

MODELLING AND ANALYSIS OF SOCCER
HEADING AND PROTECTIVE HEADGEAR
TO UNDERSTAND AND PREVENT
MILD TRAUMATIC BRAIN INJURY

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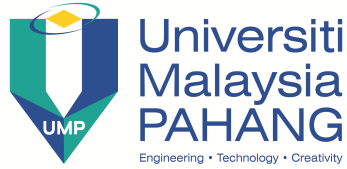
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MOHD HASNUN ARIF HASSAN

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LIST OF SYMBOLS

a_i	Linear acceleration
α_i	Angular acceleration / Temperature-dependent material parameter
β	Decay factor
β_i	Temperature-dependent material parameter
c_i	Damping coefficient
C_{i0}	Material constant
D_i	Material constant
ΔT	Impact duration / contact time
e	Coefficient of restitution
E	Elastic modulus / Young's modulus
F	Force
g	Gravitational acceleration (9.81 m/s ²)
G_i	Shear modulus
$g_R(t)$	Relaxation modulus
\bar{g}^P	Material constant
\bar{I}_i	Strain invariant
J^{el}	Elastic volume ratio
J_{ii}	Mass moments of inertia
K	Bulk modulus
k_i	Linear stiffness
$\hat{\lambda}_i$	Principal stretches
m_i	Mass
μ_i	Temperature-dependent material parameter
t	Time
τ^G	Material constant
v_i	Linear velocity
ν_i	Poisson's ratio
ω_i	Angular velocity
ω_d	Damped natural frequency
r_w	Wheel radius
U	Strain energy per unit of reference volume
x_i	Longitudinal deformation / displacement
\dot{x}_i	Linear velocity
\ddot{x}_i	Linear acceleration

LIST OF ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
ABS	Acrylonitrile butadiene styrene
AC	Alternating current
BDNF	Brain-derived neurotrophic factor
COR	Coefficient of restitution
CSDM	Cumulative Strain Damage Measure
CSF	Cerebrospinal fluid
CT	Computed tomography
DAQ	Data acquisition
DC	Direct current
DDM	Dilatation Damage Measure
DTI	Diffusion tensor imaging
FA	Fractional anisotropy
FE	Finite element
FEA	Finite element analysis
GAMBIT	Generalised Acceleration Model for Brain Injury Threshold
GCS	Glasgow Coma Scale
HIC	Head Injury Criterion
HIP	Head Impact Power
HITS	Head Impact Telemetry System
ImPACT	Immediate Post-Concussion Assessment Cognitive Testing
LOC	Loss of consciousness
MRI	Magnetic resonance imaging
mTBI	Mild traumatic brain injury
NGF	Nerve growth factor
NSE	Neuron-specific enolase
PTA	Post-traumatic amnesia
RMDM	Relative Motion Damage Measure
SD	Standard deviation
TBI	Traumatic brain injury
WSTC	Wayne State Tolerance Curve