WHITE PAPER

# THE EFFECTS OF ORIENTATION IN INJECTION MOULDING

Garry Whitehand
(Senior Technical Service Specialist)
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Find out what causes molecular orientation and which strategies can be deployed to reduce orientation in injection moulded items
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**Molecular orientation occurs as a result of sheer forces during the process of injection. Where molecules are frozen in a significantly oriented state they will impart strength in the direction of flow and weakness in the direction perpendicular to flow. The impact strength of a moulding may be significantly compromised by the resultant imbalance in properties. As the oriented molecules strive to return to their normal state they will shrink more in the flow direction, potentially resulting in distortion or even cracking of a moulding.  Attack by certain chemicals or sunlight will weaken the polymer structure and results release the molecular tension causing cracking perpendicular to the direction of flow. This paper describes a number of strategies that can be deployed to reduce molecular orientation.**

MOLECULAR ORIENTATION OCCURS IN THE INJECTION MOULDING PROCESS DUE TO MOLECULES BEING ALIGNED AND STRETCHED IN THE DIRECTION OF FLOW. THE EFFECT IS MOST PRONOUNCED NEAR THE MOULD WALL WHERE THE MOLECULES ARE FROZEN IN THEIR STRETCHED STATE.

In contrast the molecules closest to the centre of the moulding may remain in a fluid state long enough after the first stage of injection to enable relaxation to their natural un-stretched state.

## THE EFFECTS OF MOLECULAR ORIENTATION

The molecular orientation of polymers in the injection moulding process changes the properties in the flow and transverse directions compared with non-oriented samples.

Orientation leads to the following changes in the flow direction:

- Higher tensile yield strength
- Higher tensile impact strength
- Increased shrinkage Better crack resistance
- Improved environmental stress crack resistance
- Lower tensile elongation

Orientation leads to the following changes in the transverse direction:

- Higher tensile elongation
- Comparatively lower tensile impact strength
- Reduced shrinkage Lower crack resistance
- Reduced environmental stress crack resistance

The imbalance in properties that result from changing molecular orientation can significantly alter the performance of the finished mouldings.

> THE MOLECULAR ORIENTATION OF POLYMERS IN THE INJECTION MOULDING PROCESS CHANGES THE PROPERTIES IN BOTH THE FLOW AND TRANSVERSE DIRECTIONS

## FACTORS CONTRIBUTING TO MOLECULAR ORIENTATION

### Molecule size

One of the design parameters used to give polyethylene resin specific properties for particular applications is the relative mix of molecules of differing length (molecular weight), known as molecular weight distribution (MWD). The size of the molecule is one of the factors that contributes most to orientation. Polyethylene molecules tend to be larger than the molecules of many other polymers, measuring up to 0.2 microns or 1/200th the width of a human hair.

The longer a polyethylene molecule, the more it will orient under a specific set of moulding conditions. Therefore, changes in MWD results in changes in the level of orientation. A grade of polyethylene with the greatest MWD will orient more due to the presence of larger molecules. Orientation can also be affected by changes in the average molecule size of a polyethylene. As the average molecule size increases the melt flow index (MFI) of the polyethylene will reduce. For a given set of moulding conditions, the lower the MFI, the more the process of orientation will occur.

### Temperature

If the polyethylene itself is injected into the mould at a lower temperature, orientation commonly becomes more pronounced as the plastic solidifies quickly and the molecules tend to set in place in an orientated state.

Conversely, injecting the polyethylene at a higher melt temperature means that the plastic will stay molten for a longer period of time, during which the molecules relax and de-orientate after injection.

### Stages of injection

A second stage of injection is often deployed to compensate somewhat for the shrinkage that may occur in the first cooling stage. During this lower-speed stage, excessive orientation in the area of the gate may weaken the properties of the final product. In some cases, this can be severe enough to cause immediate splitting across the gate, while at other times it can happen early in the service life of the injection moulded item as the polyethylene is exposed to environmental or mechanical cracking agents. The stress placed at the area of the gate can therefore be reduced by minimising the volume of second stage of injection.

## ASSESSING ORIENTATION ISSUES

The environmental agents acting on the injection moulded article include ultraviolet radiation and exposure to chemical oxidants, while mechanical stresses commonly include bending and impact. When exposed to oxidation, for instance, the material is weakened and will become less able to withstand the orientation stresses.

In an oxidative situation the oriented material is more prone to fracture and shrink in the direction of greatest orientation. Exposure to UV light causes oxidative degradation. This degradation weakens the material such that it is no longer able to withstand the forces of the molecules trying to shrink back to their normal state. The result is the formation of bands of cracks that are perpendicular to flow on the surface of the product.

Other issues caused by excessive orientation include distortion of the moulding, commonly caused by differential shrinkage. A classic example is a propeller-shaped flat circular moulding that is centre-gated; greater shrinkage in the flow direction occurs due to molecules retracting from their oriented position. Another tell-tale sign is the failure of an impact test, usually manifesting as splits in the flow direction.

## MEASURING THE DEGREE OF ORIENTATION

Ways to assess the degree of orientation are somewhat limited. One of the more precise ways is through a reversion shrinkage test, which uses samples to measure the dimensional change as the material is re-melted. This enables the orientated molecules to relax and shrink back to their preferred length, similar to what is seen in polyethylene grades with a higher melt temperature. The degree of shrinkage then provides an indication of the degree of orientation that the polymers previously experienced in moulding.

Another suitable measure of orientation is through testing directional properties, such as tensile impact strength and tensile strength at yield. Both methods will provide a guide to molecular orientation, as the direction of flow will yield better results.

## STRATEGIES FOR REDUCING ORIENTATION

There are a number of strategies that can be deployed to reduce molecular orientation, including:

- Raising the temperature of the melt
- Raising the moulding temperature
- Increasing the speed of the first stage of injection
- Reducing the volume of second-stage injection
- Increasing the speed and therefore pressure in the second stage
- Changing the polyethylene grade, for example to one with a higher MFI
- Removing nucleating sources, such as blue and green phthalocyanine pigments

A combination of solutions may yield the best results, however it’s important to understand that there are limits to the amount of change that can be made to molecular orientation.

## HOW THE RESIN SUPPLIER CAN HELP

Qenos is committed to helping its customers produce high quality injection moulded items and offers advice on best practices as well as on-site support. Qenos supplies a range of high density, low density and linear low density polyethylene resins specifically designed for injection moulding in applications from small caps and closures to stackable crates for transport and storage, industrial mouldings as well as items requiring long term weatherability such as kerbside bins and industrial wheelie bins.

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**Qenos Pty Ltd**

471 Kororoit Creek Rd
Altona Victoria 3018 Australia

Phone 1800 063 573
ABN 62 054 196 771

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qenos.com