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A Study of Strength Property and Durability on Automotive Front Bumper Guard by Configuration

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형상 별 자동차 프런트 범퍼 가드에 대한 강도 특성 및 내구성 연구

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ABSTRACT

The automotive front bumper guard is the most important part of the vehicle for protecting the life of driver when a traffic accident happens. In order to ensure safe driving, this part must possess sufficient strength and durability. This study was carried out with structural and fatigue analyses by designing front bumper guard models. After the lowest value for maximum total deformation and equivalent stress was found through structural analysis and the highest value for fatigue life was found for all three models, it was shown that the type C front bumper guard model was the most suitable for application to a real car. The strength property and durability of the optimum design were determined through this study's results.

Key Words : Automotive Front Bumper Guard(자동차 프런트 범퍼 가드), Configuration(형상), Strength(강도), Total Deformation(전변형량), Equivalent Stress(등가응력), Fatigue Life(피로수명)

1. 서 론

A bumper, which affects the vehicle's safety significantly, generally consists of a bumper cover, shock absorber, bumper rail, and car body connecting part. A vehicle part of the front bumper guard can be mounted in front of the bumper depending on the consumer's preference, which aims to prevent physical damage during vehicle collision and give esthetic effects to the vehicle. However, the level of human casualties and vehicle damage is determined by how much the front bumper guard can absorb the collision impact during a head-on collision. Steel plate, plastic, and aluminum have been used for the materials of front bumper guards. Although aluminum is suitable for lightweight materials due to the increasing importance of fuel efficiency in recent years, it needs high-quality processing technology, which will increase the cost. Thus, the consideration of cost reduction and safety should be based on the optimal

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configuration design, and the front bumper guard is regarded as an important part because it is directly related to the driver's life during accident occurrence beyond the simple exterior tuning effect. In addition, much attention has been paid to vehicle safety by drivers themselves as the causes of accidents have diversified, such as sudden unintended acceleration due to vehicle defects, vehicle accidents due to the proliferation of smartphones, drink driving, and drowsy driving. Since people always want safer driving, the demand for vehicle parts, such as front bumper guards, has increased gradually. Thus, sufficient stiffness and durability must be provided. This study designed front bumper guard models by shape in light of this point to conduct simulation structure analysis and fatigue analysis, by which the strength characteristics and durability of the front bumper guard model were identified to contribute to the optimal design and development[1–4].

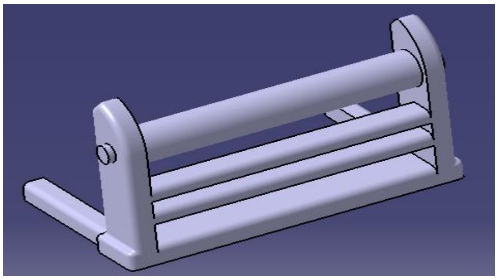
2. Study methodology

2.1 Study model

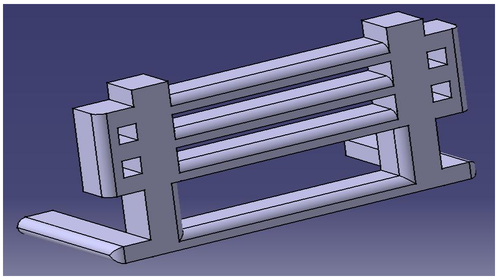
This study designed three types of models: A, B, and C types by shape, as shown in Fig. 1, with reference to the front bumper guards that were selling in the market using the CATIA V5 R11 3D design program.

2.2 Analysis conditions

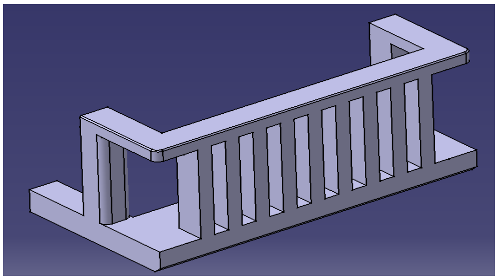
Fig. 2 shows the boundary conditions applied to each of the front bumper guard models to conduct simulation analyses. Since the same boundary conditions were applied to the three front bumper guard models, this paper took the A-type front bumper guard model as a represented example. First, a fixed support condition was given to the part where the front bumper guard was fixed, and then a 500-N



(a) A type model



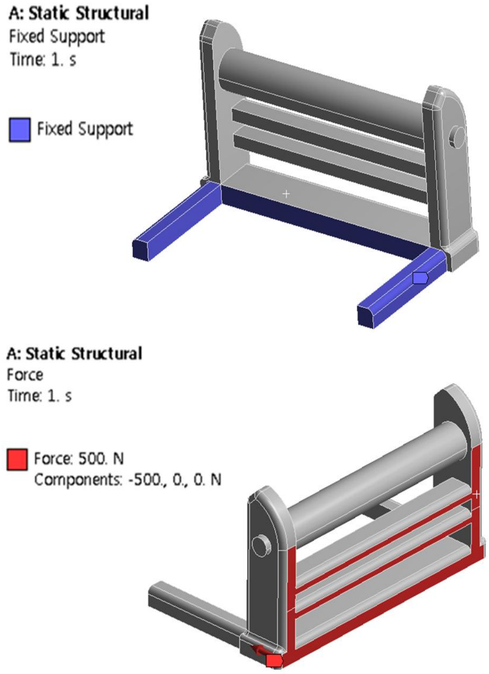
(b) B type model



(c) C type model

Fig. 1 Front bumper guard models

force condition was applied assuming that the impact or load was applied to the front part of the front bumper guard model. The simulation analysis was also conducted by applying the same boundary conditions to the other two models, the B-type and C-type front bumper guard models, and strain, equivalent stress, and durability in the fatigue situation in each of the front bumper guard models according to a shape were studied. In addition, Table 1 presents the physical properties applied to each of the front bumper models, in which structural steel was applied as the material for the models[5–10].



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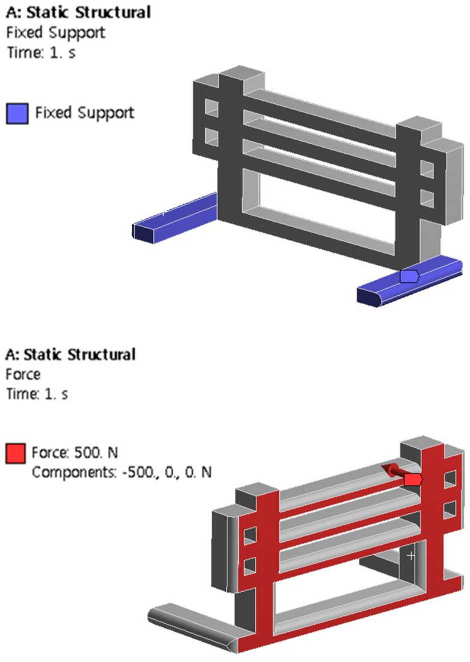
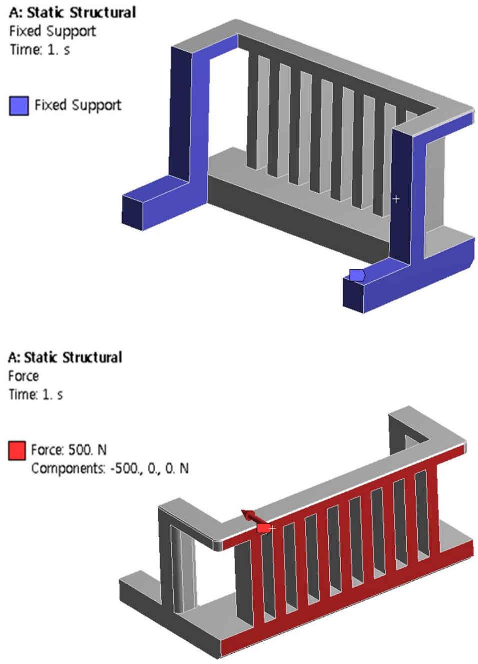


(b) B type model



(c) C type model

Fig. 2 Analysis conditions of front bumper guard models

Table 1 Material properties

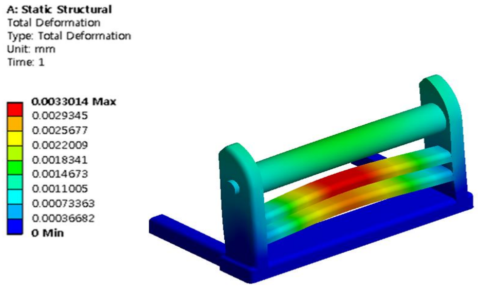
Young's modulus(GPa)	200
Poisson's ratio	0.3
Density(kg/m)	7850
Yield strength(MPa)	474.8
Ultimate strength(MPa)	626.3

3. Study results

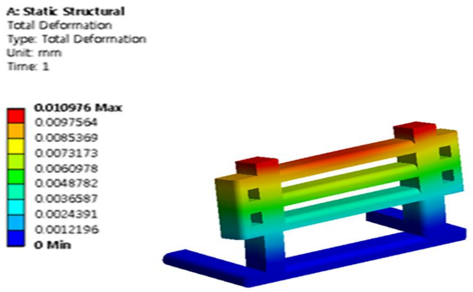
3.1 Strain of the front bumper guard models

Fig. 3 shows the simulation results of the structural analysis of the A, B, and C-type front bumper guard models, which shows the strain of each of the front bumper guard models. The analysis execution results showed that the maximum strains of the A-, B-, and C-type front bumper guard models were approximately 0.0033014 mm, 0.010976 mm, and 0.0018713 mm, respectively.

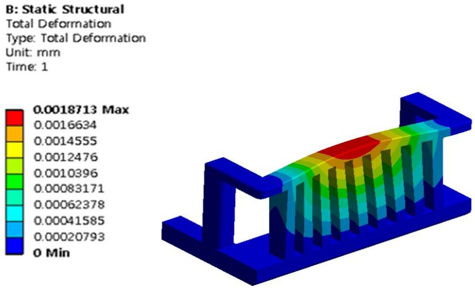
The comparison results of the models showed that the maximum strain of the C-type front bumper guard model was the smallest, and all of the three front bumper guard models had the largest strain around the center of the front part.



(a) A type model



(b) B type model



(c) C type model

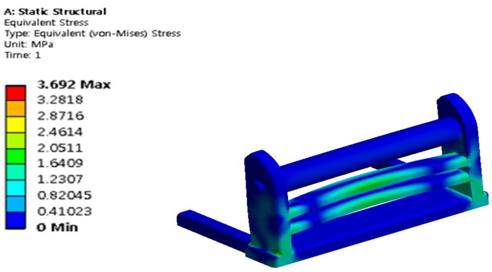
Fig. 3 Total deformations of front bumper guard models

3.2 Equivalent stress of the front bumper guard models

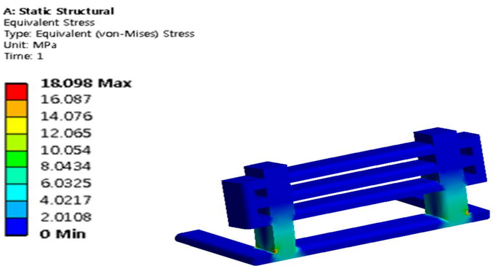
Fig. 4 shows the simulation results of the structural analysis of each of the front bumper guard models, in which the equivalent stress of the front bumper guard models is represented. The analysis results showed that the maximum equivalent stresses that occurred at the A- and B-type front bumper guard models were approximately 3.692 MPa and 18.098 MPa, respectively. The maximum equivalent stress of the C-type front bumper guard model was approximately 3.8522MPa. The inter-comparison results based on the above results indicated that the C-type front bumper guard model had the smallest equivalent stress, and the location of occurrence of the maximum equivalent stress in all of the front bumper guard models showed a similar trend except for in the B-type, the same as shown in the results for maximum strain. The distribution range of equivalent stress was narrow in the B-type front guard model, but the maximum stress result was larger than that of the other models, indicating that a significant stress concentration occurred. Thus, a measure to resolve this issue is required. In addition, when comparing each of the models with regard to the safety factor, all of the three front bumper models were within the safe state at the 500-N loading condition.

3.3 Fatigue life of the front bumper guard models

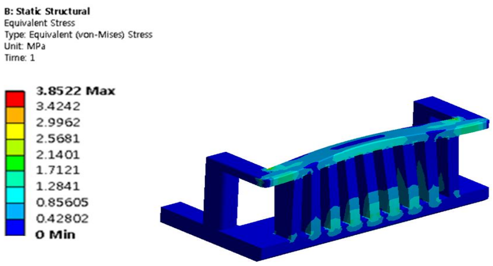
A front bumper guard is mounted in front of the bumper so it has to have sufficient stiffness against the impact and repeated load that is applied during driving. Thus, this study also conducted fatigue analysis. Fig. 5 shows the simulation results of the fatigue analysis of each of the front bumper guard models, in which the fatigue life of the front bumper guard models is depicted. The analysis results showed that the maximum fatigue life results of the A-, B-, and C-type front bumper guard models were approximately 1,171,000, 336,930, and 20,000,000 cycles, respectively. The results were compared with one another, and the B-type bumper guard model, which showed the largest maximum equivalent stress, also had the shortest fatigue life, and a fatigue-induced fracture was likely to occur at the place where the stress was concentrated. In contrast, the C-type bumper guard model had the longest fatigue life, and since the strain and maximum equivalent stress were the smallest, the C-type was recognized as the most suitable model for application to real vehicles.



(a) A type model

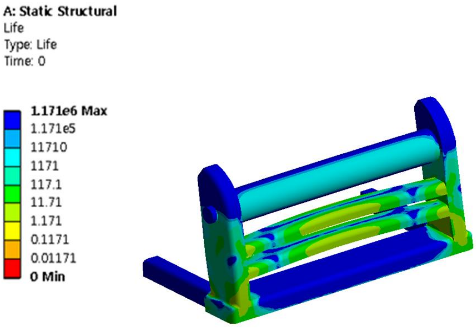


(b) B type model

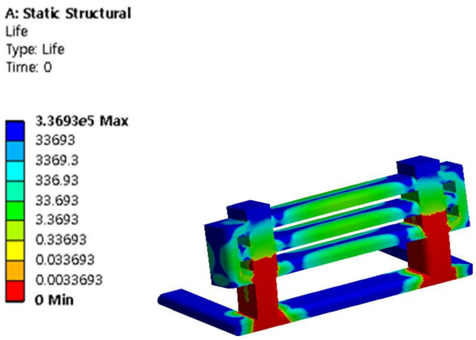


(c) C type model

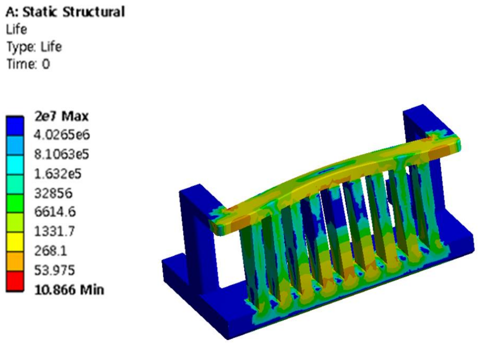
Fig. 4 Equivalent stresses of front bumper guard models



(a) A type model



(b) B type model



(c) C type model

Fig. 5 Fatigue lives of front bumper guard models

4. Conclusion

This study conducted simulations of structural and fatigue analysis on the front bumper guard models by shape, and the following conclusions could be derived.

1. The failure characteristics of each of the front bumper guard models could be identified by performing simulations of structural and fatigue analysis on each of the models by shape.
2. The B-type front guard model had the worst results in all items (strain, maximum equivalent stress, and fatigue life) compared to those of the other front bumper guard models, the A- and C-type. Thus, a study on the improvement of the worst performance should be conducted in the future.
3. The C-type front bumper guard model had the best results in all items (maximum strain, maximum stress, and fatigue life) compared to those of the other front bumper guard models, showing the most suitable model for application to real vehicles.
4. All of the three front bumper guard models showed a trend of vulnerability in the center portion of the front side. To overcome this, additional studies should be conducted from various viewpoints, such as renovation through changes in design shape. Furthermore, the data derived through this study are expected to be utilized in the design and development of a more advanced front bumper guard in the future.

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