考慮翻覆安全之大客車骨架結構最佳化設計

黎江南(Le Giang-Nam)、梁卓中

E-mail: 9808283@mail.dyu.edu.tw

摘 要

巴士是大眾運輸工具之重要一環，而巴士在翻覆意外中，上層結構(superstructure)會嚴重變形，且乘客及駕駛會承受重要的傷害。因此如何設計一輛巴士的上層建築，使巴士具有良好的勁度則為一極重要的工作。歐盟及美國均強力推動巴士翻覆的安全法規:歐規ECE R66(Regulation number 66 of the Economic Commission for Europe)及美國聯邦車輛安全法規FMVSS 220(Standard number 220 American Federal Motor Vehicle Safety Standards)。然而強化巴士上層結構卻會造成重量增加，因而在結構設計上考量輕量化亦為一重要的設計主題。因此，本論文首先研究歐規 ECE R66及美規 FMVSS 220在安全規範上之不同處；其次，在保持重量不變及強度水準不變的條件下，進行巴士上層結構的最佳化設計研究以減少乘客的損傷；最後，參考巴士骨架變形及存活空間的因素下來進行巴士結構輕量化的設計。 本研究利用LS-DYNA的FEMB模組建構有限元素模型，其間並採用巴士上部連接處之處理乃採用車輛研究中心(ARTC)及車頂邊緣的連接處之實驗數據，並應用LS-DYNA971進行求解。經比較研究歐規ECE R66及美規FMVSS220發現歐規ECE R66巴士的側翻測試，對乘客艙及殘留空間之需求較為嚴格。此外，本論文進行簡化大客車骨架結構之最適化分析時，應用LS-OPT中的連續回應表面法(Successive Response Surface Method)進行最適化的研究，發現能量吸收能力為大客車骨架結構最適化的一個重要的影響因素。本論文以上之研究成果應可提供未來大客車上層結構設計之參考應用。

關鍵詞 : 大客車翻覆、上層結構、ECE R66、FMVS 220、能量吸收、LS-DYNA、輕量化、最適化方法、LS-OPT

目錄

參考文獻

1.UNECE, (2007). Report of the IG-R.66 meeting, 93rd GRSG. 2.UNECE, (2006). GRSG-93-04 http://www.unece.org/trans/main/wp29/wp29wgs- /wp29grsg/grsginf93.html, 3.NIAR (2005). Report # FTA-002, Mass Transit Crashworthiness Statistical Data Analysis. 4.Martinez L., Aparicio F., Garcia A., Paez J., Ferichola G., (2003) " Improving occupant safety in coach rollover, " INSIA, Polytechnic University of Madrid, Spain. 5.NHTSA, (2003). Initiatives to Address the Mitigation of Vehicle Rollover. 6.JASIC, (1998). ECE Regulation No.66 S1 - Strength of Super Structure, Economic Commission for Europe, pp1-19. 7.JASIC, (2006). ECE Regulation No.66 01 - Strength of Superstructure, Economic Commission for Europe, pp 1-49. 8.NHTSA, (1991). FMVSS 220 standard – School Bus Rollover Protection, TP-220-02, Department of Transportation, Washington, DC 20590. 9.NTSB, (1999). Bus Crashworthiness Issues. Highway Special Investigation Report NTSB/SIR-99/04. Washington, DC. 10.J.C. Brown, (1990). The design and type approval of coach structures for rollover using the CRASH-D program. Int. J. of Vehicle Design, vol. 11, nos 4/5, UK. 11.T. Roca, J. Arbiol, and S. Ruiz, (1997). Development of Rollover Resistant Bus Structures. Society of Automotive Engineers 970581. 12.J. C. Anderson, (2000). Rollover Crashworthiness of a New Coach Structure. Society of Automotive Engineers. No. 2000-01-3520. 13.Belingardi, D. Gastaldin, P. Martella and L. Peroni, (2003). Multibody Analysis of M3 Bus Rollover: Structural Behaviour and passenger Injury Risk, The 18th International Technical Conference on the Enhanced Safety of Vehicle (ESV), Paper Number: 288. 14.L. Castejon, J. Cuartero, A. Miravete, M. Carrera, P. Santolaya, E. Romeo and C. Roca, (2004). Simulation and Testing of Composite Buses Roll Over, SAE paper No. 2004-01-0741. 15.Belingardi, P. Martella and L. Peroni, (2005). Coach Passenger Injury Risk during Rollover: Influence of the seat and the restraint system. The 19th International Technical Conference on the Enhanced Safety of Vehicle (ESV), Paper Number: 05-0439. 16.S.-J. Park, W.-S. Yoo, (2008). Rollover analysis for the body section structure of a large bus using beam and non-linear spring elements. Proc. ImechE, Engrs, Part D: J. Automobile Engineering, Vol. 222, No. 6, pp 955-962 17.W. Schwartz, (2004). Simulations with LS-DYNA for Registration Approval of a Coach according to ECE R66 Regulation. International Congress Center Dresden, Germany. 18.K. Elitok, F. H. Avci, (2005). Crash Analysis with LS-DYNA. CADFEM GmbH, FEA Engineer TEMSA. 19.Kecman and M. Djokic, (1990). The effect and modeling of ' finite stiffness hinges ' in the collapse analysis of roll-over safety ring in buses and coaches. Int. J. of Vehicle Design, vol. 11, nos 4/5, UK. 20.A. Subic and J. He, (1997). Improving bus rollover design through modal analysis. International journal of crashworthiness, Vol2, No2. 21.M. Matolcsy, (1998). Development Possibilities in Relation to ECE Regulation 66: Bus Rollover Protection. The 16th International Technical Conference on the Enhanced Safety (ESV), Paper Number: 98-S4-O-04. 22.S. Vincze, (1998). European Test Methods for Superstructure of Buses and Coaches Related to ECE R66: The Applied Hungarian Calculation Method. The 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Paper Number: 98-S4-P-19. 23.M. Matolcsy, (2001). Body Section Rollover Test as an Approval Method for Required Strength of Bus Superstructures. SA E paper No. 2001-01-3209. 24.K. Elitok, M.A. Guler, B. Bayram, U. Stelzmann, (2006). An investigation on the rollover crashworthiness of an intercity coach, influence of seat structure and passenger weight. The 9th International LS-DYNA Users Conference, Dearborn, MI, USA. 25.X.-T. Chiu, (2007). The design and Evaluation of Reinforcement Structure for Bus Frame. Master thesis, Da-Yeh University. 26.K. Kumagai, Y. Kabeshita, H. Enomoto, and S. Shimojima, (1994). An Analysis Method for Rollover Strength of Bus Structures. The 14th International Technical Conference on Enhanced Safety of Vehicles, Munich, Germany. 27.N. Niii and K. Nakagawa, (1996). Rollover Analysis Method of a Large-Sized Bus. The 15th International Technical Conference on the Enhanced Safety of Vehicles, Melbourne, Australia. 28.L. Castejon, A. Miravete and E. Larrode, (2001). Intercity bus rollover simulation. International Journal of Vehicle Design, Vol. 26, No 2/3. 29.K. Elitok, M.A. Guler, F.H. Avci and U. Stelzmann, (2005). Bus Rollover Simulation. Validation of a new Safety Concept, 23rd CADFEM Users ' Meeting , International Congress on FEM Technology, Bonn, Germany. 30.K. Elitok, M.A. Guler, F.H. Avci and U. Stelzmann, (2005). Regulatory Bus Roll-Over Crash Analysis Using LSDYNA, Conference for Computer-Aided Engineering and System Modeling, ?stanbul, Turkey. 31.T. Kim, (1992). Study on the Optimization of Bus Body Structure. SAE Paper 923953 32.T. Kim, (1993). Study on the stiffness improvement of bus structure. SAE Paper 931995 33.K. Lan, J. Chen, and J. Lin, (2004). Comparative analysis for bus side structures and lightweight optimization. Proc. Instn Mech, Engrs Vol.218 Part D: J. Automotive Engineering. 34.Y.-C. Lin and H.-C. Nian, (2006). Structural Design Optimization of the Body Section Using the Finite Element Method, SAE paper 2006-01-0954. 35.B.L. Boada, A. Gauchia, M.J.L. Boada, V. Diaz, (2007). A genetic-based optimization of a bus structure as a design methodology. 12th IFToMM World Congress, Besancon. 36.A.E. Matthews, (1994). Fuel efficient sheet steel automobiles. New and Alternative Mater. for Transpn Industries, pp. 163 – 164. 37.M. Saito, S. Iwatsuki, K. Yasunaga and K. Andoh, (2000). Development of aluminium body for the most fuel efficient vehicle. JSAE Rev., 21, pp. 511 – 516. 38.M. Takamatsu, (1992). Development of lighter-weight, higher-stiffness body for new RX-7. SAE paper 920244. 39.T. Pine, M.M.K. Lee and T.B. Jones, (1999). Weight reduction in automobile structures—an experimental study on torsional stiffness of box sections. Proc. Instn Mech. Engrs, Part D: J. Automotive Engineering, 213(D1), pp.59 – 71. 40.M. M. K. Lee, T. Pine and T.B. Jones, (2000). Automotive box section design under torsion. Part 1: ?nite element modeling strategy. Proc. Instn Mech. Engrs, Part D: J. Automotive Engineering, 214(D5), pp.347 – 359. 41.M. M. K. Lee, T. Pine and T.B. Jones, (2000). Automotive box section design under torsion. Part 2: behaviour and implications on weight reduction. Proc. Instn Mech. Engrs, Part D: J. Automotive Engineering, 214(D5), pp.473 – 485. 42.Y.-X. Chai, (2005). Numerical Simulation and Analysis of Bus Rollover, Master thesis, Da-Yeh University. 43.R.-H. Chang, (2006). A Study on Increasing Structural Strength of Bus, Master thesis, Da-Yeh University. 44.J.O. Hallquist, (2006). LS-DYNA Theoretical Manual, Livermore Software Technology Corporation. 45.LSTC, (2007). LS-DYNA Users Manual, Livermore Software Technology Corporation. 46.M.A. Guler, K. Elitok, B. Bayram, U. Stelzmann, (2007). The influence of seat structure and passenger weight on the rollover crashworthiness of an intercity coach. International journal of Crashworthiness, 12/6, pp.567-580. 47.T.B. Belytschko, J.I. Lin and C.S. Tsay,

(1984). Explicit Algorithm for the Nonlinear Dynamics of Shells, Comp. Methods. in Applied Mechanics and Engineering, Vol. 43, pp.251-276. 48.F. J. Harewood, P. E. Mchugh, (2007). Comparison of the implicit and explicit finite element methods using crystal plasticity. Computational materials science, vol. 39, no2, pp. 481-494. 49.LSTC, (2007). LS-OPT Users Manual: a Design Optimization and Probabilistic Analysis Tool for the Engineering Analyst, Livermore Software Technology Corporation. 50.N. Stander, W. Roux, K. Craig, (2004). LS-OPT Optimization and Robust Design Theory. Livermore Software Technology Corporation, Detroit. 51.N. Stander, W. Roux, T. Goel, T. Eggreston, K. Craig, (2008). LS-OPT Users Manual: A Design Optimization and Probabilistic Analysis Tool for the Engineering Analyst, version 3.3. Livermore Software Technology Corporation; California, US. 52.H. Mullerschon, (2005). Response-Surface Based Variable Screening and Optimization for Crashworthiness Applications with LS-OPT. Nafems Seminarunterlagen: Optimization in Structural Mechanics. Wiesbaden. 53.C.-C. Liang and G.N. Le, (2008). A Developing Method of the Bus Rollover Strength by Investigating and Re-distributing the Ability of Energy Absorption. The 13th National Conference on Vehicle Engineering, Taiwan. 54.A.K. Zaouk, N.E. Bedewi, C.-D. Kan, and D. Marzougui, (1996). Validation of non-linear finite element vehicle model using multiple impact data. International Mechanical Engineering Congress and Exposition, November 17-22, Atlanta, GA. 55.L. Martinez, F. Aparicio, A. Garcia, J. Paez and G. Ferichola, (2003). Improving occupant safety in coach rollover, ” INSIA, Polytechnic University of Madrid, Spain.