthetic, which are in general a derivative of petrochemicals, but many are partially natural. Depending upon the needs, different types of plastics are used. Plastics are generally classified by their chemical structure of the polymer's backbone and side chains. Some important groups in these classifications are the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics. Plastics can be classified by the chemical process used in their production, such as condensation, polyaddition, and cross-linking. Plastics are of two types- thermoplastics and thermosets. Thermoplastics do not undergo chemical change in their composition when they are heated and thus, can be molded all over again. Thermosets melt and take shape once. After they solidify, they retain their solid form. In the thermosetting process, a chemical reaction take place, which is irreversible in nature. Plastics can be molded into different forms and hardened for viable use. It is light, robust, and durable and can be easily molded. From the viewpoint of mold design, there are numerous parameters which affect the quality and productivity of products, such as gate size and location, runner designs, design of cooling channels, injection pressure, injection temperature, cooling time, etc. (Keun Park, *et al*, 2004).

Feed System is a flow way in the injection molding to connect the nozzle to impression in the mold. It consists of 3 important parts- Sprue; Runner, and Gate. The molten metal passes through the Sprue and Sprue Bush, from where it is connected to main runner and its branches. Gate is a channel or orifice connecting the runner with the impression (Topwell Springs, Feed System). It has a small cross sectional area. Gate plays an important role in the product manufacturing and the aesthetic looks of the component. Moreover various defects in the components occurs due to the improper gate selection, placement and size

In the injection molding processes, gate is a very important design parameter. It affects polymer capability, part shape and size, mold structure and condition, the selection of gate impacts the manner in which plastic flows in to the cavity. The selection of a gate in an injection mold is one of the most vital variables in mold design and the quality of the component (Arjun Kapila, *et al*, 2014). Gate is initially machined at a smaller value so that there is a prospect of increasing its size if a revision is required. The molding conditions, ultimately, selected are a result of the desire to overcome defects caused by improper gate size. The defects with the component gate bloom (undesirable cloudy effect); cracks in the gate area; high inherent stresses resulting in premature failure; gas entrapment (air traps); porosity within the mold (particularly around gate); deformation; sink marks; poor surface finish and lack of surface texture; poor optical properties; ovality within components, and voids within the components.

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There are various types of gates that may be used

1. Sprue Gate
2. Edge Gate
3. Overlap Gate
4. Fan Gate
5. Diaphragm Gate
6. Ring Gate
7. Film Gate
8. Pin Gate
9. Subsurface or Submarine Gate
10. Winkle Gate

Gate Size has tremendous effect on the success or failure of attempts to produce high quality parts economically. Gate size is usually the critical factor that dictates the mold filling speed. Reducing melt viscosity by raising melt temperature increases the mold filling rate, since there is less pressure drop across the gate. However, this can increase cycle time, since the heat put into the material must be removed in the mold. Although decreasing mold temperature helps achieve faster cycle times, it also requires additional injection pressure, which affects the clamp tonnage (D.V. Rosato, *et al*, 2000).

Air Traps is the air that gets trapped inside the mold cavity by converging polymer melt fronts or because the air failed to escape from mold vents or inserts. They are usually located in the area that gets filled in the end. This trapped air will, thus, result in voids and bubbles inside the molded part, a short shot, or surface defects such as blemishes or burn marks.

The objective of this paper is to simulate the behavior of varying gate sizes of two different type of gates; i.e. Submarine and Film Gates on component and its effect on the air traps, clamp force and fill time. It will ensure ease of selection of gate size and improving quality of the part with reduction in rejection and also reduction in trial and error method.

2. Part Detail

The research is done on a rectangular bucket type component as shown in Figure 1.

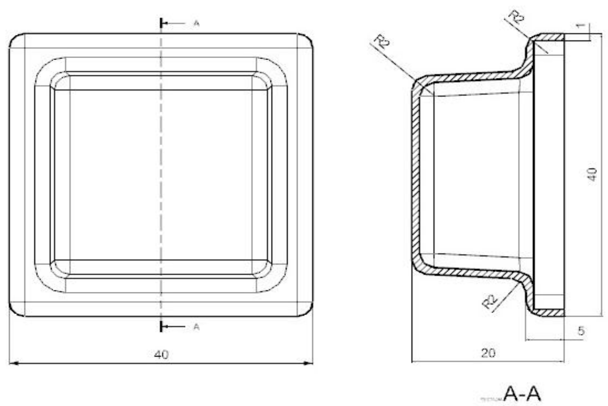

Fig.1 CAD Model of Component

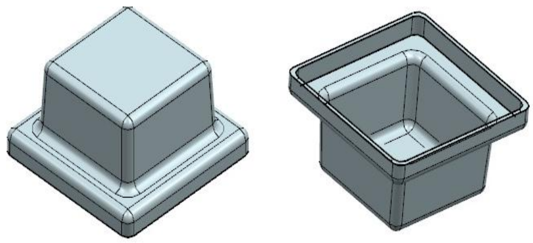

Fig.2 3D Model of Component

ABS Properties (S.H. Tang, *et al*, 2006)
Material: Acrylonitrile butadiene styrene
Abbreviation: ABS
Molecular formula: (C8H8·C4H6·C3H3N)$_n$
Part weight: 4.1grams
Density, ρ: 1050 kg/m3
Young's modulus, E: 2.519 GPa
Poisson's ratio, ν: 0.4
Yield strength, SY: 65MPa
Thermal expansion, α: 65×10−6 K−1
Conductivity, k: 0.135 W/ (m K)
Specific heat, c: 1250 J/ (kg K)
Wall Thickness: 1 mm

Acrylonitrile butadiene styrene (ABS) is a common thermoplastic. Its glass transition temperature is approximately 105 °C (221 °F). ABS is amorphous and therefore has no true melting point (Stratasys, ABS).

The most important mechanical properties of ABS are impact resistance and toughness. A range of modifications can be done to increase impact resistance, toughness, and heat resistance. Changing the proportions of its components ABS can be prepared in different grades. Two major categories could be ABS for extrusion and ABS for injection moulding, then high and medium impact resistance. Generally ABS would have useful characteristics within a temperature range from −20 to 80 °C (−4 to 176 °F) (Dynalab Corp., ABS)

3. Problem Statement

Mold designing is a job that needs manufacturing skill and knowledge for setting various parameters, gate type and location, runner shape and size etc. Mold makers use trial and error technique for mold designing. This method consumes too much time. The problem occurs when a designer cannot set certain parameters due to less experience and knowledge. Thus fault in design and manufacturing occurs. The results is loss of time and money to rectify the fault. Thus to reduce this, a large number of simulation software are available which helps designers in decision-making and selection. Simulation is the technology that can forecast the flow of the plastic inside the cavity. It also gives us a close result of a process without manufacturing mold. It is used by the designer to solve various problems at design stage by forecasting the whole process. It's one of the most appreciated software by an injection mold designer. Also, it generates 3D simulation that models the flow of plastic material into a single or multi-cavity mold. With the support of Moldflow analysis, engineers can obtain statistical data of the molding process before the mold is actually fabricated (Rahul Vashisht, *et al*, 2014). The results, thus obtained by the analysis helps the designer in choosing the optimum location for gate type, sprue and runner etc. The result obtained is accurate, cost-effective and preferred plastic parts with few trials and error/ rejection.

4. Software Used

For the research purpose various software were used to perform various trials and experiment
2.1 Autodesk AutoCAD 2013
AutoCAD software is used for part design.
2.2 Siemens NX:-8.0
Used for 3D modelling of the component.
2.3 Moldflow Simulation Software:-2013
Used for simulating molding process.

MoldFlow software is the world's leading product in deep simulations for injection process. It allows designers to determine the ideal combination of part geometry, material, mold design, and process condition (Weihua Kuang, *et al*, 2011).

Mold flow software has been developed by Mold flow International Pvt. Ltd., Australia. It aids in finite elemental analysis used in the design of plastic product, mold design and production of plastic components. Using MoldFlow, engineers can refine part and mold design, material choice, and process condition to achieve the optimum balance between quality and cost (Weihua Kuang, *et al*, 2011).

Following are the modules of MOLDFLOW software:

Flow Analysis: The Flow analysis is used to determine the gate position and filling pattern. It analyses polymer flow within the mold, optimizes mold cavity layout, balances runners and obtains mold processing conditions for filling & packing phases of the molding cycle.

Cooling Analysis: It analyses the effect of cooling on flow, optimizes cooling line geometry & processing conditions.

Process Optimization Analysis: It gives optimized processing parameters for a component considering injection molding conditions.

Warpage Analysis: This analysis simulates the effect of molding on product geometry, isolates the dominant cause of warpage so that the correct remedy can be applied.

Shrinkage Analysis: This analysis gives dimensions of mold cavities, using shrinkage determined from specific grade material shrinkage data & flow analysis results (M.B. Jagannatha Rao, *et al*, 2013).

5. Gate Location

The component is designed for a two-cavity mold. Before designing gates we have to find the suitable location for gate design. MFI software helps in finding the location that is best for us, considering the material properties, shape and size of the component. Using this result we can design the gates.

Table: 1 Input Details for plastic Advisor

Material	Techno ABS110
Grade Code	CM10278
Manufacturer	Techno Polymer
Pressure	50.6 MPa
Melt Density/Solid Density	0.954/1.054 gm./cc
Melt Temperature	220°C
Mold Temperature	50°C

(By manufacturer catalogue)

Table1 gives the inputs used for carrying simulation. The above figure gives us the result for the location of gates for the component. The best location for gate is highlighted in blue color whereas the location that is most unfavorable is highlighted with red color.

With the help of this, result designer can select and place the gate accordingly. The gates used for simulation are following:

1. Film Gate
2. Submarine Gate

The above mentioned gates will be designed on the component to find the effect of each gate on component and molding parameters. The parameters to be compared are:

1. Fill Time
2. Clamp Force

Moldflow Simulation Process Parameters

Process Settings:

Machine parameters:
Maximum injection pressure = $1.8000E^{+02}$ MPa
Maximum machine clamp force = $7.0002E^{+03}$ ton
Maximum machine injection rate = $5.0000E^{+03}$ m^3/s
Machine hydraulic response time = $1.0000E^{-02}$ s

Temperature control:

Melt temperature = 220.00 C
Mold temperature = 50.00 C
Atmospheric temperature = 25.00 C

Filling Control:

Filling control type = Automatic
Fill time = 0.50 s
Stroke volume determination = Automatic
Velocity/pressure switch-over control= Automatic

5. a Gating Suitability

Simulation is carried out to predict the best and worst location for the gate placement. This simulation help in providing important data to the designer about the placement of gate. Then the feeding system can be designed according to the placement of gate. Fig. 3 shows the best gate position in blue color and worst in red. This help the designer in designing the gate system with ease.

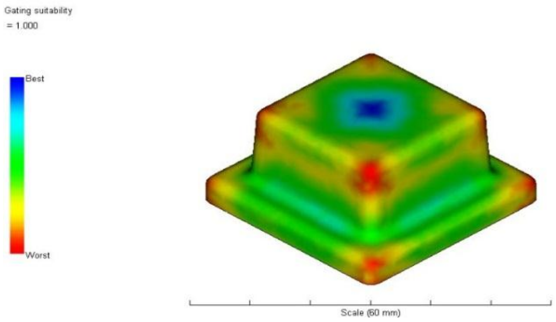

Fig. 3 Gating Suitability

The Moldflow simulation is then done for the two gates to find the effect of the same on the parameters i.e. fill time, air traps, and clamp force.

5. b Submarine Gate

An angled, tapered tunnel is machined from the end of the runner to the cavity, just below the parting line (R.G.W. Pye, Injection Molding). As the parts and runners are ejected, the gate is sheared at the part (M.B. Jagannatha Rao, *et al*, 2013). The submarine gate is selected because the gate mark on the component is comparatively lower than the edge gate. The minor diameter of the component is sliding area if the gate marking is higher the sliding is difficult (S. Selvaraj, *et al*, 2013).

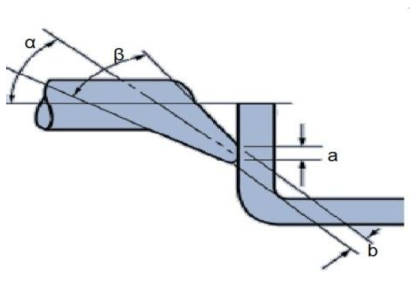

Fig 4 Submarine gate size detail

Table: 2 Input Details for Fig 4

S.no.	α	B	a	b
1.	20°	40°	1.15	0.5-1.5
2.	20°	40°	1.25	0.5-1.5
3.	20°	40°	1.35	0.5-1.5
4.	20°	40°	1.45	0.5-1.5
5.	20°	40°	1.55	0.5-1.5
6.	20°	40°	1.65	0.5-1.5
7.	20°	40°	1.75	0.5-1.5

Fig 5 Air Traps at gate size, a= 1.15mm

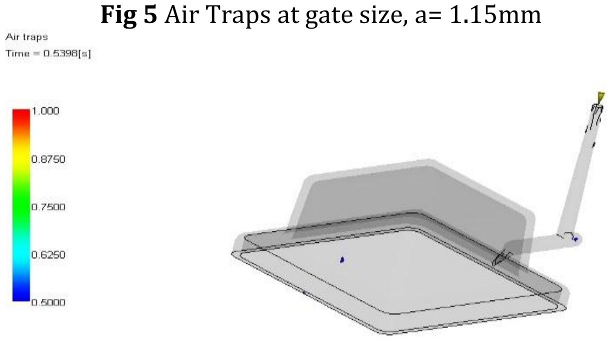

Fig 6 Air Traps at gate size, a= 1.25mm

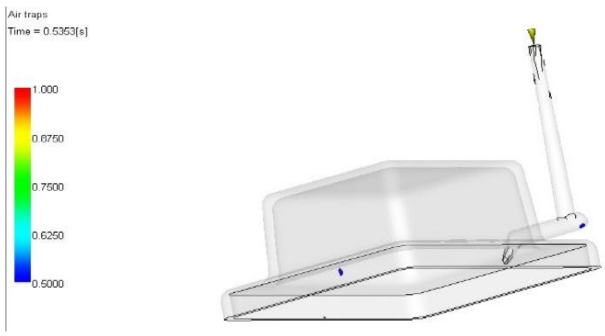

Fig 7 Air Traps at gate size, a= 1.35mm

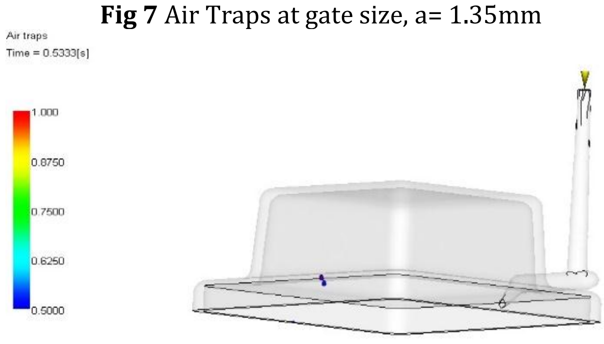

Fig 8 Air Traps at gate size, a= 1.45mm

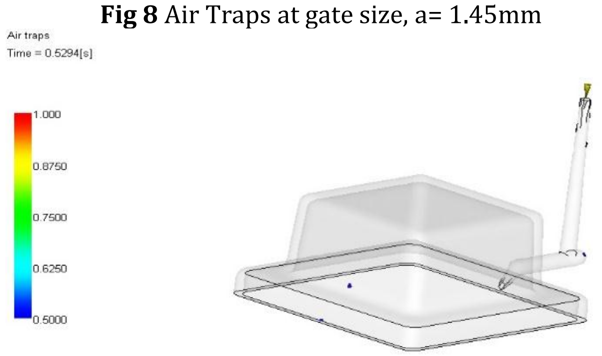

Fig 9 Air Traps at gate size, a= 1.55mm

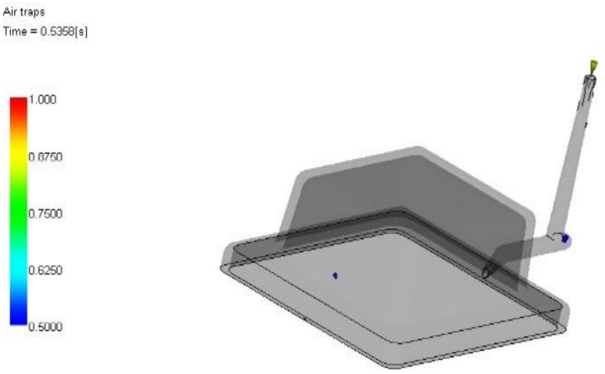

Fig 10 Air Traps at gate size, a= 1.65mm

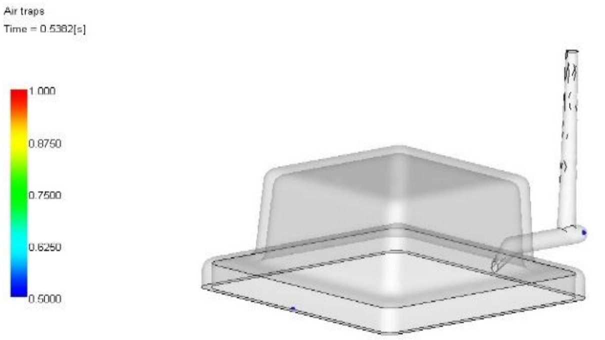

Fig 11 Air Traps at gate size, a= 1.75mm

Table 3 Result Comparison for Submarine Gate

Gate Diameter (mm)	Air Traps Location	Fill Time (s)	Clamp Force (Ton)
1.15	3	0.5304	8.2
1.25	2	0.5398	8
1.35	2	0.5353	8
1.45	2	0.5333	8
1.55	2	0.5294	8
1.65	2	0.5358	8
1.75	1	0.5382	8

5. c Film/Flash Gate

A film or flash gate consists of a straight runner and a gate land across either the entire length or a portion of the cavity. It is used for long flat thin walled parts and provides even filling (S. Selvaraj, *et al*, 2013).

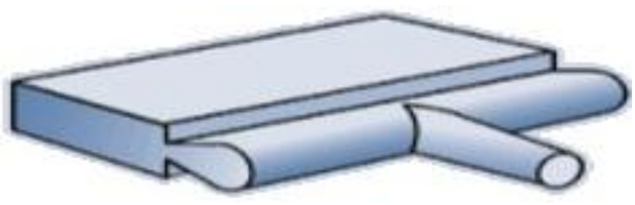

Fig. 12 Film gate size detail

Table: 4 Input Details for Fig 4.

Trial.no.	A (mm)
1.	0.25
2.	0.30
3.	0.35
4.	0.40
5.	0.45
6.	0.50

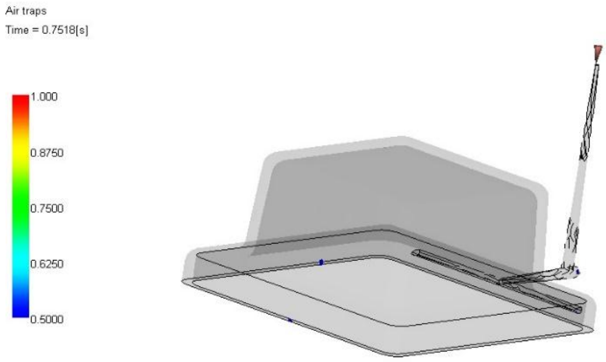

Fig 13 Air Traps at gate size A=0.25mm

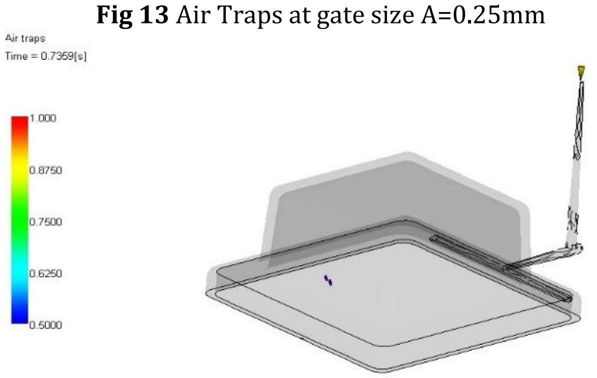

Fig 14 Air Traps at gate size A=0.30mm

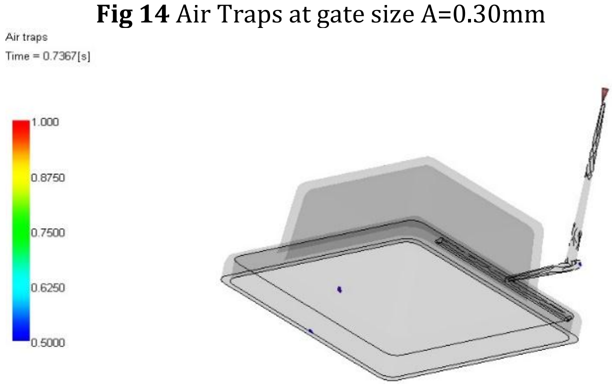

Fig 15 Air Traps at gate size A=0.35mm

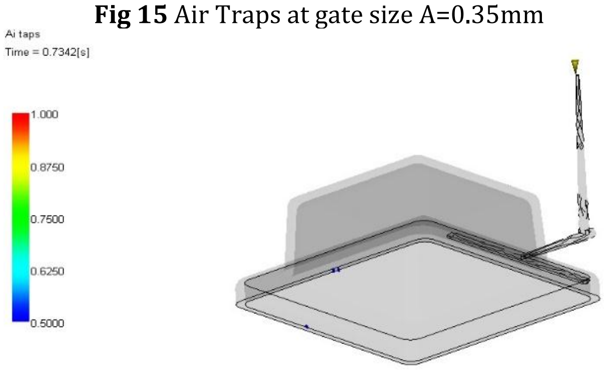

Fig 16 Air Traps at gate size A=0.40mm

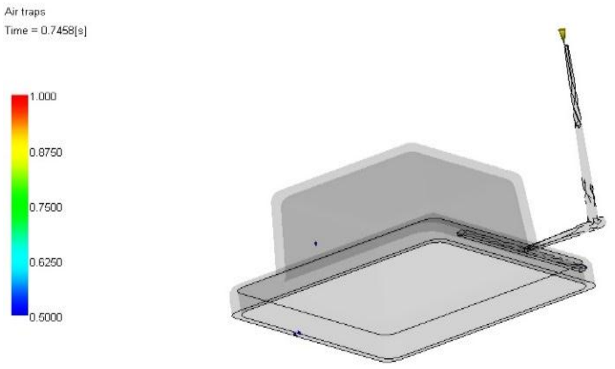

Fig 17 Air Traps at gate size A=0.45mm

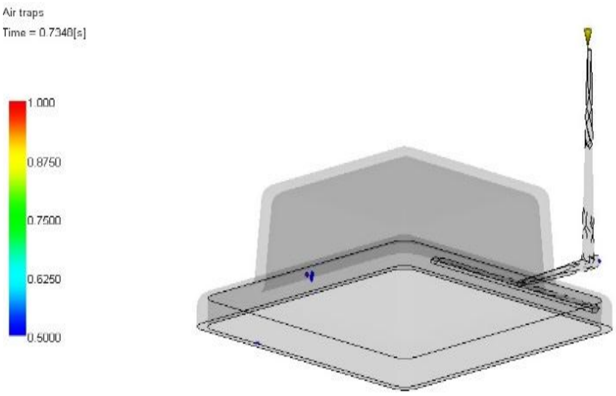

Fig 18 Air Traps at gate size A=0.50mm

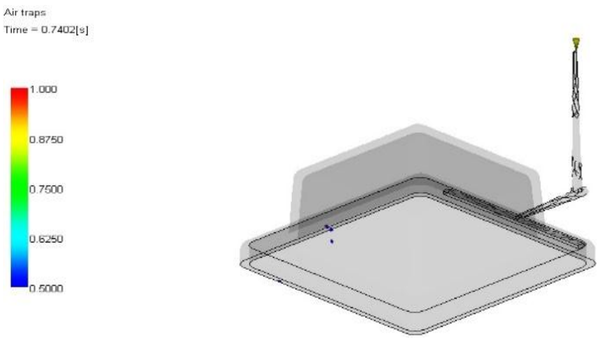

Fig 19 Air Traps at size A=0.60mm

Table 5 Result Comparison for Film Gate

S.No.	Gate Size Thickness (A in mm)	Air Traps Location	Fill Time (s)	Clamp Force (Ton)
1.	0.25	2	0.7518	6.5
2.	0.30	2	0.7359	5.9
3.	0.35	2	0.7367	5.8
4.	0.40	3	0.7342	5.3
5.	0.45	3	0.7458	6.4
6.	0.50	3	0.7348	6.3
7.	0.60	3	0.7402	6.2

7. Results

The Moldflow simulation analysis for both the gates was performed by varying gate size on the component and then a comparison of both gates from the comparative analysis was found. It was found that different gate size has a distinct effect on the air traps in component and process parameters.

For a Submarine gate, there is no such effect on the Clamp Force, which reduces from 8.2T to 8T and remains the same throughout. For fill time, it reduces in the beginning but started increasing during the final values of the simulation.

Air Traps reduced from 3 to 1 in the component as gate size is increased.

For Film gate, Clamp Force reduces from 6.5T to 5.3T, after which it increases again to 6.4T. The fill time also reduces initially from 0.75seconds to 0.734seconds, where after it increases again to 0.746seconds. Air Traps increase in number from 2 to 3.

Thus, we can deduce that number of air traps depend upon the gate size at the point of filling, though its effect may vary for different gates. The comparison result can be seen in Table 3 and Table 5 for Submarine and Film Gate respectively.

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