Material Models For Thermoplastics In LS-DYNA®
From Deformation To Failure

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AGENDA

- introduction 4a
- motivation
- material models
- material characterization
- intermediate conclusion
- outlook IMPETUS™ - dynamic impact tensile testing
intelligent reliable solutions for plastics, composites, metals, foams, ...

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from test to validated material cards

individual mapping process information

3D anisotropic material cards

efficient dynamic testing
material characterization - services

- efficient high-dynamic testing
- dynamic material behaviour
- plastics, foams, composites, …
- validated material cards ready to use for your crash-simulation
Commonly Used Material Models For Plastics

- ***MAT_024 - The workhorse**
  (*MAT_081, *MAT_089, *MAT_123, …)
- ***MAT_124 - The hidden**
- ***MAT_187 - The plastic expert**

<table>
<thead>
<tr>
<th>Material model</th>
<th>Yield surface</th>
<th>Visco-elasticity</th>
<th>Visco-plasticity</th>
<th>comp./tension asymmetry</th>
<th>Plastic Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>*MAT_024</td>
<td>von Mises</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
<td>0.5</td>
</tr>
<tr>
<td>*MAT_124</td>
<td>2x von Mises</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>0.5</td>
</tr>
<tr>
<td>*MAT_187</td>
<td>General over triaxiality</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

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Characterizing mechanical deformation behavior of plastics

Ph.D-thesis of F. Kunkel
- Injection molded PP T16 (Hostacom XBR 169G)
- specimen milled out in W0 and W90
- classical static and dynamic tests with DIC

The Old School - material characterization
as described in the material model
- Tensile
- Shear
- Compression

comparison IMPETUS™ bending
Characterizing mechanical deformation behavior of plastics

**The Old School** - material characterization as described in the material model

→ no constant loading (triaxiality) and strain rate

Source: F. Kunkel
2004 - motivation

material variety

bending load case

Source: R. Luijkx - Kunststoffmaterialien in der Interieur Funktionsauslegung bei Audi AG, 4a Technologietag 2010
efficient dynamic testing

- desktop testing device
- instrumented high speed testing
  - acceleration → force / displacement
- impact velocity 0.5 – 4.5 m/s
- maximum energy 50 J
efficient dynamic testing

Universal static testing
reverse engineering

Displacement [mm] vs. Force [N]

Source: Dynamic Material Characterization Using 4a impetus – PPS Conference 2015, Graz
from test to material card

**MAT_024**

static  dynamic

$\sigma_{vm}$  $\varepsilon_p$

Hardening

IMPETUS

VALIMAT
from test to material card - Material Parameter Identification Process

<table>
<thead>
<tr>
<th>Component</th>
<th>Asymmetry</th>
<th>Strainrate</th>
<th>Yield</th>
<th>Young’s Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Starting parameter</td>
</tr>
</tbody>
</table>
from bending → *MAT_024

... averaged test curves
— result of simulation
from bending $\Rightarrow \text{*MAT}_024$

---

<table>
<thead>
<tr>
<th>$v$ [m/s]</th>
<th>span [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0001</td>
<td>40</td>
</tr>
<tr>
<td>0.001</td>
<td>40</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
</tr>
</tbody>
</table>

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- Averaged test curves
- Result of simulation

---

Starting parameter

- Young's Modulus
- Yield
- Strainrate
- Asymmetry
- Component

---

IN PHYSICS WE TRUST
from bending $\rightarrow \text{*MAT* \textunderscore 024}$
from test to material card
from tension bending $\rightarrow$ **MAT_124/187**

- averaged test curves
- result of simulation
comparison of results
from test to material card

static tensile  dynamic cl. bending  static/dyn. puncture

**IMPETUS**

Static  Dynamic

Triaxiality

Damage/Failure

Hardening

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efficient dynamic testing

- Different load cases
  - Bending
  - Tension Bending
  - Compression
  - Puncture
  - Component
  - …

- High speed camera
  - Sync. recording

- Maximum energy 50 J

- Material Card
  Deformation → Failure
from failure $\rightarrow$ *MAT_ADD_EROSION*
from test to material card

Deformation $\rightarrow$ Failure
Creep $\rightarrow$ Static $\rightarrow$ Crash
ISOTROPIC $\rightarrow$ ANISOTROPIC
Puncture Test → Validation on component

- Force [N] vs. Displacement [mm]
  - DOM 4 m/s, 23°C
  - Measurement
  - MAT_187

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Component FAILURE
intermediate conclusion

- **IMPETUS™**
  - efficient reliable possibility for characterizing materials
  - for unreinforced as well as fiber reinforced thermoplastics
  - different testing methods for capturing *visco-elasticity, hardening & visco-plasticity, triaxiality, damage & failure*

- **VALIMAT™**
  - for generating material cards reasonable and quickly
  - MPIP → workflow for automation of the process
  - PP T16 (Hostacom XBR169): Prove of the workflow

→ Easy and accurate material modeling

see more: paper Int. LS Dyna Conference Detroit 2018
Outlook - dynamic tensile test setup

- LED Control
- Power supply force measurement
- Used highspeed camera
Outlook - dynamic tensile test setup

New stress evaluation methods (support of DIC Data)

Force measurement
Outlook - dynamic tensile test setup

- **Comparison** on Hostacom XBR 169G (PPT16)
  - Results Ph.D Thesis F. Kunkel – 0.01, 0.5, 3, 6 m/s
  - Current investigations – 3 m/s
  - Becker 2.5 mm thick samples

- Quite good matching between both test methods!
intelligent reliable solutions for plastics, composites, metals, foams, ...

for all material types
from test to validated material cards

efficient dynamic testing
plastics and composites