Optimization of Fiber Reinforced Plastic Parts by Using Injection Molding Simulation

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Bonn, Germany, 11/08/2011
Content

• Short Introduction of SimpaTec GmbH

• Tensile bar

• Bike part

• Conclusion
SimpaTec GmbH

- Reseller of Moldex3D, founded 2004 in Aachen/Germany
  - since 2005 Germany, Netherlands, Belgium, Luxembourg, France and Austria
  - 2009: Opening of branch offices in Southern Germany and France
  - 2010: Foundation of local French company SimpaTec SarL and Thailand office
- Offering services in the field of optimization for injection moulding simulation
- Development of customer specific software enhancements
- Representing Beaumont Inc., USA -> Meltflipper
- Participation in numerous research projects and working groups
- Activities in India
- Actual head count: 11 +
Theory: Consideration tensile bar

- **Simulation:**
  - Process parameter according DIN

- **Assumptions:**
  - homogeneous material properties

- **Tensile direction:**
  - independent of manufacturing process

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diagram showing dimensions:
- \( h \): Probedicke
- \( b \): Probenbreite
- \( B \): Kopfbreite (\( \approx 1,2b+3 \text{ mm} \))
- \( h \): Kopfhöhe (\( \approx 2b+10 \text{ mm} \))

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\( a \): Anfangsmesrlänge
\( L_0 \): Versuchslänge (\( L_0 \geq L_0 + 1,5 \sqrt{S_0} \))
\( L_t \): Gesamtlänge

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Bezeichnung einer Zugprobe Form E mit Probenbreite \( b = 16 \text{ mm} \) und Anfangsmesrlänge \( L_0 = 50 \text{ mm} \):

Zugprobe DIN 50125-E5x16x50
Goal: Evaluation of mesh influence for different mesh types

- Fiber orientation and Halpin-Tsai for short glass fibers
- Actual release of Moldex3D supports also long glass fiber model with patented iARD-RPR model.
Youngs modulus distribution in the part, the effects of fiber orientation are clearly to be seen.
Mesh type 1: Tetraeder fine

- ~100,000 elements
- ~4 layers of elements across part thickness
Mesh type 1: Tetraeder fine

- Fiber orientation shows non-uniform distribution according to simulation
Mesh type 1: Tetraeder fine

- Comparison Measurement vs. Simulation

Simulation was done with ANSYS, mapped model

Very good prediction
Mesh type 2: Tetraeder coarse

- ~ 3,000 elements
- ~ 1 layer across part thickness
Mesh type 2: Tetraeder coarse

- Fiber orientation shows totally other behavior
Mesh type 2: Tetraeder coarse

- Comparison Measurement vs. Simulation

Simulation was done with ANSYS, mapped model

Poor prediction
Mesh type 3: BLM Mesh

- ~ 6,000 elements
- 2 boundary layer
- inner elements done with tetraeder elements
Mesh type 3: BLM Mesh

- Fiber orientation shows similar behavior as fine tetraeder model
Mesh type 3: BLM Mesh

- Comparison
  Measurement vs. Simulation

Simulation was done with ANSYS, mapped model

pretty good prediction for element reduction with factor 1/18
Switch to reality: Real part

Brake handle of a bike equipped with wheel disc brake

Functions of housing:
• Pressure cylinder
• Fixing at handlebar,
• Bearing of control device
• Definition of brake fluid reservoir

Material: PA66 fiber filled with volume fraction > 30%
Part and load case description

- Force onto control device
- Pressure load to cylinder
- Fixation to the handle bar
Rheological simulation

- Injection simulation with totally ~1.2 Mio elements
- Evaluation of weld line positions, flow behavior and fiber orientation
- Important: Complete mold layout is included (mold inserts, cooling lines, …).
Rheological simulation

- BLM Model
- Only 1 boundary layer for direct output to structural fem-model (SIMULIA)
Rheological simulation

• process parameter for flow rate and pressure curves, valve gating if necessary

![Flow rate profile](image)

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Rheological simulation

Flow front result with weld line prediction

Animation
Rheological simulation

Flow front result with weld line prediction

Moldex3D

Animation
Rheological simulation

Flow front results:

- Weld lines
- Different flow directions in the area of the pressure cylinder
- Acceleration at the end of the flow path
Rheological simulation

Fiber orientation shows non uniform behaviour and leads to suggestions of possible problematic areas.

Inhomogenous behaviour at the pressure cylinder.

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Rheological simulation - Quality

Volumetric shrinkage

Normal range of values, no overpacking -> ok
Rheological simulation - Quality

Distribution of density

Values are within close range, no signs for eventual surface defects
Rheological simulation - Quality

Total displacement with scale factor > 1
Results depends directly of fiber result and thermal effects:
Rheological simulation

Temperatur distribution in the mold – Identification of hot spots, responsible for displacement and flow front properties.
Rheological simulation – Interfacing

- Output as ABAQUS - Mesh
- Fiber orientation included in material properties
- Clustering of material cards possible
Mechanical simulation

Model:

- Housing from Moldex3D with ~6000 different property cards
- Actuator and handle bar modelled as aluminium parts
Mechanical simulation

- Displacements used as indicator for mechanical loads (Stress / Strain)
Mechanical simulation - Results

- v.-Mises Stress

- Higher stress values are shown in the cylinder area

- also different results due to weld lines and non uniform fiber orientation

Uniform / isotropic simulation

Simulation with respect to fiber orientation
Mechanical simulation - Results

Isotropic simulation

Simulation with fiber orientation, identification of critical areas
Mechanical simulation - Results

Strain values

Simulation with fiber orientation, identification of critical areas

Isotropic simulation
Conclusion

• The project proved clearly the necessity of linking the rheological simulation of plastic parts to the structural simulation in order to capture the effects of production.
• Even with a simple model taking the fiber effects into account the simulation results showed a picture more close to reality and helped to identify problematic areas in the design.
• By using normal (?) isotropic modelling the problematic areas are not shown – this will lead to eventual failure situation.
• Regarding fo failure criterias for simulation, there should be an enhancement of actual simulation capabilities.
Thanks for your attention!

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