Estimation of Reliable Design Loads During Extreme Strength and Durability Events at Jaguar Land Rover

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Overview

• Introduction
• Fully Analytical Approach (FAA) in Jaguar Land Rover
  > General
  > Case studies
  > Issues and poor correlation
• SIMPACK model enhancements for FAA
  > Connectivity
  > Flexible chassis
  > Flexible components
• Conclusions and important points
Introduction

• Product Development optimisation and efficiency
  > Reduction of real prototypes
  > Reduction of Proving Ground (PG) testing
  > Increase in **Virtual Testing** through CAE techniques
• SIMPACK for **virtual strength and durability events**
• Strength and durability event requirements/challenges
  > High loads: 50 – 60+ kN
  > Short duration: 0.04sec
  > Force elements and components: non-linear regions
• Strength event example
Fully Analytical Approach (FAA)

General

- Full Vehicle SIMPACK Model
  - Vehicle Properties
  - Driver

Cosin FTire tyre model

Virtual representation of real road surfaces
Fully Analytical Approach (FAA)

Roads

• 2D Roads:
  > X and Z coordinates
  > Simple RDF format

• 3D Roads:
  > Laser scanned surfaces
  > More complex implementation
  > CRG converted to RGR
  > Durability events
Fully Analytical Approach (FAA)
Full vehicle for strength and durability

Flexible components

Force elements
Dampers
Bump Stops
Bush elements

Full vehicle model from vehicle dynamics department

FTire Tyre Model (x4)
FTire Model

Principles and attractive features

- Time domain
- Non-linear behaviour
- 150 to 200 Hz in and out of plane
- Suitable for high frequency and short wavelength excitations
- Suitable for contact with sharp edged obstacles
- Rim to belt contact for misuse events
FAA Case Studies
Pothole Braking - Correlation
FAA Case Studies

Pothole Braking - Correlation

Pothole braking - 20 inch - Effect of Speed on Ball Joint Long Force

Graph showing the effect of speed on ball joint long force for pothole braking. The graph plots force (kN) against speed (kph) with different markers for longitudinal and lateral forces.
FAA Case Studies
Kerb strikes – Early Issues

• Tire related issues
  > Tire model specific properties
  > Tire-to-obstacle contact point
  > Rim-to-ground contact stiffness

• SIMPACK solver settings
  > Step time settings
  > Tolerances
  > Big increase in integration times
    (1/2 minute to 7 minutes per sec)
FAA Case Studies

Kerb strikes – Poor correlation

- One of the “best” poor cases
- Damper lower loads:
  > Front: 100kN vs. 46kN (PG)
  > Rear: 70kN vs. 43kN (PG)
FAA Case Studies

Poor correlation - Search for root causes

- **Integrator - numerical error**
  - Work in ADAMS had similar issues

- **Model Setup**
  - Vehicle chassis not locally flexible
  - Suspension-to-chassis simplified connectivity
  - All suspension loads applied through the same path
FAA Case Studies
Root causes plausibility checks

Simplistic representation of revised top mount to body

Effect of Body Compliance Spring Settings on Damper Lower Joint Force

Effect of Body Compliance Soring Settings on Spring Displacement
FAA Case Studies
Poor correlation - Root cause confirmed
Correlation Improvement

Local body flexibility validation study

Body fixing locations – Subframe mounts

Front measuring locations – BIW damper tower top

FEA – ABAQUS + NASTRAN

Laboratory Test Rig
Correlation Improvement
Validation study results

Static and Dynamic Damper Tower Top Stiffness under Suspension Loading

<table>
<thead>
<tr>
<th>Front/Rear</th>
<th>Static Stiffness (kN/mm)</th>
<th>Dynamic Stiffness (kN/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>10.1</td>
<td>8.7</td>
</tr>
<tr>
<td>Rear</td>
<td>9</td>
<td>7.5</td>
</tr>
</tbody>
</table>
Correlation Improvement
Flex body generation – extra requirements

** Reduction method **
- From 1e+6 DoF – nodal (static analysis)
- To 500 DoF – modal (dynamic analysis)
- Definition of boundary conditions at specific nodes
- Nodes at interface points with other MBS structures
- Reduced files: “.pch” or “.op2”

1. **Extra nodes** to describe the stiffness of connections at the BIW-to-Suspension area

2. **Extra components**: suspension top mount components attached to the FE flex body

3. **SIMPACK FEMBS**
   - Conversion of the reduced FE model to “.SID_FEM”
   - Selection of number of normal modes
   - Introduction of FRMs and bespoke FRMs
Correlation Improvement

SIMPACK flex chassis – Modes and FRMs

Effect of Modes and Frequency Cut-off on flex body local stiffness

- Number of Modes Stiffness (kN/mm)
  - Front:
    - 100: 1454.00
    - 100 (8): 174.00
    - 100 (16): 145.00
    - 100 (36): 125.30
    - 292 (24): 229.00
  - Rear:
    - 100: 1423.00
    - 100 (8): 292 (24)

Targets from analysis:
- Front: 10.1 kN/mm
- Rear: 9 kN/mm

<table>
<thead>
<tr>
<th>Flex Body Version</th>
<th>Number of Modes (FRM)</th>
<th>Mode Frequency Cut-off (Hz)</th>
<th>Body Fixing Method</th>
<th>Front Stiffness (kN/mm)</th>
<th>Rear Stiffness (kN/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>More modes</td>
<td>100</td>
<td>51 Subframe mounts</td>
<td>1454.00</td>
<td>1423.00</td>
<td></td>
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<tr>
<td>FRM V1</td>
<td>100 (8)</td>
<td>10 Subframe mounts</td>
<td>174.00</td>
<td>229.00</td>
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<tr>
<td>FRM V2</td>
<td>100 (16)</td>
<td>20 Subframe mounts</td>
<td>145.00</td>
<td>78.30</td>
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<tr>
<td>FRM V3</td>
<td>100 (36)</td>
<td>1000 Subframe mounts</td>
<td>125.30</td>
<td>54.70</td>
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<tr>
<td>FRM bespoke load cases</td>
<td>292 (24)</td>
<td>Unlimited Subframe mounts</td>
<td>10.55</td>
<td>8.00</td>
<td></td>
</tr>
</tbody>
</table>
Correlation Improvement

Flex body optimisation effect - Static
Correlation Improvement

Full vehicle with optimised flex body
Correlation Improvement
Optimised flex body - effect on loads

Front: 58kN vs. 46kN (PG)
Rear: 50kN vs. 44kN (PG)

Improvement due to flex body:
Front: 42% (from 100kN to 58kN)
Rear: 28.5% (from 70kN to 50kN)
Conclusions and Findings
Model enhancements

FTire Validation and Tuning

- Integration with the SIMPACK model
- FTire model parameters
- Tire-to-obstacle impact point
- Rim-to-ground stiffness

Flexible body – Fully trimmed chassis

PUNCH (.pch) files
- Residual forces and imbalance (NASTRAN related)
- Restriction to cut-off frequency and number of modes
  - Robust during FEMBS
  - Smaller file size (~160KB)

Extra Weights
Passenger, luggage and other masses need to be attached to relevant master nodes of the flexible chassis.

SUPERELEMENT (.op2) files
- More output options – modes, frequencies
- No limit to number of modes and cut-off frequencies
- Can cause memory issues in SIMPACK (~1.5 GB)
- Compatibility issues with SIMPACK FEMBS
Conclusions and Findings

General

• SIMPACK is capable to simulate demanding strength events
• Strength events with high vertical loads require:
  > FTire model
  > Flexible bodies
    • Number of modes should be carefully defined
    • Local flexibilities are necessary – occurring from and above 1kHz
    • FRM defined by combined load cases are more effective
• Significant integration time increase depending on
  > Event severity
  > Model complexity
Thank You

Any Questions?