A Simulation Approach to Rubber Injection Molding

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Introduction: Part

- Body mount for a GM pick-up truck
  - Vibration isolation and damping

- Material:
  - Rubber
  - Can, shaft and rate plates: Steel
Introduction: Rubber Material

• Butyl
  • Synthetic rubber
  • poly(isobutylene-co-isoprene)
  • Filled with carbon black

• Hardness: 45 durometer (E = 5 MPa)
  • Hockey puck: 90 durometer (E = 25 MPa)

• Excellent impermeability to air
  • Tires

• High damping
  • Natural rubber (ƞ=0.09) vs. butyl (ƞ=0.3)
Introduction: Mold Configuration

- **Runner:**
  - Cold runner: dark blue
  - Hot runner: red

- **Cooling lines:** light blue
- **Heating lines:** pink

- **Insulation plates:** brown

- **Inlet melt:** 98 °C
- **Inserts:** 23 °C
Motivation for Simulation

• Scrap reduction
  • Cured rubber in the hot runner

• Mold fouling
  • Deposited rubber
  • Runner blockage

• Cycle time reduction
  • Current: 7 minutes

• Heating and cooling lines optimization
Analysis: Introduction

• SIGMASOFT
  • A customized CFD package
• Coupled flow, heat-transfer and phase-change analysis
• Meshing: Cubic elements
Analysis: Material Definition

Curing degree vs. time

Viscosity vs. shear rate

Shear thinning

Unvulcanized  Vulcanized
Analysis: Process Definition

- Total cycle time: 7 minutes
  - Placing inserts
  - Taking cured runner out
  - Filling: 50 seconds
  - Curing: 270 seconds

Injection profile

- Total cycle time: 7 minutes
- Placing inserts
- Taking cured runner out
- Filling: 50 seconds
- Curing: 270 seconds
Analysis Results: Melt Temperature

• At the end of the cold runner (left)
  • Maximum: 89 °C

• Just after entering the cavities (right)
  • Maximum: 119 °C
  • Shear heating and contact with mold plates
Analysis Results: Filling

Temperature
°C
-1e+030
-1.000e+030
-1.643e+030
-2.286e+030
-2.929e+030
-3.571e+030
-4.214e+030
-4.857e+030
-5.500e+030
-6.143e+030
-6.786e+030
-7.429e+030
-8.071e+030
-8.714e+030
-9.357e+030
-1.000e+031

Project: k2xx_Pos1_Pickup_mold.047 Version: v29
Temperature_0601_Cyc=2 t=1min.08s 008ms P=4.09%
Analysis Results: Shear at Sprues

- Critical values of shear stress and shearing rate
  - Typical critical shearing rate for an elastomer: 3000 1/s

- Polymer degradation
Analysis Results: Fouling Issue

- Tip of cold runner: 15% curing
  - Long delay between cycles increases the curing degree of cold runner

- Improper cut of hot runner
Analysis Results: Curing Level

• Significant curing after demolding
• Curing time in the mold: Possible overcuring

1 minute after demolding

15 minutes after demolding
Analysis: Validation

• Measured VS prediction

Temperature distribution in the mold plate

Injection pressure

Measured average pressure: 650 bar
Thanks for your attention!