Gas-assisted injection

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Introduction

Gas-assisted Injection Moulding is one of the most promising special injection moulding technologies for processing thermoplastics and continues to gain market shares, due to its flexibility in the design and manufacture of plastic parts. Gas-assisted injection moulding has been developed to save material, shorten cycles and improve the surface aspects of thick-walled injection-moulded parts.

The main applications of gas-assisted injection moulding are either injecting the gas into the component cavity (internal gas injection), or using the gas on the outside surface, though still inside the mould cavity to consolidate the component (external gas injection). External gas-assisted injection moulding is used for enhanced surface definition. This document will focus on the internal gas-assisted injection moulding, the most commonly used process.

In gas-assisted injection moulding, gas is injected into a mould partially filled with polymer. The gas drives the molten polymer core further into the mould, until it is completely filled. Then the gas-pressure is reduced by withdrawing the injection nozzle from the sprue, so that the gas can escape. In some designs, the gas can be allowed to escape from the cavity via the injection needle enabling to recover of the gas for re-use. The penetrating gas left behind a polymer layer at the mould walls, generates a product with a polymer skin and an inner gas channel. The gas can either be injected through the same nozzle as the melt or via one or more special gas injection needles located at either the runner or thicker walls. Usually, nitrogen gas is used to avoid burning effects.

After the mould being entirely filled, the gas is used to transmit the packing pressure to the polymer that is being cooled. Any shrinkage of the polymer material near the gas channel is compensated by an enlargement of the gas core. Once all polymer material has been solidified, the gas pressure is released. The product is then further cooled until it retains sufficient rigidity to eject it from the mould.

An alternative strategy is the plastic expulsion process, based on the filling of the mould cavity with plastic. In this process, the gas injection is followed by the opening of one or more shut-off valves that enable the expulsion of molten material into one or more secondary cavities.

The most important characteristic of gas-assisted injection moulding is the pressure dropping within the gas core being too small compared with the pressure drop for an equivalent molten polymer core, because the viscosity of the gas is roughly 10th times smaller than the polymer one. Consequently, the gas pressure can be considered constant throughout the gas core, and this accounts for most of the advantages of gas-assisted injection moulding.

Processing

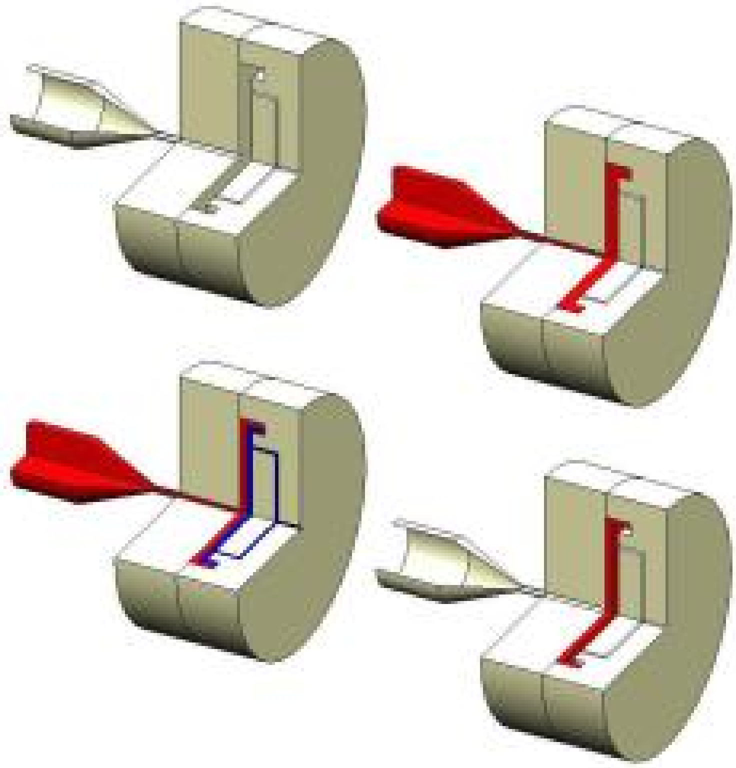


Fig 1.   External gas-assisted injection moulding

The gas-assisted injection moulding cycle can be described according to the following figure.

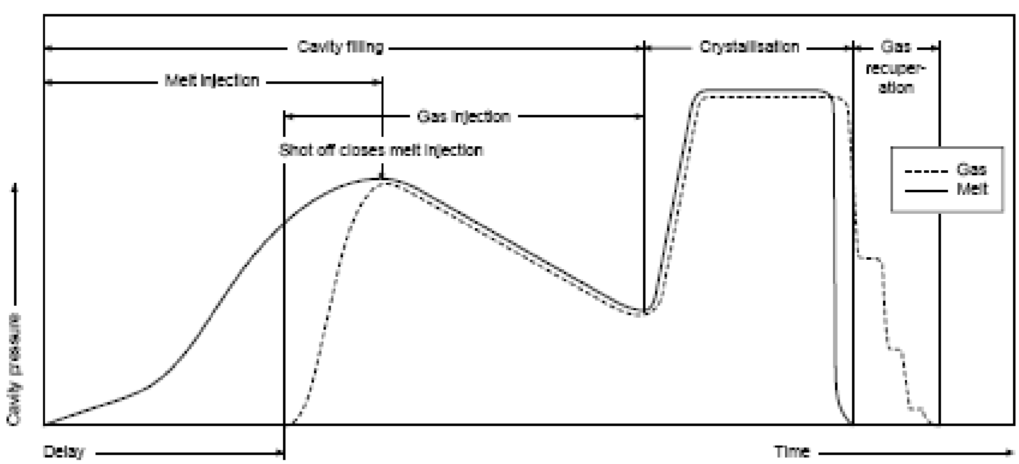


Fig 2.   Gas-assisted injection moulding process cycle

Processing

Gas assist moulding can be divided into three stages: plastic injection, primary gas penetration, and secondary gas penetration.

Stage 1: Plastic Injection

- The polymer is injected into the mould.

Stage 2: Primary Gas Penetration

- The gas is introduced into the molten core forming a bubble. Then the gas bubble displaces some of the molten core completing the mould filling.

Stage 3: Secondary Gas Penetration

- After completing the previous cycle, the gas bubble extends as the part cools and the material shrinks. Due to the material shrinking, an extra cavity volume is created which is fulfilled by an increase of the gas bubble. The pressure in the bubble also provides packing of the part during secondary gas penetration.

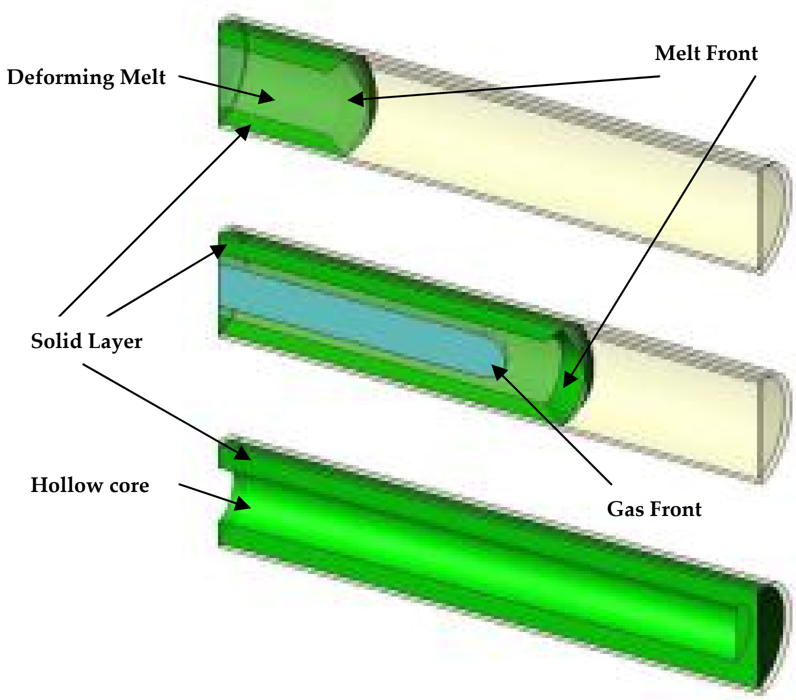


Fig 3. Gas-assisted injection moulding stages

As mentioned before, there are two types of gas-assisted injection moulding processes, internal and external injection, but within the internal gas-assisted injection moulding there are three types of processes, as follows:

- Gas-assisted injection with resin flow
- Gas-assisted injection against resin flow
- Gas-assisted injection with resin overflow

Processing

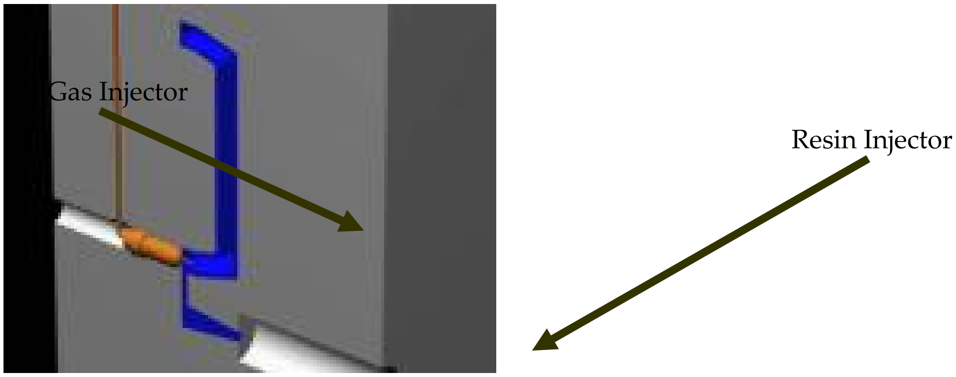


Fig 4. Gas-assisted injection with resin flow

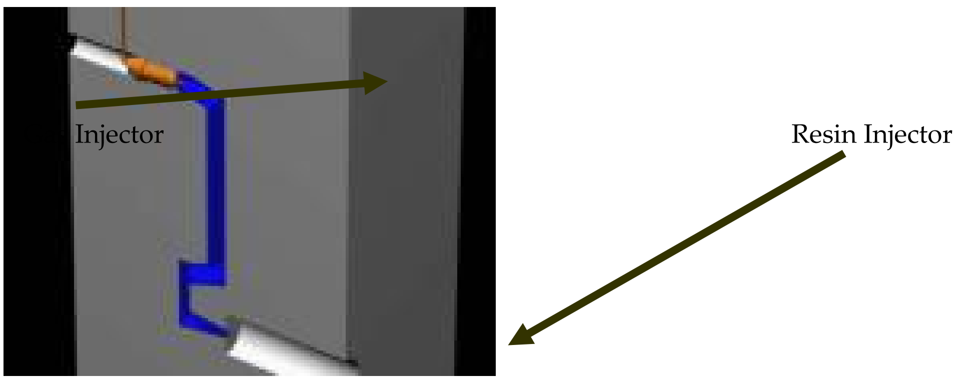


Fig 5. Gas-assisted injection moulding against resin flow

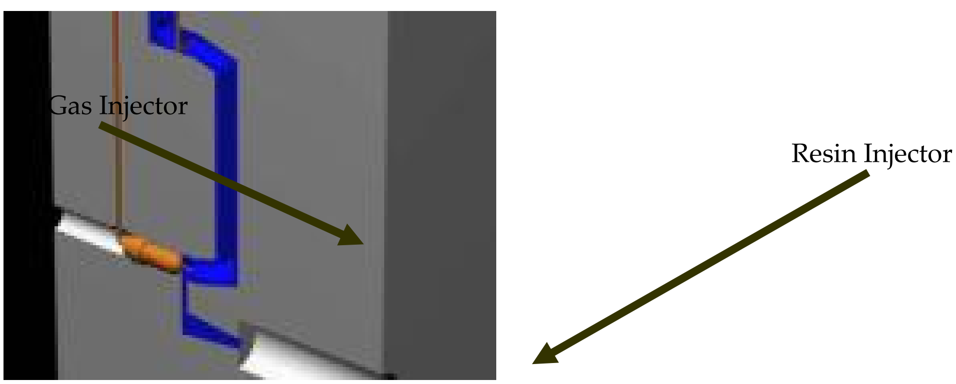


Fig 6. Gas-assisted injection moulding with resin overflow

Structural Performance of the Plastic Part

Two important categories of structural part performance are stiffness and strength. Both are system properties depending on part geometry, material, loading conditions and constraints. Part stiffness is the measurement of a part's resistance to deflection under an applied load, whereas part strength is the measurement of the load-carrying capacity of the plastic part. Gas-assisted injection moulding affects both part stiffness and strength through due to its influence on part geometry, as explained below:

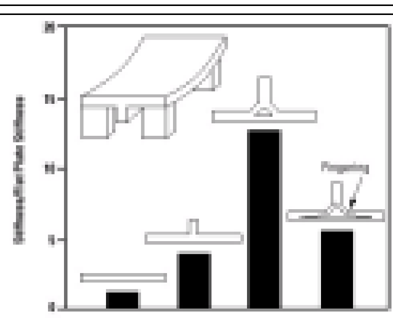
Part Stiffness

Higher stiffness-to-weight ratios can be obtained using gas-assisted injection moulding processes, through a proper design and process control, than by conventional ones. This advantage is usually more evident for parts in which the gas flows through a contained channel. For example, hollow tubes produced by gas-assisted injection moulding present stiffness-to-weight ratios of 40% or higher compared with a moulded solid one. In contrast, parts like ribbed plates usually present stiffness-to-weight ratios only 5% higher than their identical solid counterparts.

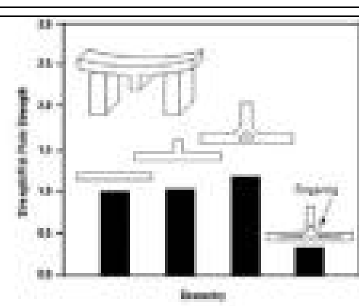
Part Strength

The influence of gas-assisted injection moulding on the part's strength for ribbed plates, either bent parallel or perpendicular to the ribs, are shown in the figures below. The strength of larger hollow rib geometries is generally greater for parts bent parallel to the rib axis than the injection moulding designs. Little increase in strength is observed for parts bent perpendicular to the rib axis, because it's the plate thickness that controls the maximum load.

The width of the gas bubble also influences part strength. Poorly formed gas channels, not centred in the rib and/or exhibiting fingering, can be expected to reduce part strength since design loads must then be carried out by thinner sections. The strength of plaques bent along their rib axis decreases slightly with increasing gas core size and fingering. However, for plaques bent perpendicular to their rib axis, there can be a sharp decrease in strength when the bubble width exceeds half of the rib base width. With extensive fingering, part strength may be reduced up to 20% of a solid part. Regarding brittle materials, such as glass-filled resins, the decreases in strength may even be more substantial. Two solutions to solve the problem of rib-stiffened plate-like geometries under bi-axial bending are: the maximum the gas core width should be less than 50% of the rib's base width or perpendicular ribs should be provided to bear this load.



Strength Parallel to Channels.



Strength Perpendicular to Channels.

Advantages and Disadvantages

Gas-assisted injection moulding offers a variety of processes and design features, which can fit project requirements. Some of these features and benefits are listed below:

- It is possible to develop hollow thick parts or sections alongside the design process, which will enable to comply with specific design aspects:
  - Large ribs or flow leaders without process penalties
  - Higher stiffness-to-weight ratios in structured parts
  - Moulding large cross-sections (parts consolidation)

- During the production process, the principal goal is to reduce production costs. This can be obtained mainly through:
  - A short shot process with hollow sections, which result in:
    1. Lower clamp tonnage
    2. Lower injection pressures
    3. Reduced cycle time vs. solid sections

  - A smoother surface appearance, which result in:
    1. Improved part aesthetics vs. structural foam
    2. Reduced secondary operations

- The dimensional stability of the plastic part can be improved through uniform packing from within the cavity. Other characteristics of the plastic part are linked to the dimensional stability, such as:
  - Reduced stresses within the plastic part
  - Reduced part warpage
  - Reduced sink marks

The following table presents a brief summary of gas injection moulding's advantages and disadvantages:

Advantageous	Disadvantageous
- Lower clamping force - Lower pressure drop - Simpler and cheaper moulds - Lower part weight (reduction up to 40%) - Fewer skin marks - Less warpage - More design freedom with non-uniform wall thicknesses	- Extra equipment - Special nozzle design/gas-injection needles - Increased shrinkage in the direction of gas channel flow - Material properties usually lower than in equivalent parts made by conventional injection moulding

Case study

Part:

Fig 7. CAD model of the part

The part is characterised by a large surface area, so it is important to avoid any flow marks. To avoid any marks associated with the transition between polymer injection and gas injection it was considered a secondary cavity to be filled by the excess of polymer. In this case, the mould cavity is completely filled by the polymer, as the gas forces the melted material out of the mould cavity into this secondary cavity.

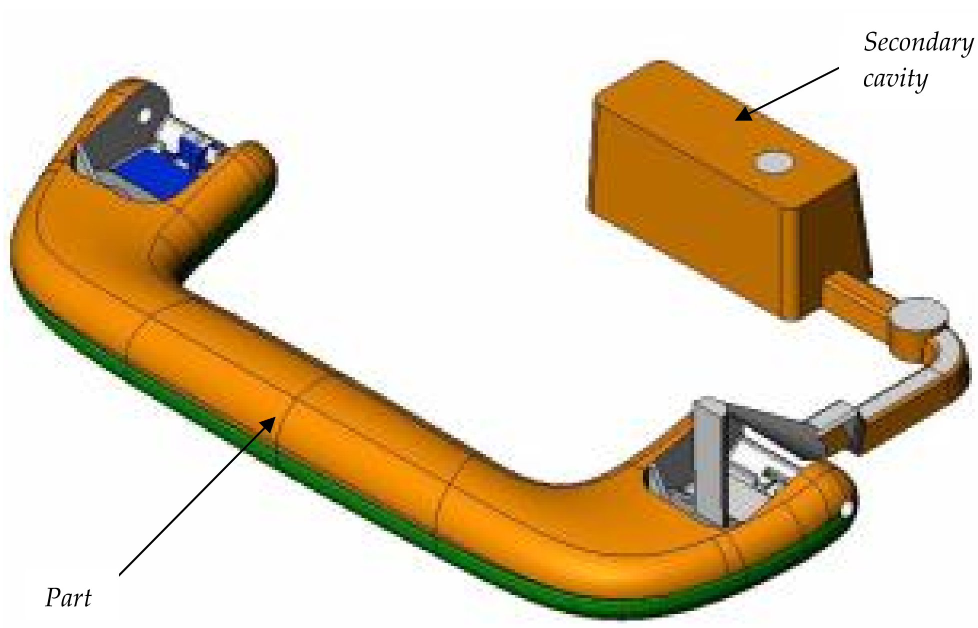


Fig 8. Part and additional cavity to receive the excess f polymer

Mould:

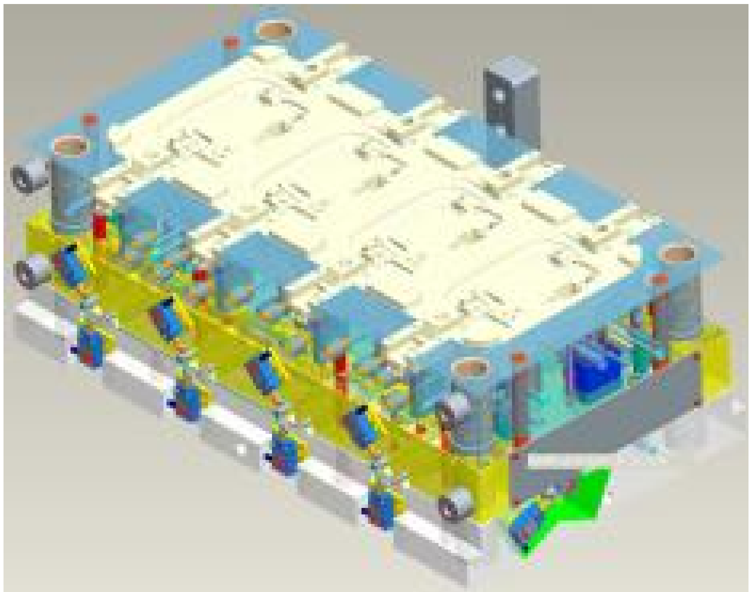


Fig 9. Four cavities mould

Gas entrance *Plastic injection point* *Secondary cavity*

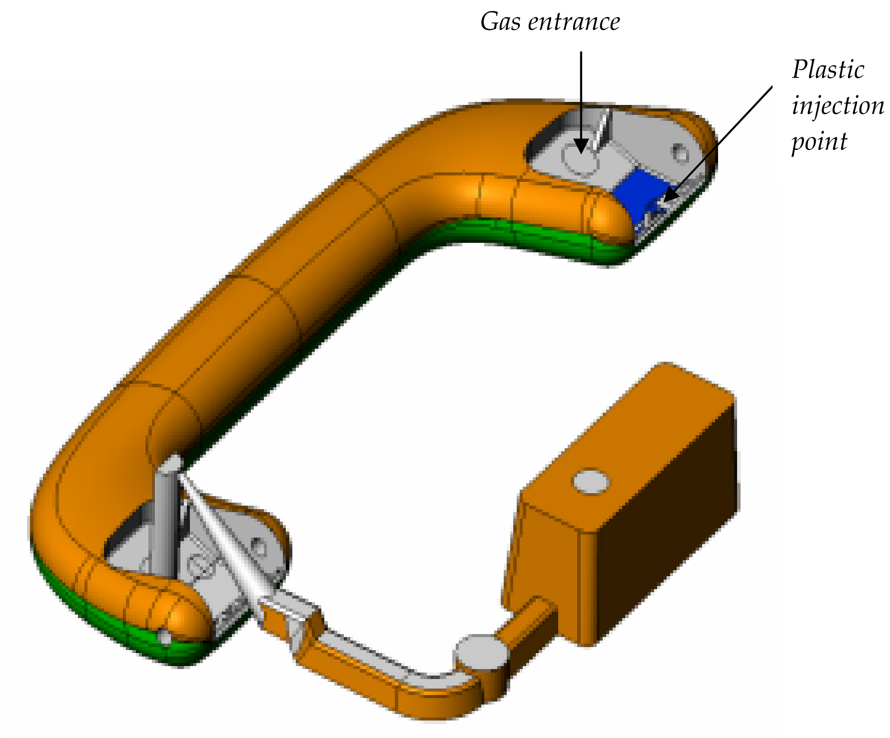


Fig 10. Position of both gas and polymer injection points

Injected part:

Fig 11. Injected part

Fig 12. Cross section of the part

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