Developing FE-TIRE Model
for Road Noise Simulation

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Concept of Virtual-Digi-Tire

Vehicle Simulation
- Crash
- Fatigue & Endurance
- NVH
- Handling

Necessity of Accurate Input Simulation via Tire from Road

Development of Tire FEM Model
- Moderate Accuracy
- Light Calculation
- Easy to Use

Current Virtual-Digi-Tire

<table>
<thead>
<tr>
<th>Large Impact</th>
<th>Crash</th>
<th>Severe Cornering</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Large Impact Image]</td>
<td>![Crash Image]</td>
<td>![Severe Cornering Image]</td>
</tr>
</tbody>
</table>

- Developed & Sale by JRI & SRI
- Developed by Nissan, JRI & SRI
  Presented at 2003

Evolution for other properties

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**Tire Construction & Modeling**

Detailed Model

- about 100 thousands elements

Large Calculation

- 4 Tire Models & Vehicle Model
- Unable Calculation for Daily Work

Development of Simplified Tire Model

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**Purpose & Merit of RN**

PURPOSE

- RN (Road Noise) : booming noise below 500HZ at slightly rough road
- matching of tire and vehicle is important
- vehicle development considering tire effect is important

CAE

- Comparing of tire models used for NV simulation

<table>
<thead>
<tr>
<th>Modulation model</th>
<th>Explicit model</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Modal model" /></td>
<td><img src="image" alt="Explicit model" /></td>
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</tbody>
</table>

- NV mechanism is clear.
- Boundary condition is difficult.
- NV mechanism is not clear.
- Boundary condition is clear.

- Trial of using explicit model
- Using LS-DYNA
Tire Model for RN Analysis

DUNLOP FALKEN GOODYEAR

<table>
<thead>
<tr>
<th>Detailed Model</th>
<th>Large Impact Model</th>
<th>RN Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Detailed Model" /></td>
<td><img src="image2.png" alt="Large Impact Model" /></td>
<td><img src="image3.png" alt="RN Model" /></td>
</tr>
<tr>
<td>About 72,000 elements</td>
<td>About 24,000 elements</td>
<td>About 36,000 elements</td>
</tr>
</tbody>
</table>

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Verification of RN Tire Model: Stiffness

**Experiment**

- Inner Pressure: 200 kPa
- Tire Axis: Fixed
- Friction Coefficient: 0.9

**Boundary Condition**

- Vertical Stiffness
  1. Inflate
  2. Vertical movement of plate

- Lateral Stiffness
  1. Inflate
  2. 450 kgf vertical load
  3. Lateral movement of plate

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**Simulation Result**

(Tire stiffness: Good correlation between simulation and experiment)

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Verification of RN Tire Model: Cleat Impact

Experiment

Boundary Condition
- Inner Pressure: 200kPa
- Load: 450 kN
- Tire Axis: Fixed Joint
- Friction Coefficient: 0.9
- Speed: 40kph

Impact timing is after 450kgf load.

Simulation Result

- Good correlation between simulation and experiment

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Verification of RN Tire Model: RN Road

Experiment

Boundary Condition

- Inner Pressure: 300 kPa
- Load: 450 kg
- Tire Axis: Fixed Joint
- Friction Coefficient: 0.9
- Speed: 40 ~ 60 km/h

Actual road surface model

Simulation Result

Tire Contact Pressure Distribution

Uneven contact pressure because of road roughness
Verification of RN Tire Model: RN Road

Frequency Result (density 3.91Hz)

- Vertical Axis Force
- Longitudinal Axis Force
- Lateral Axis Force

*iRN Road: Good correlation between simulation and experiment*

Verification of RN Tire Model: Tire Mode

- Initial: Loaded
- Longitudinal 1st: 34.9Hz
- Lateral 1st: 46.2Hz
- Steer 1st: 90.2Hz
- Vertical 1st: 72.2Hz
- Belt Torsion 2nd: 78.2Hz
- Belt 2nd: 78.5Hz
- Belt Torsion 3rd: 91.0Hz

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Summary and Future

(Summary)
+ The simplified tire model was developed. It is possible to simulate the vibration property up to 200Hz by this tire model.
+ It is possible to simulate the input force from the uneven road considering envelope effect by rolling on the road model of which the surface shape is modeled same as actual road.
+ It will be possible to simulate the road noise by running of the vehicle model with these tire models on the actual surface road model and considering the interactive effects between tire and vehicle.

(Future)
+ Road noise verification by vehicle model with tire model
+ Modeling the cavity air (about 250Hz resonance) and simulate the vibration property up to 500Hz