Development and Application of Side-Impact Sled Test Numerical Model

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ABSTRACT

Crash test is commonly employed for examining occupant protection capability of a particular vehicle. Full-scale crash tests can achieve results that closely resemble an actual accident, but the test is complex and expensive. Sled test is an effective means of evaluating crash safety of vehicle interiors. This technique can simulate real crash conditions without destroying vehicle structure. Therefore, the sled system is typically employed to assess the protective capability of safety equipment during vehicle research and development stages. Recently, advances in computer technology have allowed applied mathematicians, engineers, and scientists to solve previously intractable problems. The sled tests can be accurately performed by computer simulations. As such, computer simulations are both economical and time efficient as an alternative to physical testing. This work presents the procedure of full-scale and sled side-impact tests were based on the Federal Motor Vehicle Safety Standard No. 214 (FMVSS-214) that simulate a side-impact accident. The side-impact sled systems were based on BASIS testing system developed by TNO Science and Industry. The crash simulations utilized the finite element code LS-DYNA3D. The dynamic response of human body ’ s in crashes was discussed herein. Additionally, occupant injuries were measured. To verify the accuracy of the proposed FE (Finite Element) models of crash test and sled test, the simulation results were compared to those obtained from experimental tests. The comparison results indicated that the proposed FE models of crash test and sled test have considerable potential for estimating the crash safety performance of a vehicle and assisting future development of safety technologies. These numerical models predicted severity of driver injuries during impacts, reduced the time of research and design, and reduce experimental costs. The accuracy of the numerical model of sled test makes it a valuable approach for side-impact crashworthiness simulations. The proposed methods can be applied to examine the dynamic behavior of occupants and analyze injuries during side-impact accidents. Moreover, the proposed FE models serve as design guidelines for the vehicle structure and safety equipment required to protect vehicle occupants.

Keywords : Side impact sled test, full-scale vehicle impact test, finite element method, side impact airbag, injury of occupant, LS-DYNA 3D

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REFERENCES

[1] http://www.ttvma.org.tw/cht/industrial-survey.php [2] http://www.tno.nl/industrie_en_techniek/index.xml [3] http://www.saabnet.com/tsn/models/2001/pr23.html [4] http://media.ford.com/products/presskit_display.cfm?press_subs ection_id=424&vehicle_id=1231 [5] Kyoso Ishida, Mitsugi Fukahori, Kastsunori Hanakawa, Hideaki Tanaka and Kenji Matsuda, “ Development of a Technique to Strengthen Body Frame With Structural Foam ”, SAE Paper No.2001-01-0313, (2001) [6] S. Erzen, Z. Ren, and Anzel, “ Analysis of FRP side-Door impact beam ”, http://www.sussex.ac.uk/automotive/tvt2002/15_ erzen.pdf#search='side%20door' [7] David C. Viano,

“ Evaluation of Armrest Loading in Side Impacts ” , SAE paper 912899, (1991) [8] Roger P. Daniel, Robert W. Hultman, and Lee A. Walker, “ Research and Development for Lower Lateral Force Armrests ” , SAE paper No. 952734, (1995) [9] Yih-Charng Deng, “ The Importance of Test Method in Determing the Effects of Door Padding in Side Impact ” , SAE paper 892429, (1989) [10] F. Shokoohi, D. S. Breed, “ One-Dimensional Model for Predicting Side Intrusion Injuries Including Effects of Padding ” , SAE paper 910600, (1991) [11] Thomas J. Trella, Hampton C. Gabler III, Joseph N. Kanianthra, and J. Joseph Wagner, “ Side Impact Crashworthiness Design: Evaluation of Padding Characteristics Through Mathematical Simulations ” , SAE paper 912900, (1991) [12] S. Sundararajan, C. C. Chou, G. G. Lim, J. A. Prater, and R. R. Clements, “ Dynamic Door Component Test Methodology ” , SAE paper 950877, (1995) [13] Midoun, D. E., Rao, M. k., Kalidindi R., “ Dummy Models for Crash Simulation in Finite Element Programs ” , SAE Paper No. 912912, (1991) [14] Yih-Charng Deng, Bruce Tzeng, “ Side Impact Countermeasure Study Using A Hybrid Modeling Technique ” , SAE paper 962413, (1996) [15] Madama Gopal, Vital Anne, “ Performance Evaluation of Dooe & Seat Side-Impact Airbags for Passenger Van and Sport-Utility Vehicles ” , SAE Paper No. 980912, (1998) [16] J. R. Hopton, A. R. Payne, “ Comparison Stusy of EuroSID, USSID, BioSID Performance Using MIRA ’ s New M-SIS Side Impact Simulation Technique ” , SAE Paper No. 960103, (1996) [17] Jaekoo Chung, John M. Cavanaugh, Matt Mason Jr., albert I. King, “ Development of a Sled-to-Sled Subsystem Side Impact Test Methodology ” , SAE Paper No. 970569, (1997) [18] P. Michael Miller II, Hai Gu, “ Sled Testing Procedure for Side Impact Airbag Development ” , SAE Paper No. 970570, (1997) [19] A. R. Payne, R. Mohacsi, B. Allan-Stubbs, “ The Effects of Variability in Vehicle Structure and Occupant Position on Side Impact Dummy Response Using the MIRA M-SIS Side Impact Technique ” , SAE Paper No. 970571, (1997) [20] Douglas J. Stein, “ Apparatus and Method for Side Impact testing ” , SAE Paper No. 970572, (1997) [21] Bernadette Allan-Stubbs, “ The Effect of Changes in Seating Position and Door Velocity Time History on Side Impact Dummt Response ” , SAE Paper No. 980911, (1998) [22] S. Vaidyaraman, H. khandelwal, C. Lee, J. Xu, “ State-of-the-art Side Airbag Modeling and Its Application in Occupant Safety in Lateral Collisions ” , SAE Paper No. 980915, (1998) [23] K. Aekbote, S. Sundararajan, C. C. Chou, G. G. Lim, J. A. Prater, “ A New Component Test Methodology Concept for Side Impact Simulation ” , SAE Paper No. 1999-01-0427, (1999) [24] Young-Ho Ha, Byung-Wan Lee, “ A Device and Test Methodology for Side Impact Crash Simulation Using A Frontal Crash Simulator and Two Hydraulic Brake Systems ” , SAE Paper No. 2000-01-0047, (2000) [25] Richard Kent, Jeff Crandall, Jon Butcher, “ Sled System Requirements for the Analysis of Side Impact Thoracic Injury Criteria and Occupant Protection ” , SAE Paper No. 2001-01-0721, (2001) [26] P. Michael Miller II, Todd Nowak, Walter Macklem, “ A Compact Sled System for Linear Impact, Pole Impact, and Side Impact Testing ” , SAE Paper No. 2002-01-0695, (2002) [27] Byron Saari, Randy Ellis, “ New Methods of Side Impact Simulation for Better Waveform Reproduction and Door Interaction ” , SAE Paper No. 2004-01-0474, (2004) [28] http://www.safercar.gov/ [29] http://saab-club.com/gallery/details.php?image_id=963 [30] Laboratory Test Procedure For FMVSS No.214 “ Dynamic ” Side Impact Protection, NHTSA, January, (2003) [31] Zaouk, A.k., Marzougui, D., “ Development and Validation of a US Side Impact Moveable Deformable Barrier FE Model ” , FHWA/NHTSA National Crash Analysis Center, The George Washington University, Ashburn, (2002) [32] ” Testing for Side Impact Protection-Passenger Cars, 1991 Ford Taurus, Contract No: DTRS-57-95-C-00010(TTD#3) ” MGA Proving Grounds, Burlington, WI53105, March 31, (1997) [33] Hultman, R.W., Laske, T.G., Chou, C.C., Lim, G.G., Chrobak, E.I., Vecchio, M.T., “ NHTSA Passenger Car Side Impact Dynamic Test Procedure-Test-To-Test Variability Estimates ” , SAE Paper No. 910603, (1991) [34] LS-DYNA 970 User Manual. [35] Klaus Friedewald, “ Design Methods for Adjusting the Side Airbag Sensor and the Car Body ” , Volkswagen AG, Paper NO.98-S8-W-17 [36] http://www.safercar.gov/airbags/pages/SABFAQs.htm [37] http://www.autoblog.com/2006/04/15/new-york-auto-show- man ufacturers-flaunt-their-safety-features/