Engine Mount Force Prediction for Strength Design during Rapid Start

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■ Overview of the models
  – Engine model and clutch model
  – Engine mount model
  – Full-vehicle model

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Strength design of engine mount requires ...

- Force prediction in an early phase of design
- Force due to driving torque during rapid start
- Accurate prediction of maximum force

**This project**

Engine mount force due to driving torque

Rapid start

Suspension force due to road input

Rough road

Curb
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Engine model and clutch model

**Clutch**

\[ T = 2\mu F R \]

- **\( T \):** Torque
- **\( \mu \):** Clutch friction coefficient
- **\( F \):** Clutch clamping force
- **\( R \):** Clutch effective diameter

**Engine**

- **Engine torque** [Nm]
- **Engine speed** [rpm]
- **Throttle position**
  - 100%
  - 90%
  - 80%
  - 70%
  - 60%
  - 50%
  - 40%
  - 30%
  - 20%
  - 10%
  - 5%

**Clutch clamping force** [N]

- **Clutch engagement time**

\[ T = 2\mu F R \]
Engine mount model

**Engine mount**

Transmission mount

Torque rod

Engine mount force main direction

Power plant rotational displacement

Vehicle front

Engine side mount

Bush spring characteristic

High load curve

Displacement [mm]

Force [N]
Full-vehicle model

Rapid start of MT vehicle
Influence of coordinate and bush spring

.changed parameters of engine side mount

<table>
<thead>
<tr>
<th>Coordinate</th>
<th>50mm front</th>
<th>50mm back</th>
<th>50mm left</th>
<th>50mm right</th>
<th>50mm up</th>
<th>50mm down</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bush spring</td>
<td>× 0.5</td>
<td>× 2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vertical coordinate has a large influence on engine side mount force

Engine side mount force reduction rate [%]

- 50 mm up
- Bush spring ×2.0
- 50 mm front
- 50 mm right

Vertical coordinate has a large influence on engine side mount force.

Engine side mount force reduction rate [%]

- 50 mm up
- Bush spring ×2.0
- 50 mm front
- 50 mm right
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Wheel torque comparison

- Sufficient prediction accuracy for maximum peak value
- Time history waveform also matched closely

![Wheel torque comparison diagram](image)
Engine mount force comparison

- Transmission mount
- Torque rod
- Engine side mount

With-stopper model has sufficient prediction accuracy

- Measurement
- With-stopper model
- Without-stopper model

Force [N]

Time [s]

Peak
Wheel torque comparison for another vehicle

- This vehicle has higher torque engine

![Graph showing wheel torque comparison with measurement and simulation.](image)
Engine mount force comparison for another vehicle

- Sufficient prediction accuracy

(a) Lower torque rod
(b) Upper torque rod
(c) Transmission mount
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Wheel torque component of engine mount force

Engine mount force \( \{ \)

- Wheel torque component \( F_T \)
- Inertia force component \( F_I \)

Wheel torque component \( F_T \): \[ \frac{T}{L} \]

Wheel torque \( T \) Engine mount span \( L \)

Diagram:
- Engine mount
- Body
- Power plant
- Arrows indicating forces \( F_T \)
- Wheel torque \( T \)
Inertia force component of engine mount force

\[ \text{Engine mount force} = \begin{cases} \text{Wheel torque component} & F_T \\ \text{Inertia force component} & F_I \end{cases} \]

\[ F_I = \text{Inertia moment} \times \text{Power plant angular acceleration} \]

\[ I \times a \]

\[ \text{Engine mount span} \ L \]
Influence of power plant angular acceleration

\[ \text{Inertia force component } F_I : \frac{\text{Inertia moment } I \times \text{Power plant angular acceleration } a}{\text{Engine mount span } L} \]

- Engine mount force decreases with smaller power plant angular acceleration \( a \)

![Graph showing engine mount force and wheel torque over time for different power plant angular accelerations](image)
Influence of engine mount span

**Inertia force component** $F_I$:

\[
\text{Inertia moment } I \times \text{Power plant angular acceleration } \alpha
\]

Engine mount span $L$

- Engine mount force decreases with larger engine mount span $L$

![Graph showing the relationship between engine mount force and time for different engine mount spans (Small, Middle, Large). The graph illustrates that as the engine mount span increases, the peak engine mount force decreases.](image-url)

**Force [N]**

**Torque [Nm]**

**Time [s]**

Where:

- $L$: Small, Middle, Large
(1) SIMPACK full-vehicle model was confirmed to have adequate accuracy to predict wheel torque peak value and engine mount force peak value during rapid starts.

(2) Wheel torque, power plant angular acceleration, and engine mount span were found to have influence on engine mount force.

(3) Engine mount force is decreased by either: decreasing of power plant angular acceleration or increasing of engine mount span.
Acknowledgment

many thanks to ...

- Steven Mulski (SIMPACK AG) for building the first SIMPACK model for rapid start maneuver in 2004
- SIMPACK AG and SIMPACK Japan K.K. for extension of the model and technical support