Rigid Packaging

Materials & Properties

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Polypropylene

Characteristics relevant to Injection Molding.

PP as a material…

- Poly-propylene is a semi-crystalline polymeric thermoplastic material.
- Recycling is possible
- Density of material is lowest amongst all plastics having rigidity enough for self-supporting structures.
- Highly non-polar material, no solvents at room temp. Printing, heat sealing and ultrasonic welding is possible.
- The crystalline melting point of PP is high so is useful at temperatures of boiling water and under the hood auto-applications.
- PP is a polymer having wide acceptance of fillers owing to the amorphous-crystalline balance present.

Strength of PP

Cost Comparison of HDPE,PP and HIPS for same stiffness

Polymer	Density	Equivalent Thickness for same Stiffness	Equivalent Volume for same Stiffness	Equivalent Weight for same stiffness	Weight Index for same stiffness	Price $/kg	Cost for same Stiff-ness
HDPE	0.96	1	1	0.96	1	1.25	1.25
PP-ICP	0.905	0.9	0.9	0.82	0.854	1.3	1.11
HIPS	1.05	0.8	0.8	0.84	0.875	1.4	1.225

Strong point of PP is weight and hence cost required for equivalent thickness is minimum among commodity polymer.

PP Characteristics -Thermal

- For semi-crystalline materials there exists latent heat of fusion. For amorphous materials no latent heat of fusion is there.
- As a result the heat content in PP melts is substantially higher than melts of PS, HIPS, ABS etc.
- The specific heat of PP is also higher than PS/HIPS/ABS melts.
- The heat to be removed is higher in PP

PP Characteristics -Thermal

- Specific Heat Values

ABS	0.35 Cal/g/deg C
PS	o.32
PP	0.46

- Latent Heat Values

PP HP	21.5 Cals/g	90J/g
PP RCP	14.4	60J/g
PP ICP	18	75J/g

PP Characteristics: Volumetric

- At room temperature PP is semi-crystalline.

- Consist of amorphous regions with low density, and crystalline regions with high density (> 1)
- Difference between melt density and solid density higher in PP than in case of PS/HIPS/ABS.
- Mold shrinkage data gives a useful indication and tool.
- Shrinkage – Homo polymers higher than ICP
- PP shrinkage is higher than HIPS/ABS shrinkage.

Morphology attained in Injection Molding

- Final Morphology of a molded part is a direct result of processing during filling and subsequent solidification.
- Orientation of chains in melt with the imposed flow field.
- Heat transfer between hot melt and cold mold.
- Crystallization kinetics under flow field

- Shear Rate max at wall
- Shear induces orientation
- Shear can also enhance rate of crystallization
- Cooling rate max at walls.

- PP attains a skin and core morphology during injection molding. At the skin there are oriented crystalline regions.

Effect of various parameters..

Skin layer thickness if more contributes to better tensile and flexural modulus, yet leads to anisotropy of properties. „ Non uniform skin layer thickness can lead to uneven shrinkage and warpage.

Generally the skin layer thickness decreases with:

- ❖ Increasing melt temperature
- ❖ Increasing the distance from the gate in the flow direction.
- ❖ Decreasing resin molecular weight (increasing MFI).
- ❖ Decreasing resin polydispersity (less with narrow MWD)
- ❖ Increasing injection speed.

Increasing mold temperature.

- ❖ Skin layer thickness increases with incorporation of fillers.
- ❖ Change in skin layer thickness in direction of flow leads to more shrinkage in flow direction and less in direction transverse to theflow

SHRINKAGE

WHY DO THEY OCCUR?

- Crystalline and semi-crystalline materials are particularly prone to thermal shrinkage; amorphous materials tend to shrink less.
- When crystalline materials are cooled below their transition temperature, the molecules arrange themselves in a more orderly way, forming crystallites.
- On the other hand, the microstructure of amorphous materials does not change with the phase change. This difference leads to crystalline and semi-crystalline materials having a greater difference in specific volume between their melt phase and solid (crystalline) phase.

SHRINKAGE

WHY DO THEY OCCUR?

Shrinkage is basically a reduction in size of plastic which is inherent in the injection molding process.

Shrinkage occurs because the density of polymer varies from the processing temperature to the ambient temperature.

During injection molding, the variation in shrinkage through the cross section of a part creates internal stresses.

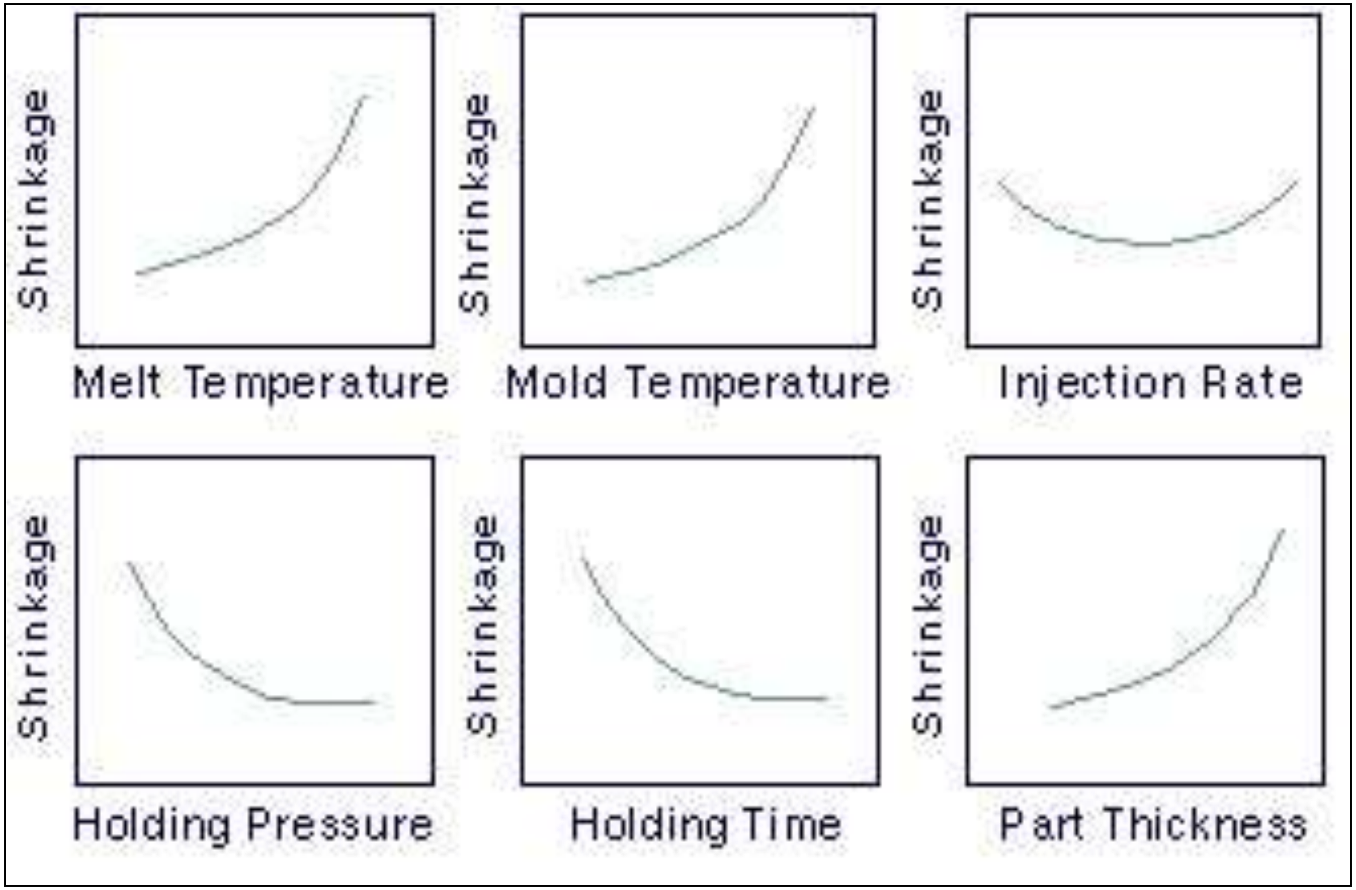
These so-called residual stresses act on a part with effects similar to externally applied stresses.

If the residual stresses induced during molding are high enough to overcome the structural integrity of the part, the part will warp upon ejection from the mold or crack with external service load.

SHRINKAGE : Problems & Solutions

- Uncompensated volumetric contraction leads to either *sink marks or voids* in the molding interior.
- Controlling part shrinkage is important in part, mold and process designs.
- Shrinkage that leads to sink marks or voids can be reduced or eliminated by packing the cavity after filling. Also, the mold design should take shrinkage into account in order to conform to the part dimension.

Processing Parameters & SHRINKAGE



- **Cooling in mould.**
- **Injection Pressure.**
- **Melt temperature.**

WARPAGE

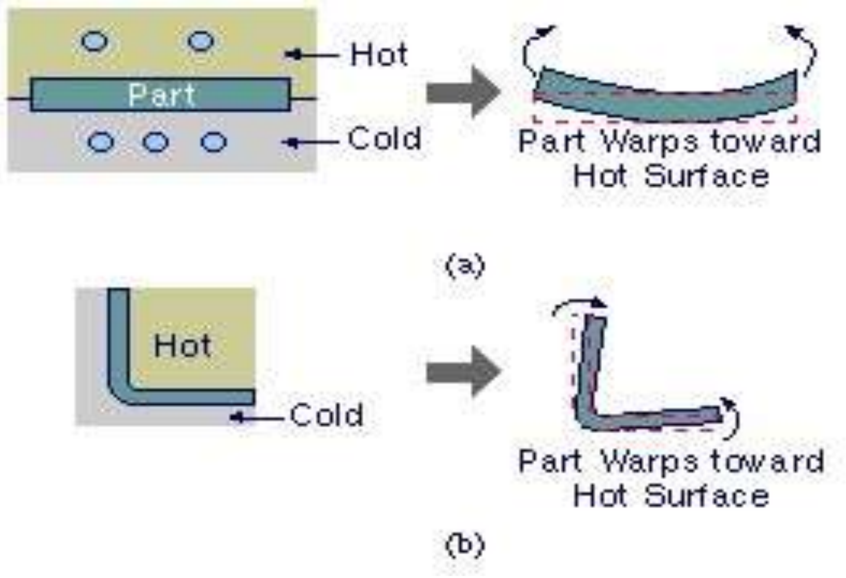
- Warpage in molded parts results from differential shrinkage.
- Warpage is a distortion where the surfaces of the molded part do not follow the intended shape of the design.
- Part warpage results from molded-in residual stresses, which in turn, is caused by differential shrinkage of material in the molded part. If the shrinkage throughout the part is uniform, the molding will not deform or warp

MAJOR CAUSES

- Non uniform mold cooling across the part thickness or over the part
- Cooling rates that differ because of part thickness variation
- Part geometry asymmetry or curvature

WARPAGE

- **Non-uniform mold cooling across the part thickness**
  Non-uniform cooling in the part and asymmetric cooling across the part thickness from the mold cavity and core can also induce differential shrinkage. The material cools and shrinks inconsistently from the mold wall to the center, causing warpage after ejection



Part warpage due to (a) non-uniform cooling in the part, and (b) asymmetric cooling across the part thickness

Thermoforming of PP

- Traditionally popular materials for thermoforming are amorphous polymers likeGPPS/HIPS/SAN, PVC, Polycarbonates, acrylics.
- PP is semi-crystalline, has different characteristics, so difference between thermoforming of amorphous materials and PP needs to be understood.
- The requirements for thermoformed products and thermoforming process needs to be taken in account while making the sheets from PP.

Sagging during PP thermoforming..

- Coefficient of thermal expansion for amorphous polymers is less so sagging is less - so sagging under control in case of styrenics.
- For crystalline polymers as temperature increases part of crystallites melt so volume fraction of crystalline zone reduce - entanglement reduce - so sag is more.

To control sag

- Provide air cushion below the sheet
- Nucleation if present then volume fraction of crystallites at forming temperature slightly high and some nucleators increase the modulus of melts - so nucleation helps
- Filled PP will reduce sag. Filler dispersion, shape & size are important.

Thank You