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

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A Thesis Submitted in Partial Fulfilment for the Award of the Degree of

Master of Engineering

Centre for Railway Engineering

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Australia

June 2007

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
$\dot{}$	Time differentiation (over dot)
$\bar{}$	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_0	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

h	Depth of Hertz elastic foundation
I	Identity matrix
K	System stiffness matrix
k	Stiffness matrix
L_e	Dimension of characteristic element
M	Mass matrix
N	Shape function
n	Normal vector to the contact surface
p	Normal contact pressure
p_0	Peak value of contact pressure at the centre of contact area
q	Tangential contact traction
R	Radius of curvature
s	Distance of loading point from the origin
t	Time
u	Displacement
v	Velocity
Z	Contact body profile
x, y, z	Coordinate of rectangular Cartesian reference system

GREEK SYMBOLS

α	Semi angle of wedge and cone
β	Measures of material difference of contact bodies
ε	Normal strain
γ	Shear stain

σ	Normal stress
τ	Shear stress
ρ	Density
ξ	Fraction of critical damping
ω_{max}	System frequency of highest mode
λ	Lagrange multiplier
ζ	Integral variable of potential function
ν	Poison ratio of the material
μ	Friction coefficient
υ	Interpolation parameter for velocity
ϑ	Interpolation parameter for displacement
Π	Energy function
χ	Penalty parameters

LIST OF ACRONYMS

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

ACKNOWLEDGEMENTS

I would like to thank all those people who have given me generous help and supports during the past two years.

Many thanks to my supervisor, A/Prof. Manicka Dhanasekar, director for Centre for Railway Engineering; I sincerely appreciated his sustained guide and support in both academic and personal way from the commencement to the completion of my master program.

I also would like to express my appreciation to the research staffs in Centre for Railway Engineering, Mr. Trevor Ashman, Mr. Grant Caynes, A/Prof. Colin Cole, Mr. Paul Boyd and many QR engineers who has made major contribution to the important and interesting experiment in this research.

Thanks to Mr. Tim McSweeney, Research Support Officer in Centre for Railway Engineering, for his generous help throughout my two years' research and precious advices in the final stage of thesis writing.

The thesis was possible thanks to the scholarship awarded by the Centre for Railway Engineering, Central Queensland University, Australia RailCRC and Queensland Rail.

Special thankfulness to my parents, my girlfriend Saina and all my friends I met in Australia, only with your support, help and understanding I could accomplish this thesis.

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