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B.S. MIN*, J.U. CHO*#

IMPACT CHARACTERISTIC ACCORDING TO THE STRUCTURE OF CRASH BOX AT THE VEHICLE

The crash box between a bumper and a car body in automobiles can reduce impacts for car bodies with a bumper at a low-speed collision by preventing the shocks. Also, this crash box is the part playing a very important role for the safety of vehicle and the reduction of repair cost, and many studies have been investigated for the performance. In this study, aluminum foam was inserted in an aluminum crash box to analyze the relationships of deformation, stress and internal energy. The compression characteristics are compared with six cases. In addition, the load due to displacement at experiment for a case is verified by modeling with finite elements and performing the structural analysis. As these study results for investigating characteristics of the crash box, it is thought that the effective designs of crash box to enhance the durability for collision are made possible.

Keywords: Aluminum foam, Crash box, Impact characteristic, Deformation, Stress, Internal energy, Durability

1. Introduction

Recently, as vehicle accidents have been increased, the stabilities upon driving and high fuel efficiency are demanded by drivers. Particularly, the fuel efficiency can be improved through weight reduction of the car body, for which new materials such as CFRP, aluminum alloys and magnesium alloys are frequently applied [1-5]. Since such a weight reduction of the car body should be realized with the stability being secured against collision, the car body design should be realized by investigating impact characteristics due to the impact of car body occurring at collision [6-9]. In general, the weight of car body with aluminum can be decreased by about approximately 30% compared with steel materials for the same rigidity, while the car body with magnesium is capable of having an effect of weight reduction by 60%. Governments around the world are contributing to secure the safety of passenger by enacting the automotive safety standards for the safety upon collision of automobiles and presenting a mode with the improvement of safety against collision through collision tests. However, if collision tests are conducted to test the safety of car bodies whenever the new product is launched, many automobiles are actually used up, resulting in wasted time and cost. Thus, time and cost can be saved by carrying out virtual collision tests through a computer simulation. Also, collision environments can be configured in a diversified manner by subjecting the automotive component to a simulation, and presenting the improvement guides for stability and durability through optimum designs. In this study, the mechanical characteristics were compared through compression tests for the crash box by playing a role of reducing the shocks upon a low-speed collision [10-12]. As shown in Fig. 1a, the crash box of an automobile is designed to improve damageability and repair-ability of the car body, which allows the absorption of impact forces through bending deformation in the relevant part at a low-speed collision, providing a suitable space in the front/rear bumper fastening parts. Also, the displacement, stress and internal energy due to the case of model were studied by modeling Fig. 1b and performing structural analysis. In addition, by investigating characteristics of the crash box, the effective designs to improve durability against a collision can be proposed.

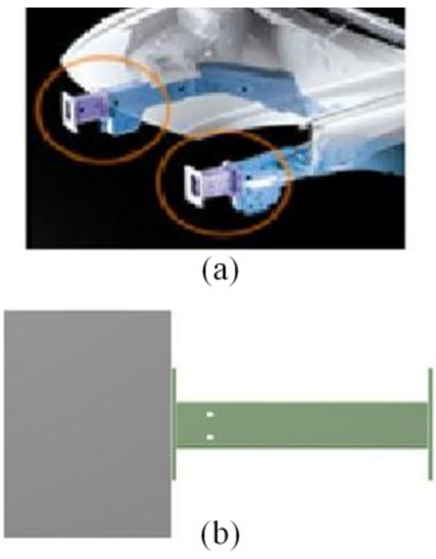

Fig. 1. Photo and model of crash box

* DIVISION OF MECHANICAL & AUTOMOTIVE ENGINEERING, COLLEGE OF ENGINEERING, KONGJU NATIONAL UNIVERSITY, 1223-24 CHEONAN DAERO, SEOBUK-GU, CHEONAN-SI, CHUNGNAM 31080, REPUBLIC OF KOREA

Corresponding author: jucho@kongju.ac.kr

2. Study model and method

Fig. 2 shows the configurations of crash boxes [13]. At Fig. 2, cases 1 and 2 shows with no aluminum foam inside the different assembly shape. Cases 3 and 5 as the same configuration as case 1 at Fig. 2c,e are inserted with the shape foams of 30 mm and 50 mm respectively. Cases 4 and 6 as the same configuration as case 2 at Fig. 2c,e are inserted with the shape foams of 30 mm and 50 mm respectively. The comparisons of compression characteristics are compared with each other for the total of 6 types of cases. The configuration of crash box has the dimensions of 40 mm in width, 55 mm in length and 1.5 mm in thickness. Two '⊏' – shaped plates were joined by welding as shown in Fig. 3. For the investigation of compression characteristics, the material for a crash box was selected to be an aluminum sheet of A5052 with the high fatigue strength, while the aluminum foam was selected to be a material employed for building materials and noise protection facilities due to excellent heat dissipation and sound-proofing properties. Table 1 shows the properties of the materials used at experiment. For the verification of analysis results on the compression characteristics of crash box, the compression test for case 3 with insertion of the 30 mm aluminum foam was conducted by using a universal tester of SHIMADZU AG-X equipment, where the compression test is carried with the rate 2 mm/min.

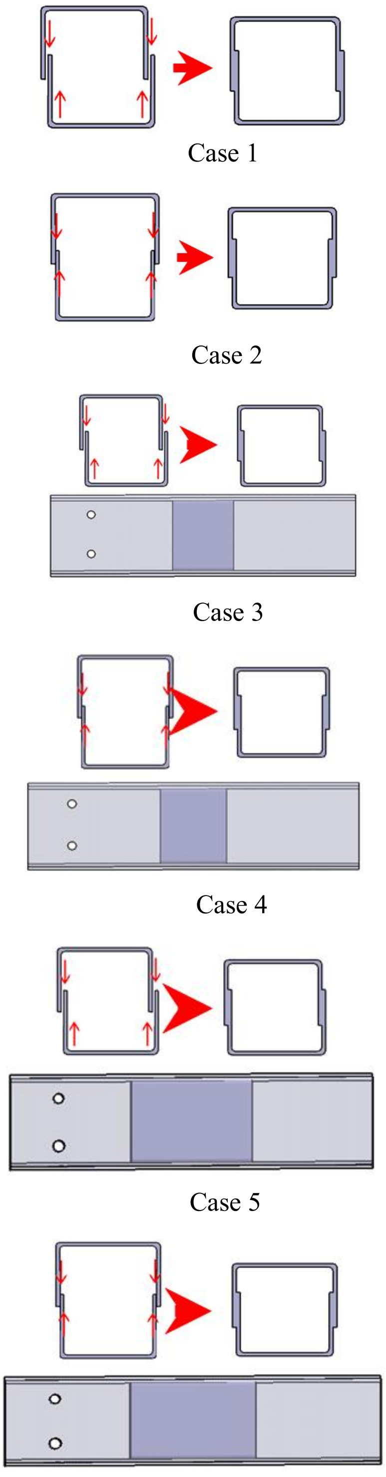

Fig. 2. Configurations of crash boxes

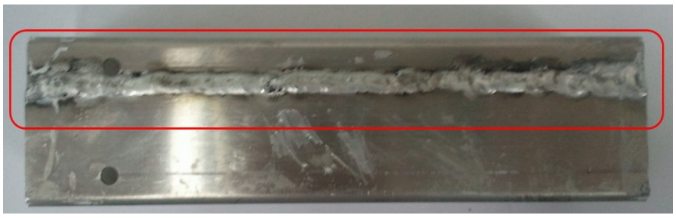

Fig. 3. Joined part of crash box

TABLE 1

Mechanical properties of materials

	Aluminum Sheet A5052	**Aluminum Foam**	**Structural Steel**
Young's Modulus (MPa)	71.7×10^3	460	200×10^3
Poisson's Ratio	0.33	0.11	0.3
Mass Density (Kg/mm^3)	2.68×10^{-6}	3×10^{-7}	7.85×10^{-6}
Tensile Yield Strength (MPa)	325	1.65	250
Tensile Ultimate Strength (MPa)	330	2.3	460

Fig. 4 shows the finite element model and constraint condition of structural analysis. The structural analysis model at ANSYS program is composed of shock box and crash box as shown in Fig. 4, and each model was divided into elements and nodes for the finite element model. The meshing size for the crash box and the aluminum foam parts as important parts of analysis was designated as 5 mm. And the meshing size for the shock box was 10 mm [14]. The shock box was applied by the forced displacement of 65 mm on the downward direction set for 65 seconds at 1 mm/s, while the stationary part had a fixed support. In terms of material properties of the study model for analysis, the same material properties as those of Table 1 used in the experiments were applied. Also, the bottom face of the shock box along with the top face of the crash box were given a frictional type of condition, while all the faces of the aluminum foam attached along with the inner face of the crash box were given with a frictional condition for the aluminum foam and the crash box. The frictional coefficient for all conditions was set to be 0.

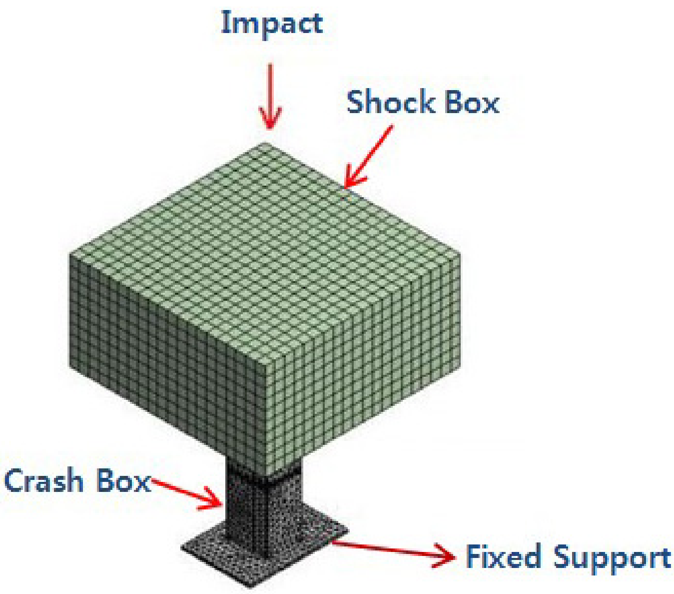

Fig. 4. Finite element model and constraint condition of structural analysis

3. Study result

Fig. 5 shows the load-displacement result of compression test for cases 3 with aluminum foam, where the maximum load was shown to be around 35000N [13]. By comparing with experimental and analysis result, the analysis data can be verified since the analysis result can be seen to approach the experimental result. Thus, such analysis data in this study are considered efficiently applicable to actual fields.

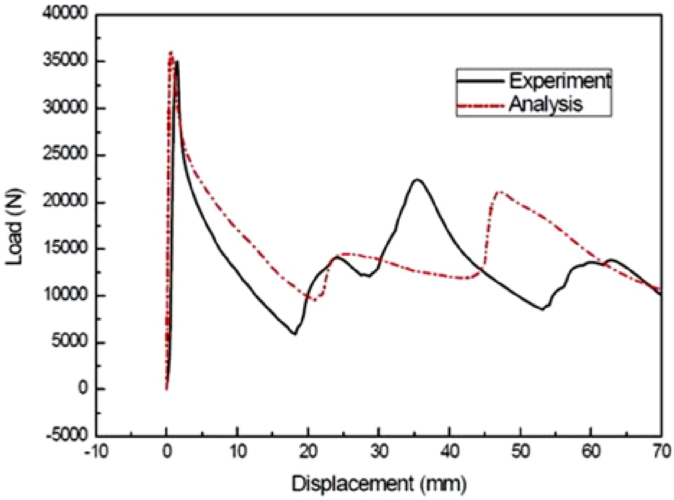

Fig. 5. Comparison of load-displacement graph among compression experiment in case 3 with aluminum foam

As analysis result, Fig. 6 shows the graph of deformations due to the elapsed times at all cases of 1-6. In Fig. 6, the deformation increases gradually according to elapsed time altogether at cases 1,2. At cases 3-6, the deformation increases gradually according to elapsed time altogether more than at cases 1,2. In cases of 3-6 with aluminum foam inside crack box, the impact energy transferred from crash box is absorbed into aluminum foam after the deformation of 20 mm proceeds.

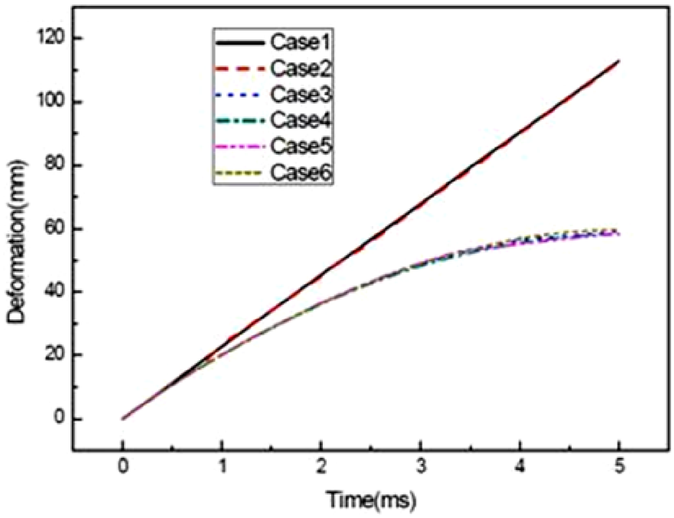

Fig. 6. Deformations due to the elapsed times at all cases of 1-6

As analysis result, Fig. 7 shows the graph of stresses due to the elapsed times at all cases of 1-6. In all cases, the stress converges on 800 MPa according to the elapsed time.

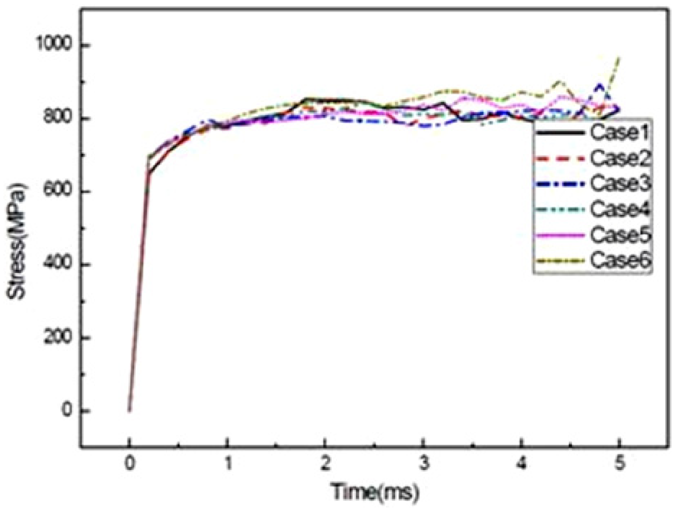

Fig. 7. Stresses due to the elapsed times at all cases of 1-6

As analysis result, Fig. 8 shows the graph of minimum internal energies due to the elapsed times at all cases of 1-6. At cases 1 and 2 with no aluminum foam, these trends are same. At cases 3 and 5 with aluminum foam of 30 mm and 50 mm at the box structure of case 1, these trends are similar. At cases 4,6 with aluminum foam of 30 mm and 50 mm at the box structure of case 2, it is shown that these trends are similar until the elapsed time of 35 ms. In case of case 4, this energy becomes higher than case 6 after the elapsed time of 35 ms. The volume of aluminum foam at case 4 is smaller than cases 3,5. And the length of aluminum foam is shorter than that of case 6. The aluminum foam is more pushed on the lower side at case 4 than cases 3,5,6. It is shown that the internal energy at case 4 becomes higher than cases 3,5,6 as lower impact absorption energy transfers into aluminum foam.

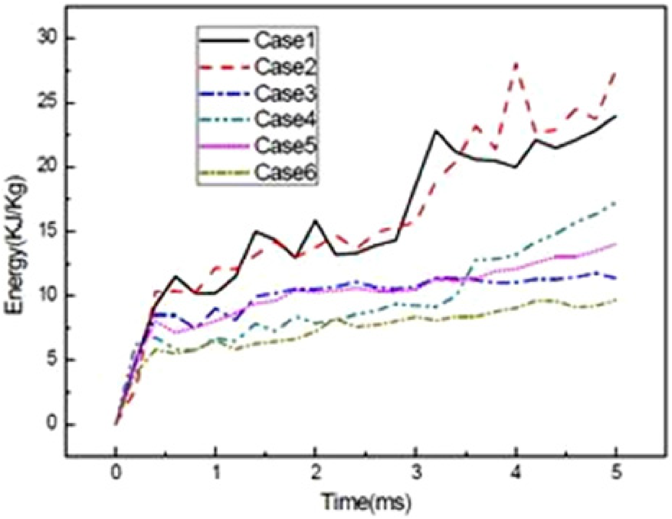

Fig. 8. Minimum internal energies due to the elapsed times at all cases of 1-6

4. Conclusion

In this study, aluminum foam was applied as the crash box capable of improving durability of a car body by reducing shocks at the low-speed collisions of automobiles. The conclusions on compression characteristics derived from the results of this study are as follows:

At cases 3-6, the deformation increases gradually according to elapsed time altogether more than at cases 1,2. The shorter and smaller aluminum foam is more pushed on the lower side at case 4 than cases 3,5,6. It is shown that the internal energy at case 4 becomes higher than cases 3,5,6 as lower impact absorption energy transfers into aluminum foam. The analysis data can be verified since the analysis result can be seen to approach the experimental result. Thus, such analysis data in this study are considered efficiently applicable to actual fields. Based on this study investigating the characteristics of the crash box through the compression analysis, the effective designs to enhance durability of car bodies with the reduction of shocks may be proposed.

Acknowledgments

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