General considerations for the influence of mesh density in LS Dyna

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Investigation on mesh density in LS Dyna

Agenda

- Tecosim-best partner for simulation
- Introduction
- FE Experiments with varied parameters
- Analysis of Results/ Conclusion
- Automatic Meshing Pro’s and Con’s
- Summary
The Company

- Company Founded 1992
- Strategic CAE Partner of Major OEM's and Suppliers
- Turnover € 7,1 Mio in 2004
- Currently **75 Employees** at 5 European Locations
- State-of-the-Art IT Infrastructure
- Comprehensive liability insurance
- Quality Management System according to ISO 9001, UM 14001 and Customer Specific Requirements (FORD Q1 Award)
- Associated member of the FAT (Forschungsvereinigung Automobil Technik) research team for finite element coupling for crash calculation
Locations & References

Rüsselsheim
- Audi AG
- Adam OPEL AG
- Claas
- Daimler Chrysler
- Daihatsu
- Fiat
- FORD
- General Motors
- HONDA
- ISUZU
- KIA
- John Deere
- Jaguar
- Landrover
- Nissan
- PORSCHCE AG
- Toyota

Köln
- AMG
- Autoliv
- Bayer AG
- Bentler
- Bertone
- Bosch/ Blaupunkt
- Degussa-Hüls AG
- Dynamit Nobel
- EADS
- Faurecia
- Getrag
- Hella KG
- Johnson Controls
- Karmann
- Lear
- Magna
- Thyssenkrupp
- TRW Automotive
- Mahle
- MAN
- Mannesmann/Sachs
- Siemens VDO
- Wagon Automotive

Leonberg
Basildon (UK)
Coventry (UK)
Igenie Office
Tokio (Japan)
The Company - Hard- & Software

- State-of-the-Art scalable NEC MPP Linux cluster (64 CPU) with short Turnaround Time for Full Car Crash Analysis
- 64 bit Numbercruncher (Itanium/Opteron) for Implicit codes
- Branches Interlinked by 2 Mbit Leased Lines
- ENX Access
- Major CAE and CAD Systems
- Development of Methods, Routines and Templates

Explicit Codes
- LS-Dyna
- PAMCrash/PAMSafe
- Radioss
- Abaqus explicit

Implicit Codes
- Nastran, Abaqus
- Ansys, Mechanica

CFD Code
- StarCD

Pre-/Postprocessor
- Ansa
- HyperWorks
- Animator
- Sofy
- Medina
- Patran

Optimisation
- OptiStruct
- HyperOpt
- HyperStudy
- I- Sight

MKS Codes
- Madymo
- Adams
- Motion solve
9. Optimization

- Linear Parameter Optimization
- Non-Linear Parameter Optimization
- Design Optimization
Any sufficiently advanced technology is indistinguishable from magic.

Introduction

- Why do we simulate?
  - Cost effective
  - Fast
  - Proven method

- We cannot test!
Introduction
Introduction

- How should a mesh look like?
Simple box crash experiment:

Box section 50 mm x 80 x 500mm, t= 1.0mm, mild steel

Varied parameters:

- average edge length  15/10/5/2,5mm
- mesh orientation       0deg/ 25deg
- different mesh/ integration method: Belytschko-Tsay/ Fully Integration
- Varied number of spotwelds
- With and without mapping or stamping data
- Renumbering and move in space

Objective:

- Is the result depending on the element length?
- Is the result depending on the element orientation?
- How does mapping influence/stabalise the results?
- How do small changes in the input influence the results?
analysis: deformation plots

v10_1: 10mm mesh, 0deg
max internal energy  6766Nmm
max displacement   278mm
analysis: defomation plots

V10_1n: 10mm mesh, 0 deg, full integration
max internal energy  6499Nmm
max displacement  241mm
analysis: deformation plots

v10_2: 10mm mesh, 25deg
max internal energy 6439Nmm
max displacement 295mm
analysis: defomation plots

V10_2n: 10mm mesh, 25 deg, full integration
max internal energy 6272Nmm
max displacement 286mm
FE Experiments with varied parameters

**analysis: deformation plots**

v10_3: 10mm triangle mesh  
max internal energy       6428Nmm  
max displacement         215mm
analysis: defomation plots

v10_4: 10mm mesh, 25deg, more spotweld
max internal energy 6560Nmm
max displacement 265mm
FE Experiments with varied parameters

**analysis: defomation plots**

V10_4n: 10mm mesh, 25 deg, more spotweld, full integration
max internal energy 6741Nmm
max displacement 295mm
analysis: defomation plots

v10_5: 10mm mesh, 0 deg, more spotweld
max internal energy 6565Nmm
max displacement 262mm
**FE Experiments with varied parameters**

**analysis: deformation plots**

v10_6: 10mm mesh, 0deg mapped
stamping data MpCCI
max internal energy 6658Nmm
max displacement 235mm
analysis: deformation plots

v10_7: 10mm mesh, 25deg mapped
stamping data MpCCI
max internal energy  6350Nmm
max displacement  243mm
analysis: defomation plots

v10_6n: 10mm mesh, 0deg mapped stamping data DYNAIN
max internal energy 6468Nmm
max displacement 250mm
FE Experiments with varied parameters

**analysis: deformation plots**

v10_7n: 10mm mesh, 25deg mapped

Stamping data DYNAIN

Max internal energy: 6376Nmm

Max displacement: 233mm

![Deformation plots](image-url)
Analysis: comparison of Displacement
10mm meshing

![Graph showing Displacement vs Time for different cases: 10_1 max 279.79, 10_2 max 294.56, 10_3 max 215.16, 10_4 max 265.30, 10_5 max 262.47, 10_6 max 227.10, 10_6n max 250.63, 10_7 max 302.08, 10_7n max 232.63.](image)
Analysis: comparison of Displacement
5mm meshing

![Graph showing Displacement vs Time for 5mm meshing with specific max values for each curve]
Analysis: comparison of Displacement
2.5mm meshing
Analysis: Comparison max. displacement

Compression is nearly independent from the element length in a range from 10mm to 2.5 mm for the same element orientation.
Analysis: Comparison max. displacement

The max displacement difference for 0° mesh and 25° mesh is small for finer meshes and big for coarser meshes.
For 10 mm the variation is about 8mm whereas the deviation for smaller elements sizes is about 3mm for the same element orientation.
Analysis: Influence on results of very small elements.

For 1.25 mm the BT (typ2) element seems to be too weak. For smaller elements sizes, full integration seems to have better results.
Analysis: comparison max displacement variation

variation for different mesh sizes

<table>
<thead>
<tr>
<th>mesh size</th>
<th>displ. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mm</td>
<td>290</td>
</tr>
<tr>
<td>5 mm</td>
<td>270</td>
</tr>
<tr>
<td>2.5 mm</td>
<td>250</td>
</tr>
</tbody>
</table>

Analysis of Results/ Conclusion
Analysis: Comparison of integration method

Calculation Time

CPU Time [s]

- Belytschko-Tsay
- Fully Integration

Bar chart showing comparison of CPU time for different integration methods.
Results

- Results for the displacement and the internal energy seem to be smooth and stable in a range from 15mm to 2.5 mm for orthogonal element orientation.
- Different element orientation give different results for coarser meshes.
- Finer mesh is not so sensitive for different element orientation, integration method, number of spotwelds, mapping, small changes in the input (renumbering, moving the model in space).
- Mapping tools are easy to use for Crash coupling. The influence of the mapping was getting smaller for smaller element sizes for the influenced zone was getting smaller and the crash mode was very stable in our example.
Conclusion

- If you know the collapse mode of a part you can use a coarse mesh which should be orthogonal in the collapse direction (so you can achieve “superconvergence”)
- If you don't know the collapse mode of a part; Please use finer meshes
- No one knows the exact collapse mode of all the parts in a vehicle!
- Meshing rules for orthogonal /Mapping/Integration schemes meshes are important for coarser meshes but not important for finer meshes.

- *Creation of finer meshes can be automated by TEC ODM!*
Automatic Meshing Pro’s and Con’s

- What is TEC-ODM?
- What can TEC-ODM do?
- How can the development process benefit from TEC-ODM?
- What is the System requirement
What is TEC-ODM?

- Tec ODM (One Day Meshing) is a automatic FE batch meshing Software for Body in White meshes for Crash and NVH analysis. Tec ODM is based on a set of 50 different explicit mesh enhancement algorithms which are implemented in iterative loops.
What can TEC-ODM do?

- **Tec ODM** creates FE shell element meshes on CAD surfaces considering different quality criteria. TEC ODM’s output is a mesh with distinguished global element sizes (11 mm or smaller) and smallest element length up to 4.0 mm.
How can the development Process benefit from TEC ODM?

- Time saving through CAE- Process Optimisation earlier results

| Conventional CAE- Process (4 weeks) | | | |
| CAD Data Preparation | Meshing | Input Assembly | Run | Analysis |

| Optimized CAE- Process (1 week) | | | |
| CAD Data Preparation | Meshing | Input Assembly | Run | Analysis |
### How can the development Process benefit from TEC ODM?

<table>
<thead>
<tr>
<th>Cost saving through CAE- Process Optimisation</th>
<th>Regular FE Process</th>
<th>TEC ODM Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Software cost for a MPP license</td>
<td>0 €</td>
<td>149.000 €</td>
</tr>
<tr>
<td>Cost for an BIW FE Mesh outsourced from CAE supplier</td>
<td>40.000 €</td>
<td>0 €</td>
</tr>
<tr>
<td>Number of updates per Year per Platform</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Number of platforms @ car manufacturer</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total cost for BIW FE mesh per year</td>
<td>2.000.000 €</td>
<td>149.000 €</td>
</tr>
<tr>
<td>Investment needed for additional Hardware</td>
<td></td>
<td>€ 288.000</td>
</tr>
<tr>
<td>eg. Linux Cluster with 192 Processors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manpowerl inhouse cost for TEC ODM operation</td>
<td></td>
<td>€ 30.000</td>
</tr>
<tr>
<td>(50 days for 50 BIW FE Mesh update)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost</td>
<td>2.000.000 €</td>
<td>467.000 €</td>
</tr>
<tr>
<td>Possible savings with TEC ODM per year</td>
<td></td>
<td>1.533.000 €</td>
</tr>
<tr>
<td>Manual Mesh</td>
<td>ODM mesh</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td><strong>Number of elements</strong></td>
<td><strong>Number of elements</strong></td>
<td></td>
</tr>
<tr>
<td>complete model</td>
<td>804819</td>
<td>complete model</td>
</tr>
</tbody>
</table>

„Model size is getting bigger with TEC ODM therefore some investment in number crunching is needed."
Ways of using TEC ODM

- 15-20 mm
- 6-12 mm
- 3-6 mm
Quality check for failed parts and elements

Classify failure type

Choose enhancement strategy out of more than 30 different types

Enhance - remesh

Iterative loop
• TEC ODM automesh process is ready to use
• TEC ODM will result in bigger FE models
• ODM process will result in faster answers to engineering questions and reduced modelling cost
• TEC ODM has nearly no “human influence” in the modelling process
• Meshing engineer becomes a quality and process checker
Thank you!

- Any questions?