

Article Info

Received: 01 Oct 2015 | Revised Submission: 01 Dec 2015 | Accepted: 01 May 2016 | Available Online: 01 Jun 2016

To Plot Graph and Establish Relationship Between Component Weight and Wall Thickness for a Component Manufacturing in Gas Assist Injection Moulding

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ABSTRACT

To check the Quality of Gas Assist Molded Part very difficult, because it depends on its Gas Channel Geometry and uniform wall thickness. These can be check only after cross section cut and those parts will be rejected, so we have to find one more factor which can be validate process and insure quality with easy method. In GAIM, Part weight is very important criteria and now we need to established relation with part wall thickness. The GAIM study, trials, result, analysis and our experiment provides part weight have proportional related with part wall thickness.

Keywords: Gas Assist; Part Weight Disc; Experiment; Gas Channel; GAIM.

1.0 Introduction

Gas assist injection moulding (GAIM) has been developed to save material, shorten cycle times and to improve the surface aspects of thick-walled injection-moulded parts. To control gas and using in plastic moulding is impossible because gas gets burnt and blast at high temperature and pressure.

But nitrogen as inactive gas which rich available in environment made it, conceptuality to live, to check the quality of gas assist moulded part very difficult, because it depends on its gas channel geometry and uniform wall thickness. These can be check only after cross section cut and those parts will be rejected.

In GAIM, Part weight is very important criteria and now we need to established relation with part wall thickness. The GAIM study, trials, result, analysis and our experiment provides part weight have proportional related with part wall thickness. In the process of making components through gas injection moulding, it is noticed that part quality and strength is always a matter of concern when its wall thickness is not uniform or uncontrolled.

And our aim is to achieve optimum wall thickness of the components according to application of the components in the field by achieving the ideal

process parameters. For this we have to establish relationship between component weight and wall thickness for a component manufactured in gas assist injection moulding.

These analysis provide optimized part weight means to ensure desire part quality maintain: Part Wt. 68.0 to 70.0 Grams; Part Wall Thickness 2.0 mm to 2.50 mm; So N₂ Pressure - P₁ – 1600 ± 100 PSI, P₂ – 750 ± 100 PSI, P₃ – 0 (Venting) and N₂ (Flow Rate Analysis Data) - F₁ - 3500 ± 100, F₂ - 1000 ± 100, F₃ - 1000 ± 100 N₂ (Blow Time) BT₁ - 20 ± 2 Sec., BT₂ - 2 ± 0 Sec., BT₃ - 2 Sec. (Venting).

The aim of the present study is to develop and show positive relationship between Part Weight and Part thickness for Gas assist injection molded component and deliver a good quality part

2.0 Objectives

- To study thoroughly plastic history & technology (IM Technique)
- To study thoroughly polymer property and behavior
- To study the product design and tool design
- To study the gas assist injection molding machine and equipments

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- To study the gas assist injection molding process and process parameters
- To study the weight analysis in weighting scale
- To study the wall thickness variation
- To study the N₂ gas and parameter like time, pressure & speed
- To manufacture components in non-uniform wall thickness and uniform wall thickness in gas assist injection moulding process
- Un-uniform wall thickness (0.5 mm – 3.5 mm) - 5 samples.
- Uniform wall thickness (2.0 mm – 2.5 mm) - 5 samples.
- Finally plotting the graph between component weight and wall thickness
- To give way for further scope of study and investigation other subject to help the technology to flourish further in the industry.

3.0 Literature Review

There are many research papers and thesis that have been written and submitted on the subject of gas assist injection moulding, some of them which have closely been referred and read are here jotted in small abstracts below.

Luyluk Vatchara 2007: This research uses the Computer Aided Engineering (CAE) technology for design and construction of gas-assisted injection molding as well as analysis of data. The polypropylene (PP) and polystyrene (PS) are used as samples. The gas pin method is selected to use for filling up the gas to the part therefore the 4 variable in gas-assisted injection molding such as gas pressure, delay time, melt temperature and shot size are studied to find the effects on the gas penetration length and residual wall thickness (RWT). Moreover the 4 cross-sectional types; rib with circular spandrel fillet, rectangular rib, rib with 45° fillet and rib with circular fillet are studied as well. Furthermore, this research also does the experiment with the same parameters as study in CAE for only the rib with circular spandrel fillet type. Finally, the results of experiment and CAE are compared. From the study, the delay time and shot size affected the gas penetration length while the gas pressure and shot size affected the RWT which the strength and quality of parts could be affected by RWT.

Frederico J. M. F. Custódio · Patrick D. Anderson Gerrit W. M. Peters · António M. Cunha · Han E. H. Meijer 2009: In this study, we analyze their development in the case of gas-assisted injection moulding (GAIM) of amorphous polymers. Flow-induced residual stresses are computed within a decoupled approach, in which elastic effects are neglected in the momentum balance, assuming a generalized Newtonian material behaviour. In a staggered procedure, the computed viscous flow kinematics is used to calculate normal stresses employing a compressible version of the Rolie - Polymodel. For the computation of thermally and pressure-induced residual stresses, a linear thermo-visco elastic model is used. A 3-D finite element model for GAIM is employed, which is able to capture the kinematics of the flow front and whose capabilities to predict the thickness of the residual material layer have been validated by Haagh and Van de Vosse (Int J Numer Methods Fluids 28:1355–1369, 1998). In order to establish a clear comparison, the development of residual stresses is analyzed using standard injection moulding and GAIM for a test geometry.

Mohammad Ali, M. Quamrul Islam and R. Mahamud 2009: In this study dynamic behaviour of liquid sheet of thermoplastic with co flowing air is discussed and numerically simulated. The Navier-Stokes systems associated with surface tension forces are solved by the Volume of Fluid (VOF) technique with a Continuum Surface Force (CSF) manner. The velocity of liquid is kept constant throughout the study whereas the velocity of air is varies which eventually varies the gas Weber number. Sulphur hexa fluoride (SF₆) and high density polyethylene (HDPE) are considered as liquid to investigate the physics of breakup process. The effects of gas Weber number on liquid sheet breakup process are discussed to reveal the underlying physics of liquid disintegration. It is found that under any flow conditions a range of gas Weber number controls the instability for the breakup of liquid sheet. The pressure as well as velocity distribution of the flow field are also discussed to study the breakup processes in details.

Sharifah Rafidah Binti Syed Hamid 2010: The objective for this project was to study the effects of injection parameters which are temperature, pressure and volume to the mechanical properties of the

injected parts. Besides that, it also to determine the optimum amount of pressure, temperature and volume at the injection machine in producing document tray. In order to achieve the objectives, the scopes of studies are performed which is the study will be using a polymer material which is Samsung Starex® SD-0150GP High Impact Grade ABS. Besides that, only pressure, temperature and volume will be varied in this study while other parameter for instant clamping unit is fixed constant. The project can be divided into 4 stages. Firstly, is the preparation of the material. Then, injection moulding machine is used to produce document tray with the parameter that control the process which is temperature (220 deg, 230 deg, 240 deg), pressure (1675 bar, 1700 bar, 1725 bar) and volume (340 cm³, 350 cm³, 360 cm³). There are 27 samples produced by using full factorial method. After the samples are produced, there will be some testing for the samples such as mechanical testing such as tensile test and hardness test and physical testing such as density test. Lastly, analysis to determine the best and high quality of the samples was done. All the data obtained can be analyze and evaluate to produce the best optimum parameter for the injected part produce. As a result, the best injected part produced is sample number 10 which has good properties and optimum parameter is temperature at 230 deg, pressure at 1675 bar and volume at 340 cm³. It gives the low value of mass, low value of density, high of strength-to-weight ratio, high value of maximum strength and high value of hardness.

Ian Brzeski 2009: In this research work, a new process of combining gas injection with compression moulding was developed and studied. The process is called Gas Assisted Compression Moulding (or Gas Comp). The principle is based on the injection of nitrogen gas during a conventional compression moulding cycle. The flow of the material due to the compressive force of the press is assisted by the injection of gas into the centre of the molten material. The gas assists in the flow by coring out the material, reducing the weight by up to 45 percent and increasing the dimensional stability of the component. Novel glass matt thermoplastic mould tools were designed and developed during the course of the research program for use with the process. These designs were of a flash compression mould

tool design with a horizontal clamping face, rather than the conventional positive plug compression mould tool with a vertical shear edge. This created a fixed volume mould tool, which when used in conjunction with a short shot of material, would allow the gas to flow the material to fill the remaining volume. Several materials were investigated for their suitability with the process. Their characterisation showed that they contained different glass fibre contents and architectures. A material with a short, dispersed glass fibre content of 11 percent proved to consistently contain a significant gas cavity. The glass architecture proved to be the most significant contributing factor in the creation of a successful gas cavity. The most significant processing parameter in the creation of a large volume cavity proved to be the gas injection delay time. The gas pressure and gas ramp time affected the cavity shape, length and extent of gas fingering. The shrinkage was reduced in the presence of a gas cavity, along with the visible reduction of sink marks. The presence of other moulding features, such as hesitation marks, gas packing and the change in fibre orientation were also discussed

4.0 Methodology

4.1 Introduction

Gas assist injection molding (GAIM) has been developed to save material, shorten cycle times and to improve the surface aspects of thick-walled injection-molded parts. To control gas and using in plastic molding is impossible because gas gets burnt and blast at high temperature and pressure. But Nitrogen as inactive gas which rich available in environment made it, conceptuality to live. Gas parameters inside the molten plastic flow are more sensitive. It have vital role in component quality and strength. GAIM is a process enhancement to conventional injection molding, involving the injection of high-pressure nitrogen gas into the melt stream immediately after the injection of the resin. The intent is not to cause mixture of the nitrogen and resin, but for the nitrogen to displace resin in flow or withdrawing the injection nozzle from the sprue so that the gas can escape. In gas channels and thicker sections of the molded product the process is a high speed, low-pressure injection method. In most cases, a short shot method

of resin fill can be use and the gas can be utilized to fill and pack out the remainder of the part.

The nitrogen is typically shot into the process at relatively low pressures as compared to conventional molding.

4.2 Principle GAIM

The gas injection molding starts with injection of plastic into the cavity figure 1-2. When the cavity is 50% to 95 % full (depending on the shape of the part- see figure 1-3), the barrel is closed by a —shut offl and the gas injection starts. It can be controlled by pressure or volume.

The gas expands in the cavity, pushing the plastic in the front of it until the cavity if filled. Then the gas pressure is reduced .

This resistance is a function of the cross-sectional area of some design the gas may be allowed to escape from the cavity via injection needle, so that the machine can recover from the gas reduce. If the gas is injected through the same nozzle as the melt, a second injection of plastic is made to seal the hole in part.

4.3 Processing & Parameter of gas pressure

There is three important parameter:

- Time (Delay Time)
- Pressure
- Speed

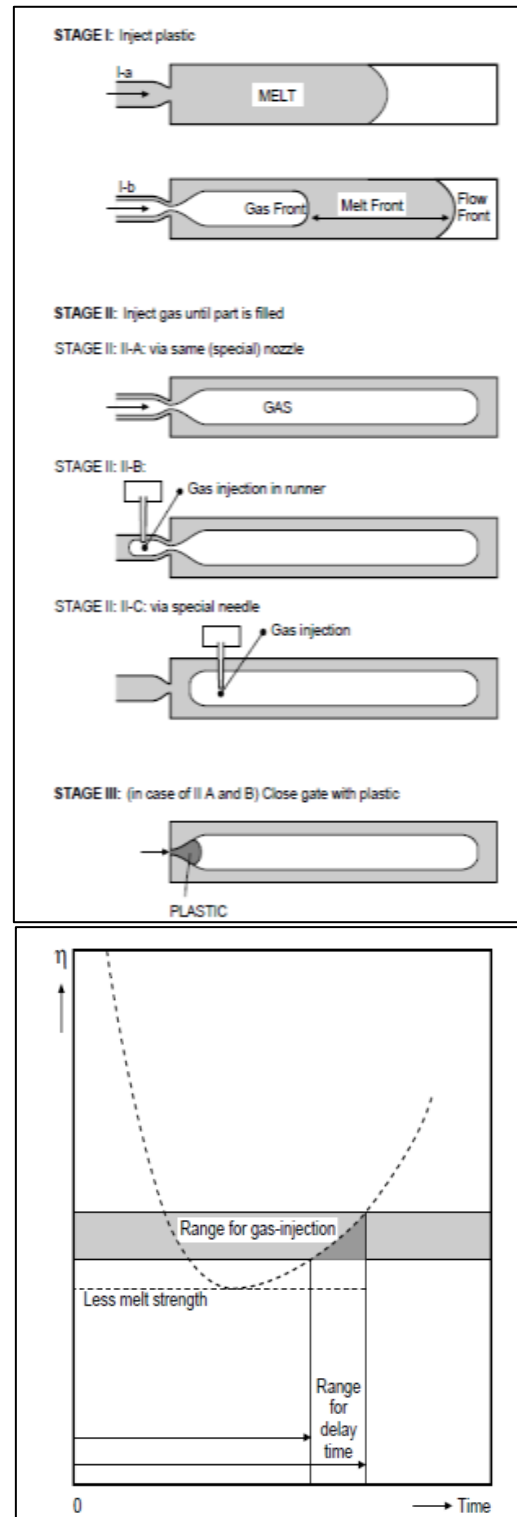
The delay time depends on the thickness of the layer frozen to the cavity wall. If the delay is too short, the gas can blow away too much material which is still liquid, leaving insufficient wall thickness. This, in addition to low melt viscosity, allows the gas to break through the melt front.

The same phenomenon can be noted if the gas pressure is not closely controlled.

The lower the resistance offered by the melt the gas channel, the thickness of the melt front, and the melt viscosity.

Too short a delay time may lead to turbulence in the gas and the melt; this can spoil the part's surface appearance.

The best results are obtained if, in addition to determining the correct delay time, the gas-pressure profile advances the flow front at a constant speed, so as to avoid flow marks on the surface. The melt front resistance decreases with time, because the amount of

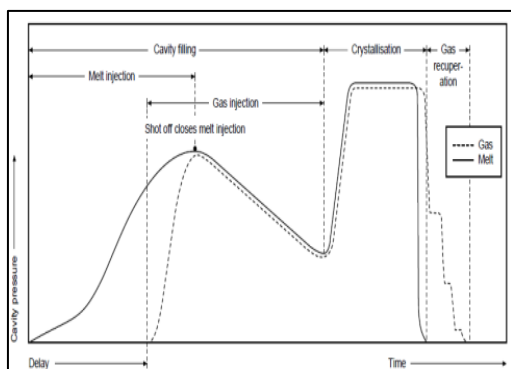


material being pushed forward by the gas is getting less. For this reason the gas pressure should be reduced as the operation proceeds, in order to keep a constant flow-front velocity. Fig. 1-5 illustrates this

principle; however, the diagram must be adjusted according to the needs of each specific application. When the cavity is completely filled, gas pressure can be increased again to obtain optimum crystallization structure, better surface appearance, better packing and fewer sink marks. Gas pressure also makes for faster crystallization time, because it keeps the surface of the part pressed against the cavity surface, so that better cooling is obtained. Typical pressures for gas injection are 100 to 500 bar.

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4.4. Design of experiment

1. Gas Assist Injection Molding machine (Machine-IM 250)

The GAM process or gas injection molding process has been used successfully with composites to mould hollow bodied parts. Hollow gas injection moldings are produced by the controlled injection of an inert gas (N₂) into the molten polymer melt compound through the runner system or into the part. The gas forms a continuous channel through the less viscous, thicker sections of the melt.

Some of the many advantages of gas-assist molding include • Curved hollow sections • Weight reduction • Cycle time reduction • Elimination of war-page • Increased stiffness and functionality. The key parameters of the hollow gas moulding process include the following

- Gas packing pressure
- Gas delay time
- Gas hold time

2 The Mould (T Mould – Gas Door Handle with Two Cavities) injection nozzle via the following sequence:

- A controlled short shot of resin is injected into the mold.
- Nitrogen gas is injected into the mold. The gas enters the part and completes the filling of the cavity, leaving a void.
- After the cavity is filled, pressure is evenly distributed throughout the part from the void created by the gas. The part begins to cool from both the inside and the outside surfaces.
- After the part has cooled sufficiently, the gas is vented to atmosphere, allowing the part to be De-moulded. The part may be vented either by sprue break or back through a gas pin.



3 Material Specifications – PC + PBT

4.5. Design of experiment

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- Gas delay time
- Gas hold time

2 The Mould (T Mould – Gas Door Handle with Two Cavity)

The nitrogen gas is introduced into the mould cavity either through gas pins in the mould or directly through the

Zone 2 – 250 °C,
Zone 3 – 260 °C,
Zone 4 – 265 °C,
HRTC – 250 °C
Melt Temperature – 260 °C,
Mould Temperature - 70 °C

Pressure

Injection Pressure – 120 MPA
Min N₂ Pressure - 150 Bar

Time

Injection Time – 1.35 Sec.,
Gas Delay Time – 1.0 Sec.
Cooling Time – 45 Sec.,
Cycle Time – 65 Sec.

3.0 Results and Discussions

3.1 Initial readings

Part Wt. (Grams.) – 85.0 ~ 55.0
Wall Thickness (MM) – 0.50 ~ 3.50
N₂ Pressure (PSI) – P1 – 1700, P2 – 850, P3 - 0
N₂ Flow – F1 – 6800, F2 - 1100, F3 - 1100 N₂
Blow Time (Sec.)
– BT1 – 22, BT2 – 2, BT3 - 4
Rejection Rate - 30 %

3.2 Process Trials

3.2.1 Weight Analysis

3.2.2 Wall Thickness Variation Analysis

3.2.3 The N₂ Pressure Analysis Data

3.2.4 The N₂ Flow Analysis Data

3.2.5 The N₂ Blow Time Analysis Data

2.4 Process Parameters

Temperature

Barrel Temperature

Zone 1 – 240 °C,

Weight Analysis

Part Weight Analysis Report

Part Weight Analysis Report			
Trial	Part 1 Wt (Grams)	Part 2 Wt (Grams)	Result
1	85.00	55.00	Not OK
2	85.00	55.00	Not OK
3	85.00	55.00	Not OK
4	85.00	55.00	Not OK
5	82.00	56.00	Not OK
6	82.00	56.00	Not OK
7	82.00	56.00	Not OK
10	80.00	56.50	Not OK

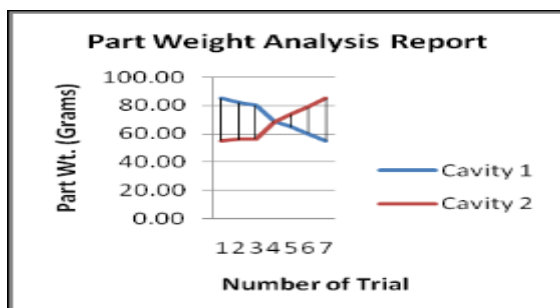
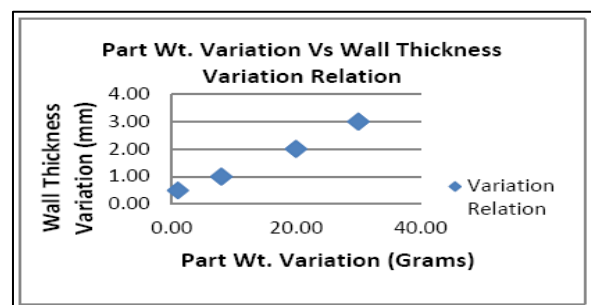
Car Door Handle Full View Result



- Part Weight Analysis Graph shows Cavity 1 and Cavity 2 intersecting at Part Wt. – 68.0 Grams. At Type 4 trials.
- Part Weight Analysis Table shows Part Wt. 68.0 to 70.0 – Components are OK.
So **Part Weight - 69.0 ± 1.0 Grams**

3.2.2 Wall Thickness Variation Analysis

Trial	Wall Thick Min. (mm)	Wall Thick Max. (mm)	Result
1	0.50	3.50	NOT OK
2	0.50	3.50	NOT OK
3	0.50	3.50	NOT OK
4	0.50	3.50	NOT OK
5	1.00	3.00	NOT OK
6	1.00	3.00	NOT OK
7	1.00	3.00	NOT OK
8	1.50	2.80	NOT OK
9	1.50	2.80	NOT OK
10	1.50	2.80	NOT OK



Result

- Part Wall Thickness Analysis Graph shows Thickness variation is very less from 2.0 mm to 2.50 mm. at Type 4 trial.
- Part Wall Thickness Analysis Table shows Part Wall Thickness 2.0 mm to 2.50 mm – Components are OK.
So **Part Wall Thickness - 2.25 ± 0.25 mm**

3.2.3 The N₂ Pressure Analysis Data

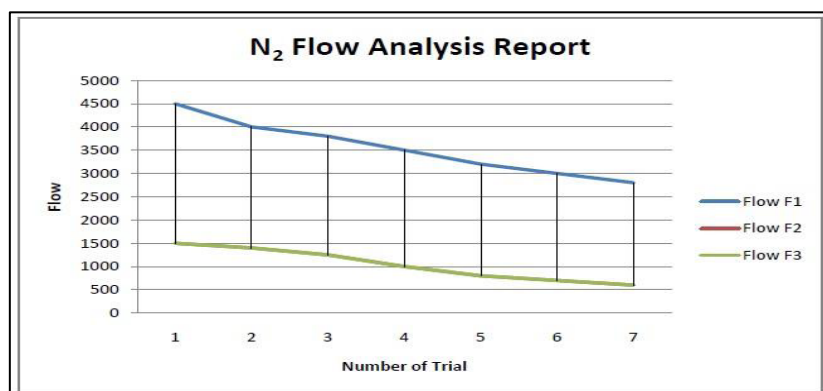
Trial	P1 (PSI)	P2 (PSI)	P3 (Venting)	Remark
1	2500	1650	0	Not OK
2	2500	1650	0	Not OK
3	2500	1650	0	Not OK
4	2500	1650	0	Not OK
5	2000	1150	0	Not OK
6	2000	1150	0	Not OK
7	2000	1150	0	Not OK

3.2.4 The N₂ Flow Analysis Data

Trial	Flow F1	Flow F2	Flow F3	Remark
1	4500	1500	1500	Not OK
2	4500	1500	1500	Not OK
3	4500	1500	1500	Not OK
4	4500	1500	1500	Not OK
5	4000	1400	1400	Not OK
6	4000	1400	1400	Not OK
7	4000	1400	1400	Not OK
8	3800	1250	1250	Not OK
9	3800	1250	1250	Not OK
10	3800	1250	1250	Not OK

3.2.5 The N₂ Blow Time Analysis Data

Trial	Blow Time BT1 (Sec.)	Blow Time BT2 (Sec.)	Venting Time BT3 (Sec.)	Remark
1	25	5	5	Not OK
2	25	5	5	Not OK
3	25	5	5	Not OK
4	25	5	5	Not OK
5	24	4	4	Not OK
6	24	4	4	Not OK



Results

- The N2 Flow Analysis Graph shows F1 –F2 and F1-F3 are parallel at type 4 Trial.
- The N2 Flow Analysis Table shows F1-3400 ~ 3600, F2 – 900 ~ 1100, F3 – 900 ~ 1100 Components are OK.

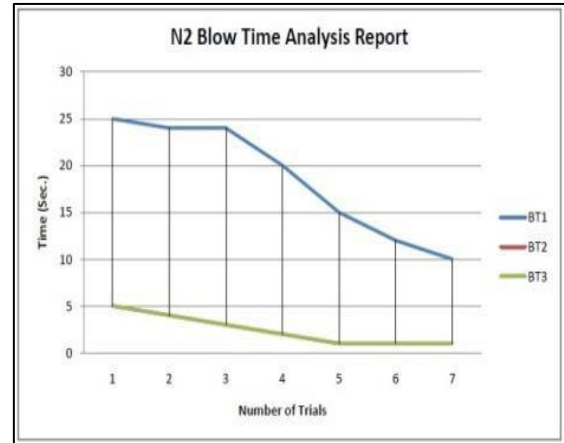
So N2 Flow - F1 - 3500 ± 100, F2 - 1000 ± 100, F3 - 1000 ± 100

Results

- N2 Blow Time Analysis Graph shows BT1, BT2 & BT3 are giving good result at Type 4 Trial.
- N2 Blow Time Analysis Table shows BT1 – 18 to 22, BT2 – 2, BT3 – 2 Components are OK.

So N2 Blow Time BT1 - 20 ± 2 Sec., BT2 - 2 ± 0 Sec. BT3 - 2 Sec. (Venting)

5.0 The Graph Between Part Wt. Variation and Wall Thickness Variation



Part Wt. Variation Vs Wall Thickness Variation Analysis Report			
Trial	Part Wt. Variation (Grams)	Wall Thickness Variation (mm)	Result
1	30	3	Not OK
2	30	3	Not OK
3	30	3	Not OK
4	30	3	Not OK
5	18	2	Not OK
6	18	2	Not OK
7	18	2	Not OK
8	18	1.3	Not OK
9	18	1.3	Not OK
10	10	1.3	Not OK

Part Wt. Variation Vs Wall Thickness Variation Relation Graph - These Graph shows positive relation means if Wall Thickness is OK then Part Wt. will be OK and same also part will be OK.

Process Parameter –

(After Process Optimization)

Temperature

Barrel Temperature
 Zone 1 – 240 °C, Zone 2 – 250 °C, Zone 3 – 260 °C, Zone 4 – 265 °C, HRTC – 250 °C
 Melt Temperature – 260 °C, Mould Temperature - 70 °C

Pressure

Injection Pressure – 120 MPA
 Min N2 Pressure - 150 Bar
 Time

Injection Time – 1.35 Sec., Gas Delay Time – 1.0 Sec.

Cooling Time – 45 Sec., Cycle Time – 65 Sec.

Part Wt. (Grams.) – 68.0 ~ 70.0

Wall Thickness (MM) – 2.0 ~ 2.50

N2 Pressure (PSI) – P1 – 1700, P2 – 850, P3 -

0

N2 Flow – F1 – 6800, F2 - 1100, F3 - 1100

N2 Blow Time (Sec.) – BT1 – 22, BT2 – 2, BT3 - 2

End Result.

Rejection (%) - 10 %

5.0 Conclusions

Check only after cross section cut and those parts will get rejected, So we have to find one more factor which can be validate process and insure

quality with easy method. In GAIM, Part weight is very important criteria and now we need to established relation with part wall thickness.

The GAIM study, trial result, analysis and our experiment provides that part weight is proportionally related with part wall thickness.

References

- [1] S. C. Chen, N. T. Cheng, and K. S. Hsu, (1996), Simulations of gas penetration in thin plates designed with a semicircular gas channel during gas-assisted injection molding, *International Journal of Mechanical Sciences*, 38,335-348.
- [2] S. Chao, S. Wang, and S. Chen, (1999), Evaluation of gas pressure dynamics for gas-assisted injection molding process, *International Communications in Heat and Mass Transfer*, 26,85-93.
- [3] Pual Dier and Richard Goralski, (2000) *Gas Assist Injection Moulding*. Norfolk: Bauer Compressors.
- [4] Jack Avery (2001). *Gas-Assist Injection Moulding*. Cincinnati: Gardner Publishers,
- [5] Y.K. Shen (2001), —The study on polymer melt front, gas front and solid layer in filling stage of gas-assisted injection molding, *Elsevier Science Ltd* , 28, 139-148.
- [6] M.A. Parvez, N.S. Ong , Y.C. Lam, and S.B. Tor, (2002), *Gas-assisted injection molding: the effects of process variables* .
- [7] S.Han, J.Kwag, C.Kim, Tae-Won Park ,and Yeong-Deug Jeong, (2004), —A new process of gas-assisted injection molding for faster cooling, *Journal of Materials Processing Technology*, 155–156, 1201-1206.
- [8] Marcilla, A. Odjo-Omoniyi, R. Ruiz-Femenia, J.C. García-Quesada,(2006), Simulation of the gas-assisted injection molding process using a mid-plane model of a contained-channel part, *Journal of Materials Processing Technology*, 178, 350-357.
- [9] M.Sánchez-Soto, A.Gordillo, B. Arasanz, J. Aurrekoetxea, L. Aretxabaleta, Optimising the gas-injection moulding of an automobile plastic cover using an experimental design procedure, *Journal of Materials Processing Technology*, 178, 2006,369-378.