Studies on Wheel/Rail Contact – Impact Forces at Insulated Rail Joints

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ABSTRACT

To investigate the wheel/rail contact impact forces at insulated rail joints (IRJs), a three-dimensional finite element model and strain gauged experiments are employed and reported in this thesis. The 3D wheel/rail contact-impact FE model adopts a two-stage analysis strategy in which the wheel-IRJ railhead contact is first established in the static analysis and the results transferred to dynamic analysis for impact simulations. The explicit FE method was employed in the dynamic analysis. The Lagrange Multiplier method and the Penalty method for contact constraint enforcement were adopted for the static and dynamic analyses respectively.

The wheel/rail contact-impact in the vicinity of the end post is exhibited via numerical examples from the FE modelling. The wheel/rail contact impact mechanism is investigated. The strain gauged experiments which consist of a lab test and a field test are reported. The signature of the strain time series from the field test demonstrates a plausible record of the dynamic responses due to the wheel/rail contact impact. By using the experimental data, both the static and the dynamic FE models are validated.

It is found that the stiffness discontinuity of the IRJ structure causes a running surface geometry discontinuity during the wheel passages which then causes the impact in the vicinity of the end post. Through a series of sensitivity studies of several IRJ design parameters, it is shown that the IRJ performance can be effectively improved with optimised design parameters.
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LIST OF SYMBOLS

MATHEMATICAL SYMBOLS

[] Rectangular or square matrix

[]^T Matrix transpose

[]^-1 Matrix inverse

∥∥ Norm of a matrix or a vector

. Time differentiation (over dot)

- Boundary value (over bar)

LATIN SYMBOLS

a Major axis of elliptical contact area

A Contact area

B Strain-displacement matrix

b Minor axis of elliptical contact area

C_d Material damping

c_o Stress wave propagation speed

D Elasticity matrix

E Young’s modulus

F Concentrated force

f Body force

f_b Boundary force

g Gap function of contact surfaces

G Shear modulus
Depth of Hertz elastic foundation

Identity matrix

System stiffness matrix

Stiffness matrix

Dimension of characteristic element

Mass matrix

Shape function

Normal vector to the contact surface

Normal contact pressure

Peak value of contact pressure at the centre of contact area

Tangential contact traction

Radius of curvature

Distance of loading point from the origin

Time

Displacement

Velocity

Contact body profile

Coordinate of rectangular Cartesian reference system

Semi angle of wedge and cone

Measures of material difference of contact bodies

Normal strain

Shear stain
\( \sigma \) Normal stress
\( \tau \) Shear stress
\( \rho \) Density
\( \xi \) Fraction of critical damping
\( \omega_{\text{max}} \) System frequency of highest mode
\( \lambda \) Lagrange multiplier
\( \zeta \) Integral variable of potential function
\( \nu \) Poison ratio of the material
\( \mu \) Friction coefficient
\( \nu \) Interpolation parameter for velocity
\( \vartheta \) Interpolation parameter for displacement
\( \Pi \) Energy function
\( \chi \) Penalty parameters
## LIST OF ACRONYMS

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<tr>
<th>Acronym</th>
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<tbody>
<tr>
<td>2D</td>
<td>Two-dimension</td>
</tr>
<tr>
<td>3D</td>
<td>Three-dimension</td>
</tr>
<tr>
<td>CRE</td>
<td>Centre for Railway Engineering</td>
</tr>
<tr>
<td>CQU</td>
<td>Central Queensland University</td>
</tr>
<tr>
<td>DOF</td>
<td>Degree of Freedom</td>
</tr>
<tr>
<td>FE</td>
<td>Finite element</td>
</tr>
<tr>
<td>FEA</td>
<td>Finite element analysis</td>
</tr>
<tr>
<td>FEM</td>
<td>Finite element method</td>
</tr>
<tr>
<td>HCT</td>
<td>Hertzian contact theory</td>
</tr>
<tr>
<td>HTL</td>
<td>Heavy Testing Laboratory</td>
</tr>
<tr>
<td>IRJ</td>
<td>Insulated rail joint</td>
</tr>
<tr>
<td>QR</td>
<td>Queensland Rail</td>
</tr>
<tr>
<td>RMD</td>
<td>Rigid multibody dynamics</td>
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DECLARATION

The work contained in this thesis is a direct result of the original work carried out by me and has not previously been submitted for the award of a degree or diploma at any other tertiary institution in Australia or Overseas

Signed: ___________________________ Date: 29th June, 2007

Tao Pang

Author