International Journal of Design and Manufacturing Technology (IJDMT)
Volume 13, Issue 1, January-December 2022, pp. 19–23, Article ID: IJDMT_13_01_003
Available online at https://iaeme.com/Home/issue/IJDMT?Volume=13&Issue=1
ISSN Print: 0976 – 6995 and ISSN Online: 0976 – 7002
DOI: https://doi.org/10.17605/OSF.IO/KUB

OPTIMIZED DESIGN OF SAFETY STRUCTURAL FRONT OF PASSENGER CARS WHEN A HEAD-ON COLLISION

Vu Hoang Phuong[*1], Nguyen Dinh Viet[2], Tran Hoang Long[3], Nguyen Hoang Vu[4]
[*1-4]Faculty of Technology, Dong Nai Technology University, Dong Nai, Vietnam

ABSTRACT

Passenger car is one of the popular and important vehicle in transportation but the accidents caused by head-to-head collision are always leading to injuries and fatalities to passengers and drivers. Therefore, studying the structural optimization of passenger car's head is urgently needed. This thesis is based upon the standard ECE R94 and ECE R66, applications of computer engineering (CAE) software which HYPERMESH to build finite elements model then simulate and analyze the structural safety of passenger car's head when head- to-head collision happens with LS-DYNA. Base on the structural problems of the passenger car's head, proceeding to give these improvement design to ensure the sustainability of structure and does not violate the safety space. In the selected solution, A5052 Aluminum is used in the structural improvement design of passenger car's head. Then proceed to optimize structure to reduce mass and acceleration impact. Using the method of orthogonal experiment design to design simulation, applying software SPSS regression equation construction for optimal goal. Applying Genetic Algorithm in Mat-lab to calculate to find the optimize value. The results showed that the volume of the variables after the optimization reduced 9.8 % compared with the previous optimization, acceleration reduced 9,9 %, compared to before the optimization that safe space is still not compromised safety standards when head - to head collision occurred

Key words: ECE R94 standard, injury, MADYMO software.

Cite this Article: Vu Hoang Phuong, Nguyen Dinh Viet, Tran Hoang Long and Nguyen Hoang Vu, Optimized Design of Safety Structural front of Passenger Cars When a Head-On Collision, *International Journal of Design and Manufacturing Technology (IJDMT)*, 13(1), 2022, pp. 19-23.
https://iaeme.com/Home/issue/IJDMT?Volume=13&Issue=1

1. INTRODUCTION

Passenger vehicles are the most common and important means in the road network, but accidents caused by frontal collisions always result in major injuries and casualties for drivers and passengers. Therefore, conducting research and optimizing the visitor car head structure to reduce impact volume and acceleration is essential.

This study is based on ECE R94 and ECE R66 standards, applying computer engineering (CAE) in which HYPERMESH software builds a finite element model, then simulates and analyzes the safety of passenger car head structure when head-on collision by LS – DYNA. Based on the existing problem of passenger car front structure [1-15], design improvement options are proposed to ensure the durability of the structure and not infringe on the safe space according to ECE R66 [16]. Among the selected options is the use of A5052 Aluminum material in the design of improving the structure of the passenger car's front bumper.

Then proceed to optimize the structure to reduce the mass and acceleration of the collision. Using the orthogonal experimental design method, conduct simulation design, apply SPSS software to build regression equations for the optimal goal. Applying genetic algorithm GA in Matlab to calculate the optimal value. The results show that the volume of variables after optimization is reduced by 9.8%, acceleration is reduced by 9.9% compared to before optimization, but the safe space is still not violated according to safety standards when a collision occurs direct touch.

2. SIMULATION MODELS

2.1. Design Model

Based on the dimensional parameters from the 2D Autocad drawings provided by the manufacturer Tracomeco, the author proceeds to build 3D drawings using Catia software.

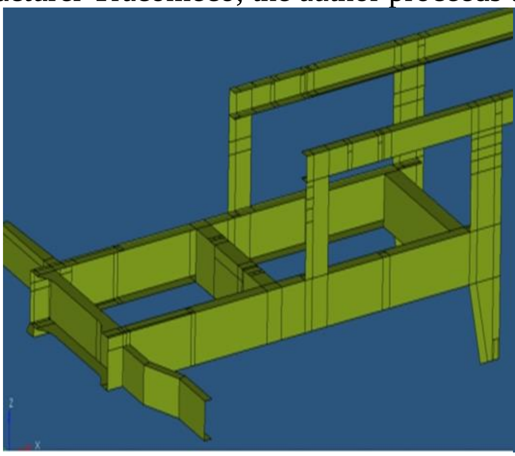

Figure A. Front frame not improved

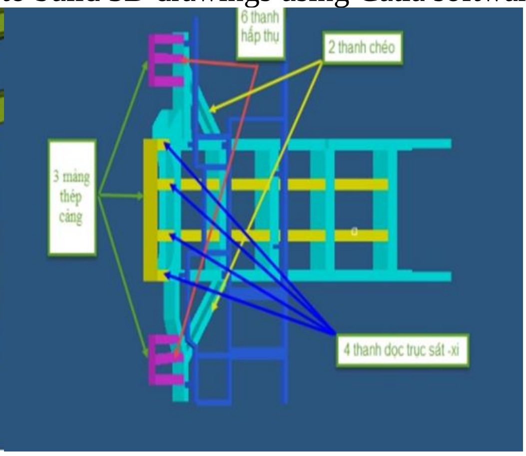

Figure B. The car's front frame after improvement

Figure 1 Front frame

Table 1 Material parameter

Material name	Mass separately	Elastic modulus E	Poisson's	Stress of fluidity
Q235B	7850	206	0.3	235
Q345B	7850	210	0.3	345
A5052	2750	68	0.3	130

2.2. Finite Element Analysis Model

The model meshing is the basis for building a quality assurance model in HyperMesh to provide the necessary calculation and analysis results. First we have to choose a mesh type, in this section choose a mixed mesh (Mixed) with a size of 20 mm on the entire passenger car skeleton.

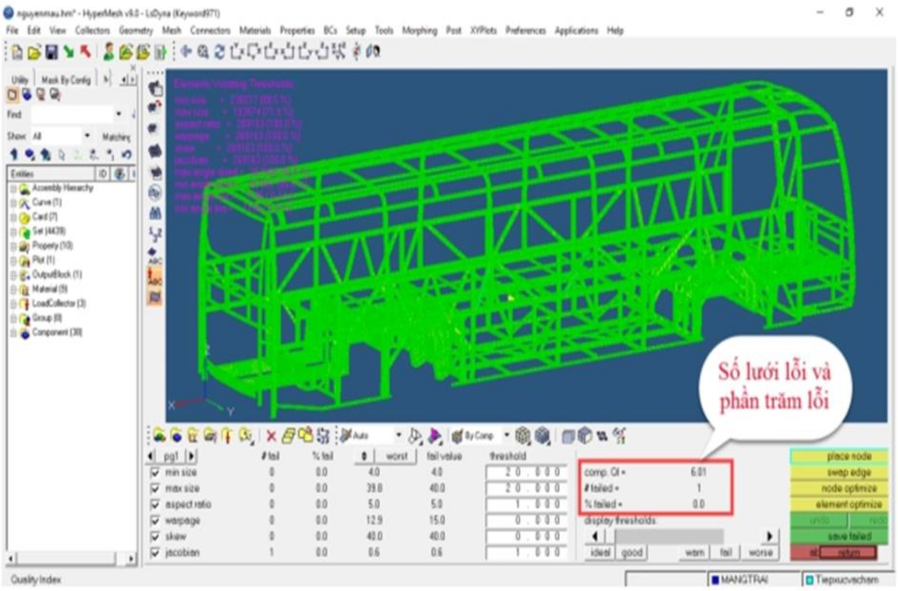

Figure 2. Full model mesh error check

2.3. Human Injury Analysis Model

Head injury index of according to formula 1.

$$HIC = \max\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)\,dt\right]^{2,5} (t_2 - t_1) \qquad (1)$$

t_1, t_2 : time to change the maximum acceleration value

$t_2 - t_1$: maximum range 36m/s

a: acceleration with time at the center of the dummy head.

3. ANALYZE SIMULATION RESULTS

3.1. Results of Structural Strength Analysis of Integrated Seats

Based on the initial simulation results, it is shown that the front bumper of the passenger car is deformed very much, the safe space is violated, and the acceleration at the vehicle's center of gravity is small, which is necessary when considering hurt people. But this distortion violates the ECE R66 safe space (Figure 3).

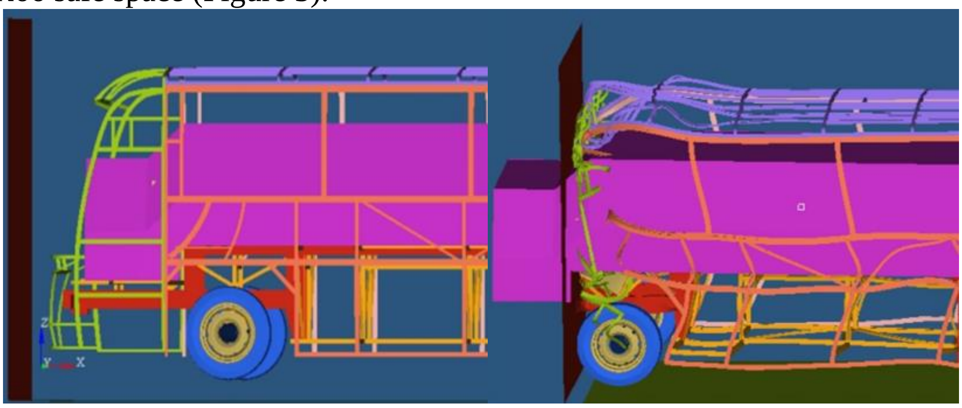

Figure A. Model of skeleton before head-on collision

Figure B. Skeletal model after impact at 180 ms

Figure 3 The skeleton model is not optimized for collision.

From the values of the variables found above, set the thickness property in HyperMesh and run the optimization simulation again to test

Figure A Model of skeleton before head-on collision

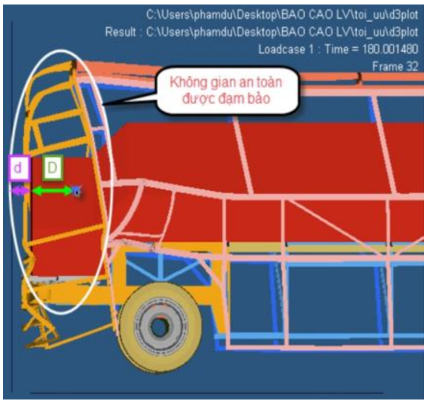

Figure B Optimal simulation results when a head-on collision occurs

Figure 4. Skeletal model after optimization during collision

4. CONCLUSION

Using CAE computer technology, successfully built a finite element analysis model according to the standard of ECE R94 frontal collision combined with safe space in ECE R66. The simulation results of the initial analysis of the vehicle's front skeleton are completely deformed, the safe space is violated. The author improved the steel bars and force-absorbing bars with a custom cross-section, resulting in a safe space, but the mass of the front passenger car increased by 54.55% and the acceleration increased by 44.3%. Using A5052 Aluminum material in the initial improvement and together with changing the folding structure of the first part of the absorbing rods, the new improved results have the following advantages: The weight of the front of the car is reduced compared to the original improvement 15.7% and acceleration reduced by 20.8%. From improvement towards this Aluminum material. Through the optimization problem, conduct simulation experiments by experiments based on the U6*(64) model, give the regression equations simulated by SPSS. Solving the regression equation by genetic algorithm GA in Matlab finds the optimal thickness size of the selected variables. Comparing the total mass of the post-optimal variables with the pre-optimum reduced by 9.812%, the survey acceleration was reduced to 9.9% without the safe space being violated according to ECE R66 standard.

REFERENCES

[1] Liu, C.K., Song, X.P. and Wang, J. (2014), *Simulation Analysis of Car Front Collision Based on LS-DYNA and Hyper Works*. Journal of Transportation Technologies, 4, 337-342.

[2] Jakobsson, L., U. Lechelt, and E. Walkhed. The balance of vehicle and child seat protection for the older children in child restraints. in protection of Children in Cars 10th International Conference. 2012.

[3] Chien-Hsun Wu, Chung-Yung Tung, Jaw-Haw Lee - Automotive research & testing center and Caleo C. Tsai, China Motor Corporation, *Improvement Design of Vehicle's Front Rails for Dynamic Impact*, 5th European Ls-DYNA Users Conference.

[4] Frej, D. and Grabski, P., 2019. The impact of the unbalanced rear wheel on the vibrating comfort of the child seat. Transportation research procedia, pp.678-685. 40.

[5] Boberg, S. and T. Fredrikson, Child Comfort in Rear Seats of Cars: A seating comfort study of how to improve and evaluate older children's perceived comfort when riding on a belt-positioning booster. 2017.

[6] Baranowski, Paweł, Krzysztof Damaziak, J. Malachowski, L. Mazurkiewicz, and Artur Muszyński. "A child seat numerical model validation in the static and dynamic work conditions." Archives of Civil and Mechanical Engineering 15, pp : 361-375. no. 2 (2015)

[7] Liu Jiang, Gui Liangjin, Wang Qingchun & Fan Zijie. Multi-objective Optimization on the Body Structure of Integral Bus. *Automotive Engineering*. 30 (2), 170-173, 2008

[8] Björnstig, Ulf, Johanna Björnstig, and Anders Eriksson. "Passenger car collision fatalities–with special emphasis on collisions with heavy vehicles." Accident Analysis & Prevention 40, pp 158-166no. 1 (2008)

[9] Ma, Sai, Nhan Tran, Vladimir E. Klyavin, Francesco Zambon, Kristin W. Hatcher, and Adnan A. Hyder. "Seat belt and child seat use in Lipetskaya Oblast, Russia: frequencies, attitudes, and perceptions." Traffic injury prevention 13, pp 76-81 no. sup1 (2012)

[10] Savino, Giovanni, Federico Giovannini, Michael Fitzharris, and Marco Pierini. "Inevitable collision states for motorcycle-to-car collision scenarios." IEEE Transactions on Intelligent Transportation Systems 17, pp2563-2573 no. 9 (2016)

[11] Weizhong, N. I. U., L. I. U. Jinxin, and P. A. N. Shengjuan. "Influence of collision location and speed on the car body security in pole side impact of a passenger car." Journal of Automotive Safety and Energy 7, pp 55. no. 01 (2016)

[12] ZHENG, Fu-rong, Yan-xia LIU, Hao LV, B. L. Wang, and W. L. Yan. "Evaluation on safety of passenger car collision and safety design of car body collision [J]." Tianjin Auto 4 (2006)

[13] Schneider, L., Frings, K., Rothe, S., Schrauf, M., & Jaitner, T. (2021). Effects of a seat-integrated mobilization system during passive driver fatigue. Accident Analysis & Prevention, 150, 105883.

[14] Grotz, B., Straßburger, P., Huf, A., & Roig, L. (2021). Predictive Safety-Perception-based Activation of Pre-crash Systems. ATZ worldwide, 123(1), 18-25.

[15] Windharto, A., Iskandriawan, B., & Mustafa, N. S. Y. (2021, February). Sleeper seat design for inter-island hi speed vessel with integrated digital design method. In IOP Conference Series: Earth and Environmental Science (Vol. 649, No. 1, p. 012053). IOP Publishing

[16] EURONCAP. Internet : https://en.wikipedia.org/wiki/Euro_NCAP