IM: Flow induced fiber orientation

Use of short fibers:

- Enhanced polymer properties
- Easy to mold
- Weight saving
IM: Flow induced fiber orientation

Orientation of the fibers:
• Not random, not unidirectional
• Determined by polymer flow
=> Determines structural properties
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Velocity profile very important
Depends on mould shape, polymer rheology, injection speed (strain rate), particle fraction etc.

Bay and Tucker, Polymer Composites, 13 (1992) 317
IM: Flow induced fiber orientation

Transverse rib
4mm thick plate
Rib 3mm thick
0.8s fill
270°C

Fibre fraction
40% w/w (23% v/v)

Orientation map of $a_{xx}$

$<\cos^2\theta_X>$

• Expansion near gate aligns fibres perpendicular to flow.
• Core fibres stay in this orientation (no velocity gradient).
• Shear aligned shell layers either side of a central core.
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- Core thinner, shell thicker
  - more even across width
- Alignment in shell layer saturates? fibre-fibre interactions?
- Max orientation of shell layer similar

![Diagram showing flow induced fiber orientation](image)

Position across the sample thickness (%) vs. $<\cos^2 \theta>$

- $Y_A$
- $X_A$
- $X_B$
- $Y_B$
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$<\cos^2\theta_X>$
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- Core almost gone.
- Alignment in shell layer again at the same maximum value.
- Average orientation higher.

Transverse rib 4mm and 2mm

Position across the sample thickness (%)
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Split 2mm plate into outer layers of a 4mm plate

Through thickness FOD structure of 2mm superimposes over outer 2mm of 4mm plate
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Influence on warpage!

2mm wall thickness
5mm thick rib

Injection 1
Injection 2
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Different injection point causes different fibre orientation
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Different injection point causes different fibre orientation

Injection 1

Injection 2
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Different injection point causes different fibre orientation

Injection 1

Out of plane deformation

Injection 2
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Different injection point causes different fibre orientation

Injection 1

Injection 2

Out of plane deformation
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- Technical part
- Injection molding of high performance fiber reinforced polymer strength: 130MPa / 50MPa
- Pressure is applied during use
- Product fails at injection location
- Explanation?
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- Fill pattern
- 3 injection points
- Unbalanced filling
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- Fiber orientation result

Varying orientation in bottom plane

Strong orientation in internal ribs
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- Shrinkage leads to sink marks
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- Shrinkage leads to deformation of the part
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- Internal stresses due to shrinkage
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- Alternative design:
  Replace single thick rib by 2 thinner ribs
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- Alternative design
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- Thick ribs cause sink marks at the bottom of the part
- “random” fibre orientation in the bottom vs. high level of orientation in the ribs causes large differences in shrinkage → (too) high internal stresses
- Solutions:
  Multiple thinner ribs are preferred over a single thick rib
  Decrease the number of ribs to allow shrinkage differences without causing excessive internal stresses
IM: Autodesk moldflow

- Autodesk moldflow Synergy simulation Demonstration
- Autodesk moldflow Adviser hands on