FORMULATION OF AN ENERGY ABSORPTION MODEL FOR A PTW TO ESTIMATE PRE-IMPACT SPEED IN REAL-WORLD ROAD CRASH

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by

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AUTHORS DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of my thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis will be made electronically available to the public.

KULDEEP SINGH

CERTIFICATE

This is to certify that the thesis entitled "**Formulation of an energy absorption model for a PTW to estimate pre-impact speed in real-world road crash**" being submitted by **Mr. Kuldeep Singh** to the Indian Institute of Technology Delhi for the award of Doctor of Philosophy in the Department of Mechanical Engineering is a record of bonafide research work carried out by him. He has worked under our guidance and has fulfilled the requirements for the submission of the thesis, which, in our opinion, has reached the requisite standard.

The results in this thesis have not been submitted in part or full, to any University or Institute for the award of degree or diploma.

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The direction towards this work is also a result of being a part of a pilot project collecting accident data from National Highway-8 connecting Delhi to Jaipur in collaboration with NATRiP and led by IIT-Delhi under the guidance of Dr. Anoop Chawla as the academic partner. This project aims to collect road traffic accident (RTA) data such as vehicle damage and occupant injuries from hospitals and insurance companies and conduct an in-depth analysis and reconstruction.

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ABSTRACT

*To estimate damage energy and related impact speed for a typical Indian PTW crash, this work addresses the research question, "***Is there a deformation-based energy model to estimate impact speed of a PTW in crash reconstruction studies?***"*

Estimation of the damage energy related to significant energy absorbing components under dynamic loading has been quantified. A component-level testing under dynamic loading conditions was conducted for the tubular structure of a PTW in a crash. Deformation measurement and the absorbed energy were quantified from a three-point bending test under a drop tower test setup. The FE model of the front fork tube under bending load conditions was validated using experimental data. The Finite Element (FE) and Multi(-Rigid)-Body (MB) models of a typical Indian PTW (Engine capacity: 100 cc) were developed and partially validated in a rigid wall crash test. The feasibility of using a FE PTW model in a crash was evaluated and compared to a similar class of PTW used in the crash tests for a frontal impact against the door of a passenger vehicle (PV). The energy absorbed and related impact speed of the developed PTW FE model against a FE model of the passenger vehicle used in the simulation was reasonable.

A real-world PTW crash with damage details was selected from National Highway-8 (NH-8) database collected by IIT-D and reconstructed in FE. The events in the FE simulation, the direction of motion, and the final rest position after impact were correlated. The damage energy and deformation of the front fork in FE analysis were reasonably correlated with experimental data. A method to predict energy absorbed and related impact speed based on the damage component was demonstrated. Hence this study serves as a good starting point to predict impact speed based on damage details of significant energy absorbing components of a typical Indian PTW in a real-world road traffic accident (RTA).

सार

एक विशिष्ट भारतीय पीटीडब्ल्यू दुर्घटना के लिए क्षति ऊर्जा और संबंधित प्रभाव गति का अनुमान लगाने के लिए, यह कार्य अनुसंधान प्रश्न को संबोधित करता है, "क्या दुर्घटना पुनर्निर्माण अध्ययनों में पीटीडब्ल्यू की प्रभाव गति का अनुमान लगाने के लिए विरूपण-आधारित ऊर्जा मॉडल है?"
गतिशील लोडिंग के तहत महत्वपूर्ण ऊर्जा अवशोषित घटकों से संबंधित क्षति ऊर्जा का अनुमान लगाया गया है। एक दुर्घटना में पीटीडब्ल्यू की ट्यूबलर संरचना के लिए गतिशील लोडिंग स्थितियों के तहत एक घटक-स्तरीय परीक्षण किया गया था। एक ड्रॉप टॉवर परीक्षण सेटअप के तहत तीन-बिंदु झुकने परीक्षण से विरूपण माप और अवशोषित ऊर्जा की मात्रा निर्धारित की गई थी। बेंडिंग लोड स्थितियों के तहत फ्रंट फोर्क ट्यूब के एफई मॉडल को प्रयोगात्मक डेटा का उपयोग करके मान्य किया गया था। एक विशिष्ट भारतीय पीटीडब्ल्यू (इंजन क्षमता: 100 सीसी) के परिमित तत्व (एफ-ई) और मल्टी-(कठोर)-बॉडी (एम-बी) मॉडल विकसित किए गए और कठोर दीवार दुर्घटना परीक्षण में आंशिक रूप से मान्य किए गए। एक दुर्घटना में एक एफ-ई पीटीडब्ल्यू मॉडल का उपयोग करने की व्यवहार्यता का मूल्यांकन किया गया था और एक यात्री वाहन (पी.वी.) के दरवाजे के सामने सामने के प्रभाव के लिए दुर्घटना परीक्षणों में इस्तेमाल किए गए पीटीडब्ल्यू के समान वर्ग की तुलना में। सिमुलेशन

में इस्तेमाल किए गए यात्री वाहन के एफ-ई मॉडल के खिलाफ विकसित पीटीडब्ल्यू एफ-ई मॉडल की ऊर्जा अवशोषित और संबंधित प्रभाव गति उचित थी।

IIT-D द्वारा एकत्र किए गए राष्ट्रीय राजमार्ग-8 (NH-8) डेटाबेस से क्षति विवरण के साथ एक वास्तविक-विश्व PTW दुर्घटना का चयन किया गया और एफ-ई में पुनर्निर्माण किया गया। एफ-ई सिमुलेशन में घटनाएं, गति की दिशा, और प्रभाव के बाद अंतिम आराम की स्थिति सहसंबद्ध थी। एफ-ई विश्लेषण में फ्रंट फोर्क की क्षति ऊर्जा और विरूपण प्रयोगात्मक डेटा के साथ उचित रूप से सहसंबद्ध थे। क्षति घटक के आधार पर अवशोषित ऊर्जा और संबंधित प्रभाव गति की भविष्यवाणी करने की एक विधि का प्रदर्शन किया गया। इसलिए यह अध्ययन एक वास्तविक दुनिया सड़क यातायात दुर्घटना (आरटीए) में एक विशिष्ट भारतीय पीटीडब्ल्यू के महत्वपूर्ण ऊर्जा अवशोषित घटकों के नुकसान के विवरण के आधार पर प्रभाव की गति की भविष्यवाणी करने के लिए एक अच्छा प्रारंभिक बिंदु के रूप में कार्य करता है।

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NOMENCLATURE

ABBREVIATIONS

ACEM	Association of European Motorcycle Manufacturers
C.G.	Center of Gravity
cc	Cubic Centimeters
CCSA	Centre for Collision Safety and Analysis
CDC	Collision Deformation Classification
CNRB	Constrained Nodal Rigid Bodies
CoE	Conservation of Energy
CRCS	Cold rolled commercial steel
DAQ	Data Acquisition System
DC	Damping Constant
E	Young's Modulus
EES	Equivalent Energy Speed
EL	Effective Length
ELFORM	Element Formulation
FE	Finite Element
FFLT	Front Fork Lower Tube
FFUT	Front Fork Upper Tube
HPC	High Performance Computing
IE	Internal Energy
IIT-D	Indian institute of Technology-Delhi
JARI	Japan Automotive Research Institute

Kg	Kilograms
L	Length
LC	Lower Clamp
M	Mass
MAIDS	Motorcycle Accidents In-depth Study
MATD	Motorcycle Anthropometric Test Devise
MB	Multi-Body
MIROS	Malaysian Institute of Road Safety
Mpa	Mega Pascal
NASS	National Automotive Sampling System
NATRiP	National Automotive Testing R&D Infrastructure Project
NCRB	National Crime Record Bureau
NH-8	National Highway-8
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
OV	Opposing Vehicle
PTW	Powered Two Wheeler
PV	Passenger Vehicle
RWBT	Rigid Wall Barrier Test
SE	Specific Energy
SIAM	Society of International Automotive Manufacturers
SL	Span Lengh
TRL	Transport Research Laboratory
UC	Upper Clamp
V	Velocity

VRU	Vulnerable Road Users
w.r.t	with respect to
WHO	World Health Organisation