Predicting Performance of Thermoplastic Composites
Taking Into Account the Fiber Orientation Effects
Utilizing ULTRASIM™ Technology

PART I: METHODOLOGY

September 15, 2011

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OUTLINE

• PART I – ULTRASIM™ Methodology of Integrative Simulation
  ▪ Motivation
  ▪ Fiber Orientation Effects
  ▪ BASF Material Law – Features
  ▪ Summary & Benefits

• PART II – ULTRASIM™ Simulation Applications
  ▪ Case Studies
Standard Simulation Method

Component Design

Only component geometry information is transferred.

Standard CAE Structural Analysis Software using nominal or ‘analyst adjusted’ material properties

Predictions based on nominal material properties and analyst adjustments

BASF Integrated Simulation Method = Improved Accuracy

Component Design and Mold Filling Analysis

Anisotropic Material Characterization

Multiple Strain Rate / Moisture Level / Stress Tensor / Temperature Characterizations

Advanced CAE Structural Analysis Inputs

Excellent Accuracy for Prediction of Part Performance

Technology Unique to BASF
- Traditional CAE methods do not predict the true performance of short glass fiber reinforced thermoplastics.

- For high performance parts, extreme conditions, or on safety products. Where parts see:
  
  • High forces
  • High temperature
  • Vibration forces
  • Impact and/or crash forces
  • Long-term forces (creep)
  • Warping

Conventional methods are not good enough!

Therefore

• **Integrative Simulation**
  (developed by BASF)
Cross section of a Polyamide With a GF30% Reinforcement

- Flow aligned fibers near mold walls
- Perpendicular to the flow fibers in middle layer
- Boundary layer remains stable whereas core layer thickness increases with increasing thickness. This results in different behaviour of the directional properties of the “laminate”
Mechanical Behavior of Anisotropic Layered Shells

- Longitudinal orientation in the boundary layers
- Transversal orientation in the core layers
- Fountain flow
- Flow direction
- Stiff in tension
- Flexible in tension
- Flexible in bending
- Stiff in bending
Evolution of Fiber Orientation During Filling Process

Due to shearing effects in the boundary layers closed to the mold walls the fibers are oriented in flow direction.
Upper view

Fibers are being oriented in stretching direction in the core layers
Why is Anisotropic Material Modeling Important?

Anisotropy due to fiber orientation effects in flow and cross flow directions. Materials also exhibit different behavior when subjected to tensile or compressive loading.
Specimens cut from a rectangular plague, which is edge gated to yield a uniformly oriented test specimen, result in noticeable differences in performance. In contrast, standard ASTM/ISO tensile bars are highly oriented specimens.
Material Test Data Measurements

Strain rate, temperature and other environmental effects are captured during testing.
ULTRASIM™ Stress-Strain Data

Test Data are Used to Calibrate ULTRASIM Material Model

Solid Lines: simulation
Points: test measurements

Stress [MPa] vs. Strain [-]
Stress rate: longitudinal, transversal

Test Data are Used to Calibrate ULTRASIM Material Model
ULTRASIM™ Integrated Simulation Methodology

- **ABAQUS, LS-Dyna**
  - Finite Element Simulation
  - Geometry, Boundary Cond.

- **MOLDFLOW**
  - Filling-simulation
  - homogenization of orientation
  - anisotropic material model

- **ULTRASIM™**
  - homogenization of fibers and polymer
  - Material parameter
  - Material model for fibers
    - elastic
    - brittle
  - Material model for polymer
    - elastic
    - Elastic-plastic
    - viscoplastic
Process Description

1. Mold filling simulation
   “MOLDFLOW”
   - Material properties
   - Process parameters
   - Degree of fiber orientation

2. Material model
   “ULTRASIM™” of BASF
   - Material properties:
     - Anisotropic
     - Inhomogeneous

3. Structural behavior
   “LS-DYNA”, “ABAQUS”, other
   - Structure
   - Dynamic
   - Crash behaviour
Flowchart of Integrative Simulation

Part geometry information

Filling simulation

Fiber orientation predictions

Integrative Simulation

Performance evaluation by failure criteria

Structural simulation using material model by ULTRASIM™
ULTRASIM™ – Is a proprietary software that maps material and Moldflow process information to the structural mesh

- Anisotropic Material Model based on Glass Fiber Orientation
  - Non-Linear
- Strain Rate Dependant Behavior
- Asymmetric in Tensile & Compressive Behavior
- Advanced Failure Criteria Based on
  - Fiber Orientation
  - Stress State
  - Strain Rate
- Extensive Testing of BASF Materials
  - Moisture Content, Temperature Dependant Properties