Finite element analysis and tests of an offset sandwich mount

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Rail  Marine  Specialist Vehicles  Truck  Industrial  Defence

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Main outlines of the presentation

- Offset sandwich mount
- Finite element model
- Rubber compressibility
- Rubber fatigue consideration
- Conclusions
Offset Sandwich Mount in Rail Industry

- The mount acts as a primary suspension on UK suburban cars.

- Over the past 20 years there have been upgrades to the vehicles, resulting in:
  - Different loading conditions
  - Different Stiffness requirements

But:
- Same space envelope

- Various hardnesses give differing product load/deflection curves
Offset sandwich mounts in the Rail Industry

- The mounts can be used for primary (or secondary) suspensions on rail vehicles.
- Various configurations will provide different stiffness combinations at the axlebox, i.e. Vertical : Lateral : Longitudinal.
  - For this application each spring is inclined 13 degrees vertical.
- The key issue is that
- Current applications are operating at continuous higher loading conditions.
- This causes rotation of the plates due to unresolved moments - and reduced life expectancy.

Design resultant force

In service resultant force

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Finite element model

- One component is modelled due to symmetrical deformation
- Surface constrained during the moulding process
- Moulding temperature dropped to room temperature
- Loading procedure
Rubber elasticity

- **Mooney-Rivlin model**
  
  \[ U = C_{10}(I_1 - 3) + C_{01}(I_2 - 3) + \frac{1}{D_1}(J_{el} - 1)^2 \]

- **Polynomial model**
  
  \[ U = C_{10}(I_1 - 3) + C_{01}(I_2 - 3) + C_{20}(I_1 - 3)^2 + C_{11}(I_1 - 3)(I_2 - 3) + \]
  \[ + C_{02}(I_2 - 3)^2 + C_{30}(I_1 - 3)^3 + C_{21}(I_1 - 3)^2(I_2 - 3) + C_{12}(I_1 - 3)(I_2 - 3)^2 + \]
  \[ + C_{03}(I_2 - 3)^3 + \frac{1}{D_1}(J_{el} - 1)^2 + \frac{1}{D_2}(J_{el} - 1)^4 + \frac{1}{D_3}(J_{el} - 1)^6 \]

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Rubber compressibility

The rubber compressibility at moulding temperature (typical value 160°C) is doubled compared with the room temperature (a typical value 20°C) and the compressibility varies linearly against temperature.

\[ D_T = \frac{T + 120}{140} D_{20} \]
Rubber fatigue

• Crack initiation approach:
   The three-dimensional effective stress criterion was employed. The fatigue failure was taken as visual crack observation (normally 1-2 mm).

\[ \sigma_f = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2} \quad \sigma_1 \geq \sigma_2 \geq \sigma_3 > 0 \]
Table 1  Bonded thickness change comparison

<table>
<thead>
<tr>
<th>Test</th>
<th>FEA $D_{20}$ (Error)</th>
<th>FEA $D_T$ (Error)</th>
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<tbody>
<tr>
<td>141.65</td>
<td>139.63 (60%)</td>
<td>141.23 (12%)</td>
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**D--- compression coefficient**
Simulation for the stiffnesses

Current component (IRHD 60)

Modified component against the current component (IRHD 45)
Moment as a design guide

10 mm deflection

30 mm deflection

80 mm deflection
Rubber fatigue verification

Results from finite element analysis:

photo showing the current component
Conclusions

The compressibility of the rubber may be modelled using the linear equation of coefficient with temperature variable.

It is found that moment distribution is a good guide when multi-layer rubber sections are involved in the suspension spring design.

For rubber fatigue design the effective stress concept is an appropriate method to evaluate the crack initiation in the design stage.
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Thank you for your attention