

Development and Validation of Pedestrian Deformable Finite Element Model

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ABSTRACT

Recently, Pedestrian protection has become an increasingly important consideration in vehicle crash safety. Pedestrian-vehicle crashes cause a significant number of pedestrian fatalities and injuries globally. Computer models are powerful tools for understanding how to reduce the injuries severity in such crashes. Real-world studies of pedestrians provide an important source of information for evaluating pedestrian model dynamic performance and ability to reconstruct injury-causing events. This study describes the validation process of deformable pedestrian model using published post-mortem human subject (PMHS) trajectory and head resultant velocity corridors, and demonstrates its applicability to pedestrian - vehicle impact research, the pedestrian injuries are also analyzed in impact with vehicle at three velocities 25, 32 and 40km/h. This study implemented the deformable pedestrian model using LS-DYNA finite element code. The pedestrian model is validated by comparison the displacement trajectories of the head, pelvis, knee and foot with PMHS data. The pedestrian injuries are analyzed in this study include serious injuries of parts which will effect on the pedestrian life such as injuries of head, leg, thigh, thorax, neck and pelvis. The finite element pedestrian model thus obtained can help assess the friendliness of vehicles with pedestrian in traffic crash and assist in the future development of pedestrian safety technologies.

Keywords : Pedestrian deformable model, pedestrian injuries, pedestrian protection, pedestrian-vehicle impact, full scale pedestrian model.

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REFERENCES

1. NHTSA ' s (National Highway Traffic Safety Administration) Annual Assessment of Motor Vehicle Crash: Motor Vehicle Traffic Crash Fatality Counts and Estimates People of Injured for 2005 – Updated December 13, 2006.
2. L. Astrid, M. Clay, C. Anthony, Y. Jikuang, O. Dietmar, Mathematical Simulation of Real-World Pedestrian-Vehicle Collisions, Paper No. 05-285, 2005.
3. SUSPA Gaspedern: <http://www.suspa.com>
4. Road Safety and Motor Vehicle Regulation Directorate, Pedestrian Fatalities and Injuries in Canada -1992-2001, December 2004.
5. P. P. Michael, G. C. Christopher, Assessment of Pedestrian Protection Afforded by Vehicles in Australia, March 2000.
6. F. A. Berg, M. Egelhaaf, J. Bakker, H. Burkle, R. Herrmann, J. Scheerer, Pedestrian Protection In Europe-The Potential of Car Design and Impact Testing.
7. K. Ingo, F. Flavio, Improvements to Pedestrian Protection as Exemplified on a Standard-Sized Car, Report No. 283, Germany, 2000.
8. M. Yoshiuki, I. Hirotooshi, Summary of IHRA Pedestrian Safety WG Activities- Proposed Test Methods To Evaluate Pedestrian Protection Afforded by Passenger Cars, Paper Number 280.
9. Ingenieria Y A Sistemas S.A: www.arise-ingenieria.com.
10. O. Yutaka, A. Akihiko, O. Masayoshi, K. Yuji, A Study of The Upper Leg Component Tests Compared With Pedestrian Dummy Tests, Paper Number 380.
11. K. Atsuhiko, I. Hirotooshi, K. Robert, Development of computer simulation models for pedestrian subsystem impact tests, JSAE Review 21 (2000) 109 – 115.
12. L. Astrid, C. Anthony, D. Clay, F. Brian, Y. Jikuang, S. Laurie, Mathematical modelling of pedestrian crashes: Review of Pedestrian Models and Parameter Study of The Influence of The Sedan Vehicle Contour, Victoria, Australia, 2003
13. V. R. Lex, B. Kavi, M. Mark, I. Johan, C. Jeff, L. Douglas, T. Yukou, D. Yasuhiro, K. Yuji, Pedestrian Crash Reconstruction Using Multi-Body Modeling with Geometrically Detailed, Validated Vehicle Models and Advanced Pedestrian Injury Criteria, Paper Number 468, 2003.
14. I. Masami, O. Kiyoshi, K. Hideyuki, N. Yuko, T. Atsutaka, W. Isao, M. Kazuo, H. Junji, O. Fuminori, Recent advances in THUMS: Development of Individual Internal Organs, Brain, Small Female, and Pedestrian Model, 4th European LSDYNA Users Conference, 2002.
15. Dipl. Ing. Dr. Franz Laimbock, Book: Safety and Crash Behavior, March 1993.
16. S. Jiri, C. Viktor, Pedestrian – Vehicle Collision: Vehicle Design Analysis, 2003- 01-0896.
17. Hexcel Composite: Hexcel ' s Product for Automotive Pedestrian Impact Protection: Automotive Pedigree and Efficient Energy Absorbing Solutions.
18. M. Tetsuo, A. Toshiyuki, Development of pedestrian protection technologies for ASV, SAE Review 23 (2002) 353 – 356.
19. IMM – Institute for Informatics and Mathematical Modelling-Technical University of Denmark: www2.imm.dtu.dk/courses02431.
20. Ulrich Mellinghoff, Protecting Pedestrians the Mercedes Way.
21. S. Jason, A. Barsan-Anelli, Adaptation of a Human Body Mathematical Model to Simulation of Pedestrian/Vehicle Interaction, 4th MADYMO User's Meeting of the America's, Detroit, October 24th, 2001.
22. EEVC Working Group 17 Report, Improved Test Methods to Evaluate Pedestrian Protection Afforded by Passenger Cars (December 1998 with September 2002 updates).
23. Y. Jikuang, Review of Injury Biomechanics in Car - Pedestrian Collisions (Report to European Passive Safety Network), February 28th, 2002.
24. V. R. Lex, M. Mark, N. Kavi, C. Jeff, L. Douglas, T. Yukou, D. Yasuhiro, K. Yuji, The evaluation of the kinematics of the MADYMO human pedestrian model against experimental tests and the influence of a more biofidelic knee joint, 2005.
25. Michael Paine, Pedestrian Protection by Vehicle Design an International Seminar, Australia on 25 & 26 February 1999.
26. Find Articles: Ward ' s Auto World Pedestrian Impact.htm
27. The Insurance Institute for Highway Safety-The Highway Loss Data Institute (Q&A: PEDESTRIANS): <http://www.iihs.org/default.html>
28. O. N. Mark, K. Heui-Su, J.T. Wang, F. Takanobu, N. Katsumi, Development of LS-Dyna Finite Element Models for Simulating EEVC Pedestrian Impact, Paper Number 335.
29. L. Alexandra, A. Robert, The development and validation of the IHRA pedestrian model using MADYMO and AutoDOE, Proceedings of the 2005 Madymo Users Meeting, November 2006.
30. K. Atsuhiko, Reconstruction analysis for car – pedestrian accidents using a computer simulation model, JSAE Review 23 (2002) 357 – 363.
31. K. Atsuhiko, I. Hirotooshi, S. Akira, A study on pedestrian impact test procedure by computer simulation - The Upper Legform to Bonnet Leading Edge Test, Paper Number 98-S 10-W- 19, 2349-2356
32. F. Rikard, H. Yngve, Y. Jikuang, Evaluation of A New Pedestrian Head Injury Protection System with A Sensor In The Bumper and Lifting of The Bonnet ' s Rear Part, Paper number 131.
33. M. S. Neale, B. J. Hardy and G. J. L. Lawrence, Development and review of the IHRA (JARI) and TNO pedestrian models, Paper Number 499.
34. Vehicle Design & Research Pty Limited: <http://www1.tpgi.com.au>
35. LS-DYNA User Manual Version 960, Livermore Software Technology Corporation, 2002.