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Sung-Ling Twu

General Motors

Prenscia 2018 User Group Meeting
• **Prediction of Vibration Fatigue Life** is an important milestone during product design and development of Vehicle Brackets.

• **CAE simulation** for Fatigue Life prediction gives useful information early in design cycle, and saves considerable time and cost compared with physical Shaker Table tests.

• **ABAQUS & nCODE Simulation** for **Random Vibration Fatigue (RVF) Life** of Bolt-on Metal Bracket is developed using **SN Approach (DesignLife V12)**.

• **Random loading** is provided via the Power Spectral Density (PSD), which describes excitation acceleration levels in the frequency domain.

• **System response to unit excitation** is calculated using ABAQUS’ **Steady State Dynamics Analysis**.

• **The Stress FRF and Random Loads** are then combined to calculate the Stress PSD, which is cycle-counted and used for the calculation of Fatigue Life.
• In GM, Bracket design can be validated with CAE Simulation.

• Typical Bracket Performances;
  • (1) Resonant Frequency,
  • (2) Mechanical Shock from Road Loads like Pot Hole,
  • (3) Mechanical Shock from Minor Collision
  • (4) Random Vibration Fatigue.

• GM Bracket Validation Specifications; Public

• Bracket Suppliers can buy GM Documents on-line at HIS Markit Standards Store.
• **Random Vibration Fatigue (RVF) is the scope of work.**

• **Vehicle Vibration Fatigue**
  • the loading is non-deterministic for most parts
  • vibration environments are not related to a specific driving frequency
  • have input from multiple sources; Road Profiles and Powertrain Vibrations
  • **Input PSD for Car HVAC (GMW17010) shown below**

• **Component-level simulation is chosen in order to**
  • (1) utilize the existing GMW Validation Specification of physical Shaker Table test
  • (2) efficiently apply to all Brackets independent from the parent Vehicle

![PSD Graph](image)
- Green: Fore-Aft 48 hours/axis Grms = 1.27 (12.5 m/s²)
- Red: Lateral 48 hours/axis Grms = 1.59 (15.8 m/s²)
- Orange: Vertical 48 hours/axis Grms = 1.40 (13.7 m/s²)
• An HVAC Bracket is chosen to demonstrate simulation of RVF using ABAQUS and nCODE.

• A Sub-system of Steel Brackets and Elastomer Bushings holds HVAC Module.

• 2mm Gage HSLA Steel Bracket is the subject of this presentation.

• The sub-system undergoes PSD Input of Random Road and Powertrain Excitation specified in a GMW17010.

• The bracket is mounted to the vehicle structure by one M8 Bolts.

• M8 Bolt is represented in hexa dominant mesh.

• Shaker table is modeled to represent the vehicle fastening ideally representing the fixture.
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

HVAC Bracket

Geometry

Mesh

M8 Bolt

HVAC Bracket

Elastomer
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

Process

MA: Modal Analysis
SSD: Steady State Dynamics
RVF: Random Vibration Fatigue
MA: Modal Analysis
SSD: Steady State Dynamics
RVF: Random Vibration Fatigue
PSD: Power Spectrum Density
FRF: Frequency Response Function
SN: Stress Life Curve
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

Wide Spread of Life Prediction – HVAC Case

Test vs Previous Approach

NEW APPROACH FOR CORRELATION

A NEW MATERIAL CURVE WAS GENERATED TO CONSIDER THE EFFECT OF NEUBER ON SN ANALYSIS
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

CRFM Bracket - Damping Ratio Variation

Damping Cards in ABAQUS Steady State Dynamics

### Damping Ratio on Design Life

<table>
<thead>
<tr>
<th>Damping</th>
<th>X-Vib</th>
<th>Y-Vib</th>
<th>Z-Vib</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>0.000</td>
<td>0.001</td>
<td>7.2E+3</td>
</tr>
<tr>
<td>4%</td>
<td>0.003</td>
<td>0.009</td>
<td>6.5E+4</td>
</tr>
<tr>
<td>5%</td>
<td>0.026</td>
<td>0.068</td>
<td>1.9E+5</td>
</tr>
<tr>
<td>6%</td>
<td>0.154</td>
<td>0.364</td>
<td>8.3E+6</td>
</tr>
<tr>
<td>8%</td>
<td>2.386</td>
<td>4.744</td>
<td>7.1E+7</td>
</tr>
</tbody>
</table>

RVF Lives in HRs with Damping Variations

SSD

RVF Lives in HRs with 3% Damping
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

CRFM Bracket - Damping Ratio Variation

- PSD GMW17010
- Bracket Material - HSLA
- Damping Ratio - 4%, 6%, 8%, 10%
- Rubber Isolators Material - HyperFoam

<table>
<thead>
<tr>
<th>Damping Ratio</th>
<th>RMS Stress (MPA)</th>
<th>Life (Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4%</td>
<td>182</td>
<td>0.5</td>
</tr>
<tr>
<td>6%</td>
<td>127</td>
<td>3.2</td>
</tr>
<tr>
<td>8%</td>
<td>99</td>
<td>11.5</td>
</tr>
<tr>
<td>10%</td>
<td>82</td>
<td>33.0</td>
</tr>
</tbody>
</table>
Rubber Isolator Material Property

1. HyperElastic in ABAQUS : C3D8H

*MATERIAL, NAME=HYPER_ELASTIC
*DENSITY
1.2000E-09,23.0
*HYPERELASTIC, OGDEN, N=3
0.800618842, 2.61956569, 1.83307234e-7, 9.5771679, -0.452430078, 2.23760422, 0.0, 0.0
0.0, 23.0

2. HyperFoam in ABAQUS : C3D8R

*MATERIAL, NAME=HYPER_ELASTIC
*DENSITY
2.2500E-10,23.0
*HYPERFOAM, N = 2, TEST DATA INPUT
*UNIAXIAL TEST DATA
0.0 ,0.0 ,0.0083333
1.5 ,0.05 ,0.0083333
2.0 ,0.1 ,0.0083333
2.5 ,0.15 ,0.0083333
2.7 ,0.2 ,0.0083333
2.8 ,0.25 ,0.0083333
3.0 ,0.3 ,0.0083333
3.2 ,0.35 ,0.0083333
3.5 ,0.4 ,0.0083333
3.8 ,0.45 ,0.0083333
4.1 ,0.5 ,0.0083333
4.4 ,0.55 ,0.0083333
5.6 ,0.6 ,0.0083333
7.4 ,0.65 ,0.0083333
10.0 ,0.7 ,0.0083333
13.5 ,0.75 ,0.0083333
493.5 ,0.99 ,0.0083333
0.0 ,0.0 ,1.0
1.9755 ,0.05 ,1.0
******************************************************************************
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

CRFM Bracket- Material Variation

Elastomer Property on Design Life

Hyper Foam

Damping  
4%  
10%

X-Vib  
0.51  
33

Hyper Elastics

Damping  
4%  
10%

X-Vib  
0.74  
48

RVF Lives in HRs for HyperFoam and HyperElastic Elastomer with 4% Damping
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

CRFM Bracket- SN Curve Variation

- PSD GMW17010
- Bracket Material- HSLA with Neuber Correction and HSLA
- Damping Ratio - 4%, 10%
- Isolators Material- HyperFoam

<table>
<thead>
<tr>
<th>Damping Ratio</th>
<th>Life (Hrs)</th>
<th>Damping Ratio</th>
<th>Life (Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4%</td>
<td>0.51</td>
<td>4%</td>
<td>0</td>
</tr>
<tr>
<td>10%</td>
<td>33.02</td>
<td>10%</td>
<td>6.93</td>
</tr>
</tbody>
</table>

SN Curves on Design Life
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE
CRFM Bracket- RVF Life comparison with two different design

<table>
<thead>
<tr>
<th>Geometry</th>
<th>RMS Stress (MPA)</th>
<th>Life (Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>182</td>
<td>0.5</td>
</tr>
<tr>
<td>Beads</td>
<td>82</td>
<td>30.0</td>
</tr>
</tbody>
</table>

- **PSD GMW17010**
- **Bracket Material- HSLA**
- **Damping Ratio - 4%**
- **Isolators Material- HyperFoam**
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE
CRFM Bracket With Stamping

Stamping Gage Variations

Neutral Gage Thining

Thicken

Neutral

Thining
Random Vibration Fatigue Life Simulation of Metal Bracket using ABAQUS and nCODE

CRFM Bracket With Stamping

Stamping Stress Variations

Medium-Low Stamping Stress

Lowest Design Life Spot

Higher

Medium

Low
ABAQUS & nCODE Simulation for Random Vibration Fatigue (RVF) Life of Bolt-on Metal Bracket is developed using SN Approach.

RVF Life Prediction Wide Spread depending on assumption of parameters;

- Damping Ratio
- Elastomer
- SN Curve
- Mean Correction
- Geometry

Future Consideration
- EN Approach (DesignLife V13.1)
- Fastening
- Stamping
- Gage Variation
- Input PSD

Correlation study is needed to prove the simulation provides results that are realistic representation of reality.

End