Indian Journal of Science and Technology, *Vol 9(43), DOI: 10.17485/ijst/2016/v9i43/105124, November 2016* *ISSN (Print) : 0974-6846*
ISSN (Online) : 0974-5645

A Durability Study on the Bumper of Mini Vehicle by Shape through Simulation Analysis

Jung-Ho Lee[1] and Jae-Ung Cho[2*]

[1]Division of Mechanical Engineering, Graduate School, Kongju National University, 1223-24, CheonanDaero, Seobuk-gu, Cheonan-si - 31080, Chungnam, Republic of Korea; jungholee8@kongju.ac.kr

[2]Department of Mechanical and Automotive Engineering, Kongju National University, 1223-24, Cheonan Daero, Seobuk-gu, Cheonan-si - 31080, Chungnam, Republic of Korea; jucho@kongju.ac.kr

Abstract

Objectives: Studies on aluminum alloy bumpers applied to vehicles are being actively carried out. This study aims at investigating the durability according to the compact car bumpers per shape. **Methods/Statistical Analysis:** In this study, two types of compact car bumper models were designed as 3D modeling and then simulation structural analyses were performed by the finite element analysis program of ANSYS. The durability of the bumper model of light passenger car by each configuration is investigated through this study. The analyses of structure and vibration on the bumper model of light passenger car by configuration are carried out. **Findings:** Although all comparison variables were shown to be smaller when the bumper model 1 was compared with the bumper model 2, the stress distribution was observed to be wider so that the reinforcement of material or the change of design for improvement is considered necessary. Through this study result, the deformation, equivalent stress due to natural frequency are investigated by each bumper model of light passenger car. According to the study results, the bumper model 1 exhibited a better durability compared with model 2, and hence is considered to be a safe and more suitable model for the vehicle application. The results are considered to be able to contribute to the development of more advanced bumpers having durability. **Improvements/Applications:** It is considered that the data obtained through this study can be utilized for the design of the bumper having an improved durability compared with the existing bumpers.

Keywords: Bumper of Compact Car, Durability, Equivalent Stress, Shape, Total Deformation, Vibration

1. Introduction

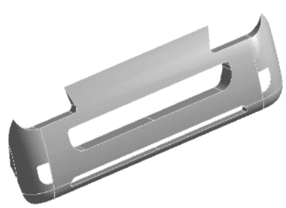
Technology development for today's car industry is being realized with a focus placed on weight reduction for vehicle bodies and collision safety aspects, and the materials such as aluminum, plastic, composite materials, etc. are being used in diversified ways. Among those materials, aluminum alloy has the excellent specific strength, corrosion resistance, thermal conductivities besides light weight characteristics. and this material has a higher rigidity than the existing iron materials as an outstanding composite alloy material in heat resistance and impact, despite having a lighter weight than the existing iron materials.[1–3] While the advanced car businesses in Europe, North America, Japan, etc. are developing and mass-producing aluminum alloy bumpers in lieu of the steel plates used in the past to secure more advanced durability and a lighter weight, their utilization has been lagging domestically with their research with the insufficient development so that development and commercialization of

**Author for correspondence*

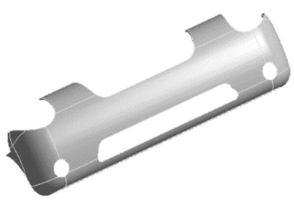
light-weight high-strength aluminum alloy bumpers is urgently needed. For such reasons, the studies on the application of aluminum alloy bumpers to vehicles are being actively carried out in recent times. And the durability according to structure for compact car bumpers per shape and was conducted in this study. If the results derived on this basis are combined and applied to the design of bumpers, they are considered to be able to contribute to the development of more advanced bumpers having durability.[4–6]

2. Research Models

In this study, a total of two types of compact car bumper models were used for 3D modeling by using CATIA design program as shown in the following Figure 1 with reference to the compact car bumpers being sold in the market. Also, the material for the two compact car bumper models was an aluminum alloy, whose material properties are given in Table 1.



(a) Model 1



(b) Model 2

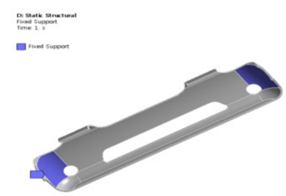
Figure 1. Configuration of compact car bumper models.

Table 1. Property of material

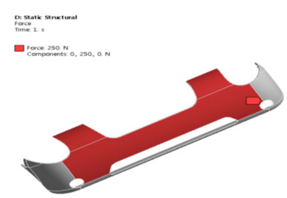
Material	Aluminum alloy
Density(kg/m^3)	2770
Young's Modulus(GPa)	71
Poisson's ratio	0.33
Yield strength (MPa)	280
Ultimate strength (MPa)	310

3. Research Method

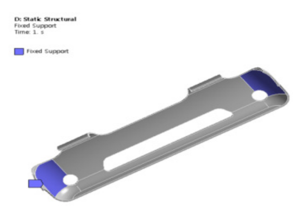
The following Figure 2 show the boundary conditions applied to the compact car bumper models per shape. The same boundary conditions were applied to both of the two types of bumper models. First, the fixed support condition was imposed for fixing by assuming that the tip parts on both sides of model 1 and model 2 were fixed to the frame of car body, and the force condition was imposed by assuming that the load was applied to the front part of the bumper for a simulation analysis by applying the force of 250N. Through this analysis, durability of the bumper models was to be studied in terms of total deformation and equivalent stress distribution, natural frequency, etc. for the bumper models according to shape.



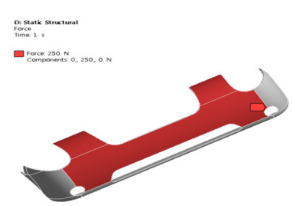
(a) Model 2



(b) Model 2



(a) Model 2



(b) Model 2

Figure 2. Boundary conditions of models.

4. Simulation Analysis Results

The Figures 3 and 4 schematically shown represent the results of simulation structure analysis for each of the bumper models of model 1 and model 2, showing total deformation of each bumper model. According to the results of performing the simulation analysis, the maximum total deformation for the bumper model 1 was shown to be about 0.583mm, and about 2.6255mm for the bumper model 2. When the models were compared with each other, the maximum total deformation of the bumper model 2 was shown to be larger than that of the bumper model 1, and the maximum total deformation was seen to occur in the part of front face unit for both of the two types of bumper models.

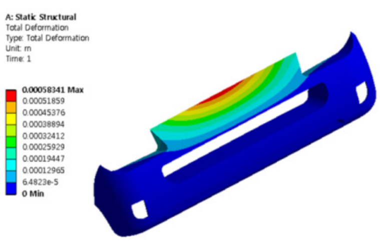


Figure 3. Total deformation of bumper model 1.

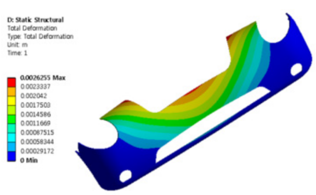


Figure 4. Total deformation of bumper model 2.

In the case of the following Figures 5 and 6, the equivalent stress distributions are shown for the bumper models resulting from the simulation structure analysis for each bumper model. According to the analysis results, the maximum equivalent stress for the bumper model 1 was shown to be about 169.68MPa, while that for the bumper model 2 was shown to be about 961.2MPa. When a comparison was made on the basis of the corresponding results, the bumper model 1 showed a smaller maximum equivalent stress that that of model 2. However, since the stress distribution was shown to be wider than that for the bumper model 2 so that a large-scale reinforcement or design change is considered necessary. In the case of the bumper model 2, the phenomenon of stress concentration is considered to occur as the maximum stress was shown to be very large although the stress distribution was shown to be narrow and intermittent.

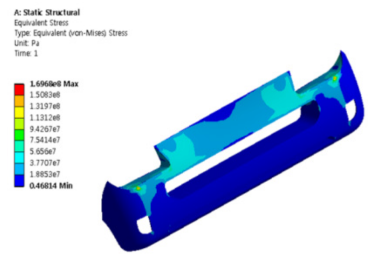


Figure 5. Equivalent stress of bumper model 1.

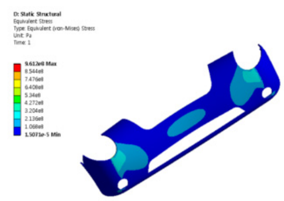


Figure 6. Equivalent stress of bumper model 2.

Figures 7 and 8 represent the results of simulation vibration analysis for each model, showing the appearances in the modes where the maximum total deformation occurred in the bumper models of model 1 and model 2. In the case of the bumper model 1, the maximum mode was observed in the 3'rd mode, for which the maximum total deformation was shown to be about 927.14mm, and the natural frequency 1706.3Hz. In the case of bumper model 2, the maximum total deformation occurred in the 6'th mode, where the maximum total deformation was shown to be about 1188mm, and the natural frequency of 2247.6Hz. Also, the following Tables 2 and 3 show natural frequencies and total deformations in each mode for each bumper model. Also, the following Figures 9 and 10 show the amplitude displacement responses for the natural frequency in each bumper model, and the resonance frequencies were affirmed according to the corresponding frequency regions since the natural frequencies for both models were within the range of 600 to 2400Hz. In the case of the bumper model 1, the critical frequency of

2346Hz was observed , while that of 672Hz was observed in the case of the bumper model 2, with the amplitude displacements at the critical frequency shown to be about 0.00530mm and about 0.14912mm, respectively. Figures 11 and 12 show the maximum total deformation and the maximum equivalent stress at the critical frequency for each bumper model. In the case of the bumper model 1, the maximum total deformation at the critical frequency of 2346Hz was shown to be about 24.012mm, and the maximum equivalent stress about 32140MPa, while the maximum total deformation at the critical frequency of 672Hz was shown to be about 191.22mm,and the maximum equivalent stress 61234MPa in the case of the bumper model 2. As the critical frequency was increased, the durability was improved, according to which the bumper model 1 could be affirmed to have a better durability than the bumper model 2.

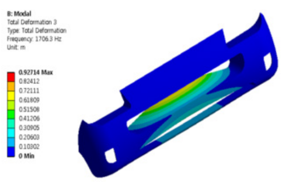


Figure 7. Natural frequency and maximum total deformation in the 3'rd mode of bumper model 1.

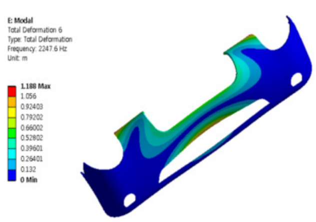


Figure 8. Natural frequency and maximum total deformation in the 6'th mode of bumper model 2.

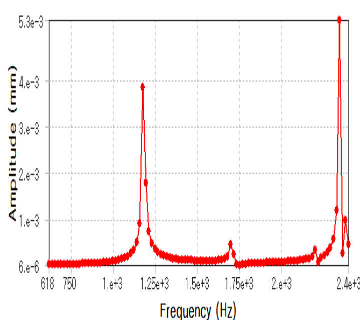


Figure 9. Frequency responses of amplitude total deformations of bumper model 1.

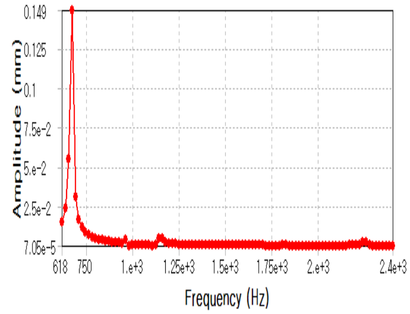


Figure 10. Frequency responses of amplitude total deformations of bumper model 2.

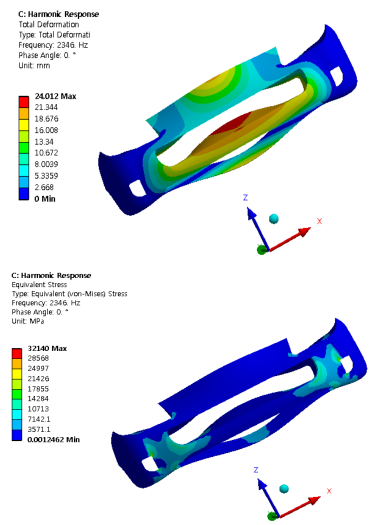


Figure 11. Total deformation and equivalent stress at critical frequency of bumper model.

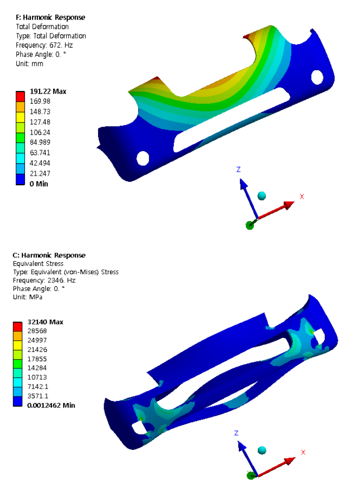


Figure 12. Total deformation and equivalent stress at critical frequency of bumper model.

Table 2. Maximum total deformation and natural frequency per mode for model 1

	Natural frequency(Hz)	Total deformation(mm)
1'st Mode	916.84	804.36
2'ndMode	1181.6	898.84
3'rd Mode	1706.3	927.14
4'th Mode	2207.8	671.79
5'th Mode	2343	378.96
6'th Mode	2373.5	708.43

Table 3. Maximum total deformation and natural frequency per mode for model

	Natural frequency(Hz)	Total deformation(mm)
1'st Mode	667.18	740.84
2'nd Mode	953.88	1034.9
3'rd Mode	969.97	1039.2
4'th Mode	1146.8	751.64
5'th Mode	1838.2	950.76
6'th Mode	2247.6	1188

5. Conclusions

In this study, the analyses of structure and vibration were performed for compact car bumper models per shape and the following conclusions were drawn.

1. In the case of the bumper model 2, all comparison variables including the maximum total deformation, the maximum equivalent stress, the maximum total deformation and the critical frequency per mode, the maximum total deformation and the maximum equivalent stress at the critical frequency were shown to be larger than those for the bumper model 1.
2. Although all comparison variables were shown to be smaller when the bumper model 1 was compared with the bumper model 2, the stress distribution was observed to be wider so that the reinforcement of material or the change of design for improvement is considered necessary.
3. The maximum total deformation for the bumper model 1 was shown to be about 0.583mm, the maximum equivalent stress about 169.68MPa, and the maximum total deformation of about 927.14mm in the 3'rd mode, i.e., 1706.3Hz of natural frequency. Also, the critical frequency was shown to be 2346Hz, for which the maximum total deformation was shown to be about 24.012mm, the maximum equivalent stress about 32140MPa. In the case of the bumper model 2, the maximum total information was shown to be about 2.6255mm, and the maximum equivalent stress about 961.2MPa, while the maximum total deformation of about 1188mm was observed in the 6'th mode, or 2247.6Hz of natural frequency, and the critical frequency 672Hz, for which the maximum total deformation was shown to be about 191.22mm, and the maximum equivalent stress about 61234MPa.
4. According to the study results, the bumper model 1 exhibited a better durability compared with model 2, and hence is considered to be a safe and more suitable model for the vehicle application.
5. It is considered that the data derived through this study can be utilized for the design and development of the bumper having an improved durability compared with the existing bumpers.

6. References

1. Shathesh S, Durairaj M. An intelligent hybrid mechanism to predict the risk of cardio vascular disease. Indian Journal of Science and Technology. 2016; 9(4):1–8.
2. Kang S, Lee J. Evaluation of fatigue life and structural analysis for dish-type and spoke-type automobile wheels. Transaction on Korean Society Mechanical Engineering A. 2011; 35(10):1315–21.
3. Song K, Lee H, Hong S, Park H. Macroscopic high-temperature structural analysis model of small-scale PCHE Prototype (II). Transaction on Korean Society Mechanical Engineering A. 2011; 35(9):1137–43.
4. Lee D, Kim H, Kim B, Lee S. Underwater structure-borne noise analysis using finite element/boundary element coupled approach. Transaction on Korean Society Mechanical Engineering A. 2012; 36(7):789–96.
5. Lee J, Lee Y, Lee H, Jun J, Kim J, Kim C. Structural analysis on the heavy duty diesel engine and optimization for bearing cap. Transaction on Korean Society Mechanical Engineering A. 2008; 32(5):402–10.
6. Aminuddin W, Ismail W, Harunarashid H. Estimating emergency department maximum capacity using simulation and data envelopment analysis. Indian Journal of Science and Technology. 2016; 9(28):1–10.