PROPOSAL OF CFRTP AUTOMOBILE BONNET FOR PEDESTRIAN SAFETY

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SUMMARY

We propose adoption of CFRTP for the body parts of automobiles as an alternative to steel, especially focused on the bonnet, where the pedestrian's head is most likely to be struck in case of collision. The results show that the bonnet using CFRTP has an advantage compared to that of steel in terms of pedestrian safety and lightweight.

Keywords: *CFRP, FEM, Automobile, Bonnet, Pedestrian Safety*

INTRODUCTION

The high number of road fatalities is one of the most severe problems facing our society today, and also the greatest threat to public safety. It is prospected that aging society over coming decades largely induce the increase of traffic accident due to the increase of elderly drivers. Enhancing safety and security of automobiles is now recognized as the urgent issue, demanding immediate and drastic action. On the other hand, it is also required for automobiles to meet environmental functionality, such as fuel efficiency and gas emission. Car industry is now facing this conflicting matter; the heavier car becomes, the more crashworthy it will be, instead of the worse fuel efficiency. In fact, however, heavier does not equal to safer especially for pedestrians (see figure 1). In this paper we propose pedestrian protection bonnet using CFRTP (carbon fiber reinforced thermoplastics) that offers higher levels of safety without the increase of vehicle weight.

CURRENT STATUS OF PEDESTRIAN SAFETY

Safety Standard for Pedestrian Protection

It has been reported that front parts of car body were most likely to strike at pedestrians and fatal injury was occurred by head impact from there (see figure 2). In particular bonnet is the parts that have the strongest possibility to contact the head compared to the others (see figure 3). With this background, regulation for pedestrian protection has been settled in Japan in order to enhance safety functionality of bonnet, which most directly contributes to reduce damage to pedestrian in case of accident.
The regulation was mainly based on the discussion results of IHRA/PS (international harmonized research activity for pedestrian safety) and was focused on shock absorbing capability of the front parts of automobiles for pedestrian head protection. Figure 6 is illustration of the experimental test of this regulation; a head impactor is shot toward the bonnet at a certain condition and total damage to a head is assessed at HIC (head injury criterion), which can be calculated by equation (1), where a (m/s^2) is resultant

acceleration measured by accelerometer built-in the impactor and t_1, t_2 ($t_2 - t_1$<15msec) are selected to obtain maximum value of HIC.

$$HIC = \left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} \frac{a}{9.8} dt \right]^{2.5} (t_2 - t_1) \qquad (1)$$

This impact test is repeated several times a car, changing the hitting point for comprehensive evaluation. It is obligation that every automobile satisfies this safety criterion. HIC is known to have a good relationship with AIS (abbreviated injury scale) which is a degree of head damage as shown in figure 7, so that lower HIC is better for pedestrian and HIC < 1000 is required to automobile bonnet.

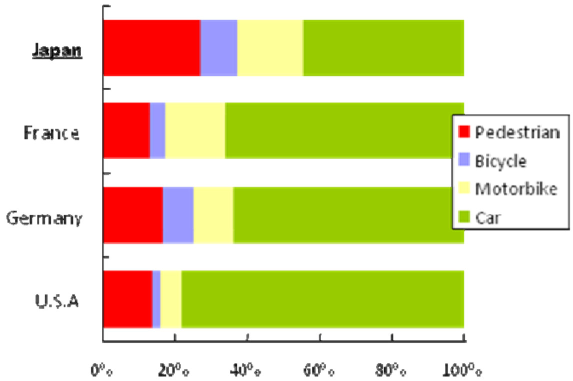

Figure 1 Proportion of people died in traffic accidents by country.

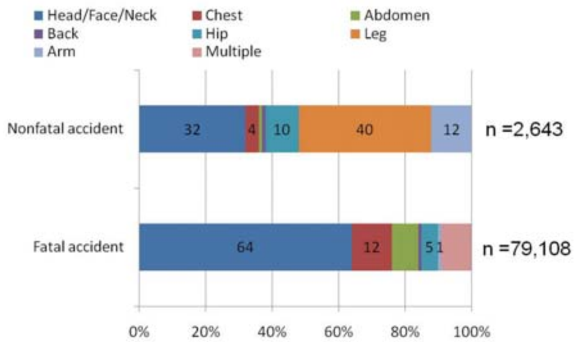

Figure 2 Damaged body parts in traffic accident.

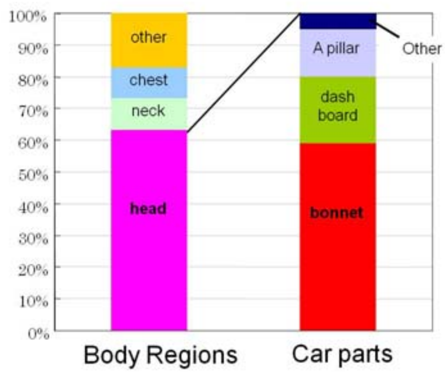

Figure 3 Damaged body parts in traffic accident and site of the collision.

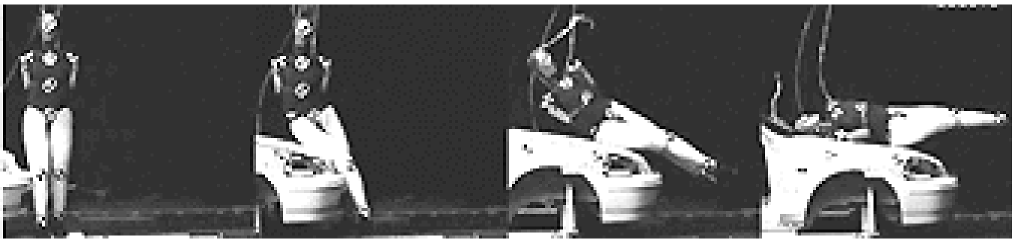

Figure 4 Pedestrian collision experiment by dummy doll.

Figure 5 Finite element simulation of pedestrian collision.

Figure 6 Illustration of head impact test.

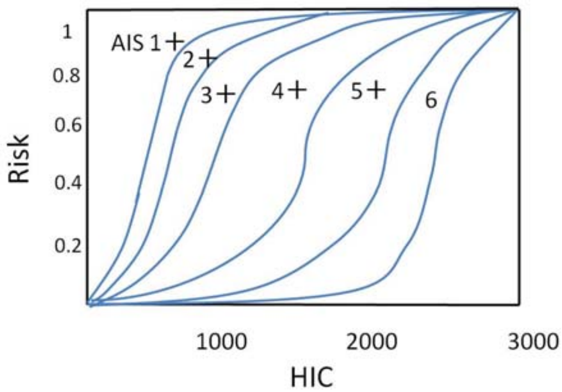

Figure 7 Head injury risk curve.

FINITE ELEMENT ANALYITICLA MODEL

Head-form impactor is modeled as shown in figure 8, and analytical result shows good agreement with experimental result as shown in figure 9. Figure 10 shows an analytical model and condition of head-form impact test, and figures 11 and 12 are analytical result of steel bonnet.

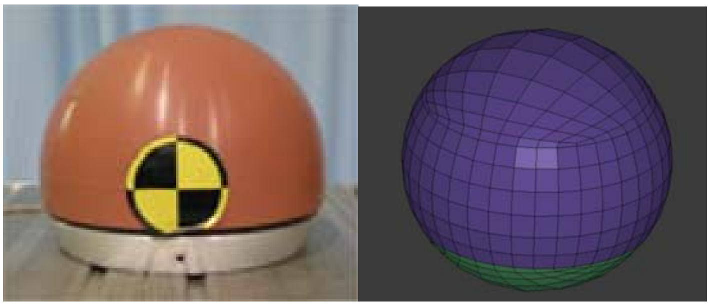

Figure 8 FE model of head-form impactor.

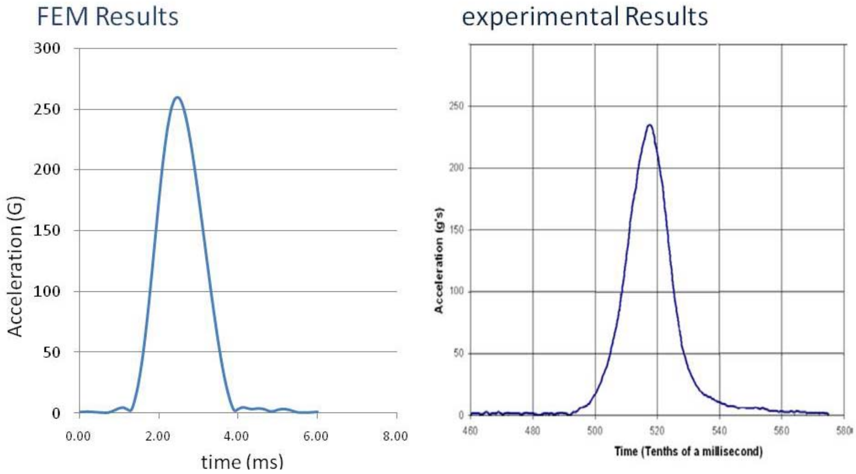

Figure 9 Comparison of time-acceleration curve.

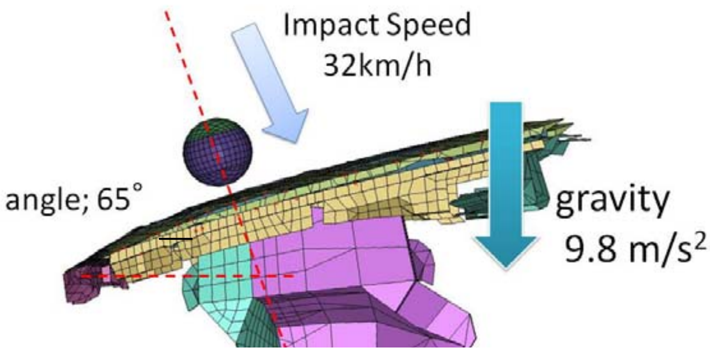

Figure 10 FE analytical model and condition of head-form impact test.

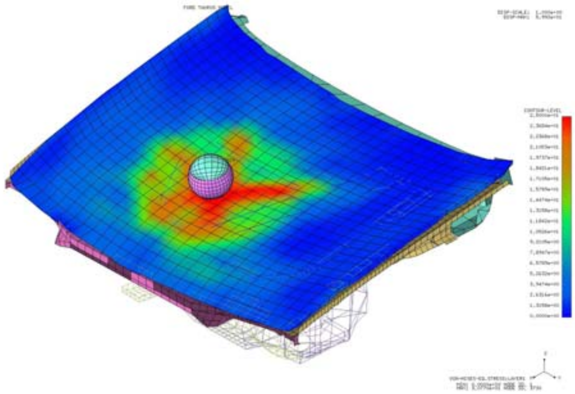

Figure 11 FE analytical result in steel bonnet (Contour: Von Mises stress).

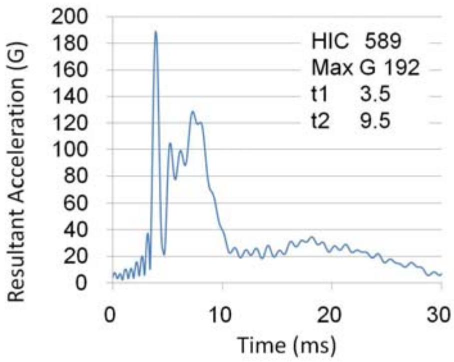

Figure 12 Time - acceleration curve of head-from impactor in case of steel bonnet.

OPITMIZATION OF BONNET STRUCTURE BY CFRTP

First we investigate an effect of rib structure on maximum acceleration and HIC. We change depth, width, radius, curvature and position of rib as shown in figure 13, and perform sensitivity analysis. Then the rib depth is found to be the most sensitive parameter for pedestrian safety. And there is an optimal rib depth as shown in figure 15, where deep rib induce stiffer bonnet and shallow rib induce secondary collision with harder engine part.

Sensitivity analysis is also performed for thickness, curvature and installation angle of hood. Then lower elastic modulus of hood material is better for pedestrian safety, when proper hood thickness is necessary to avoid the secondary collision (see figure 16).

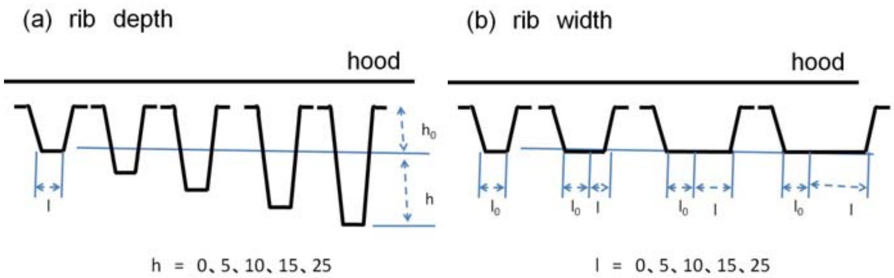

Figure 13 Parameters of rib structure.

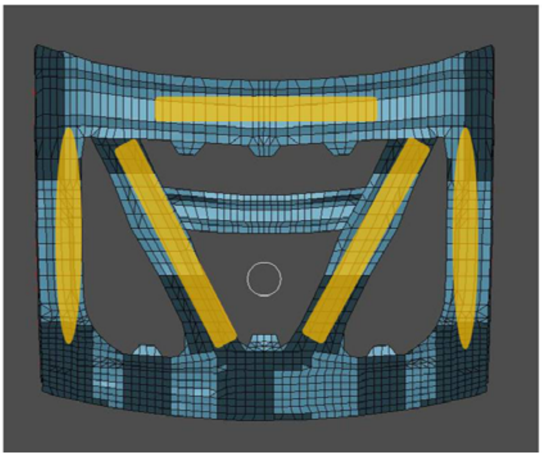

Figure 14 Modified area for the sensitivity analysis of rip structure.

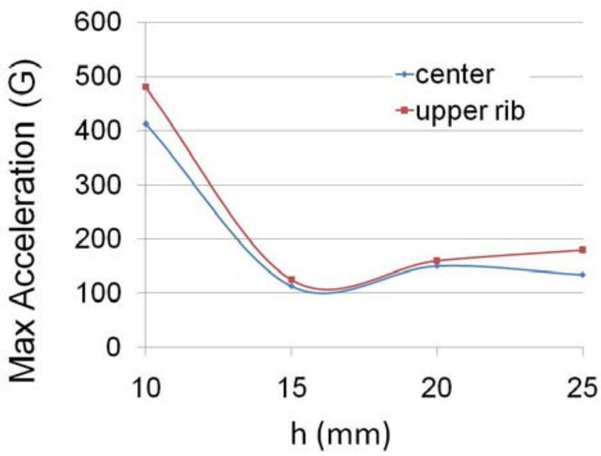

Figure 15 Relation between rib depth and maximal acceleration of head impactor.

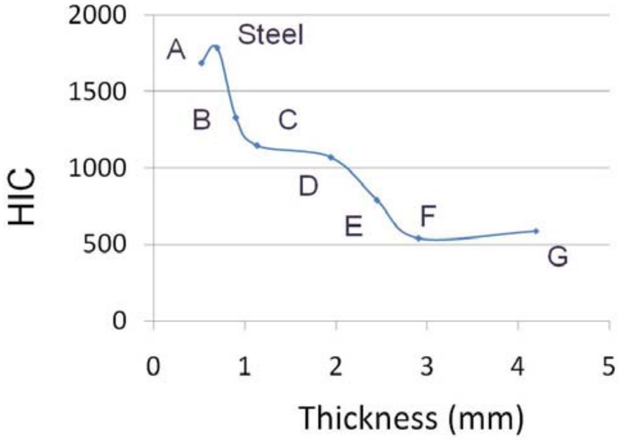

Figure 16 Relation between HIC and hood thickness.

DEVELOPMENT OF CFRTP SANDWICH PANEL FOR BONNET

We prepare CF/PP and CF/EP form sandwich panels (see table 1), and compare these features by static and dynamic three points bending tests. Obtained results are summarized in figures 17 to 20. In especially, as figure 20 shows, CF/PP shows good toughness as we expected to be a better feature for automobile application.

Table 1 Properties of specimen.

	Thickness (mm)	Density (g/cm^3)
CF/PP foam Sandwich	15.4	0.28
CF/EP foam Sandwich	15.1	0.684

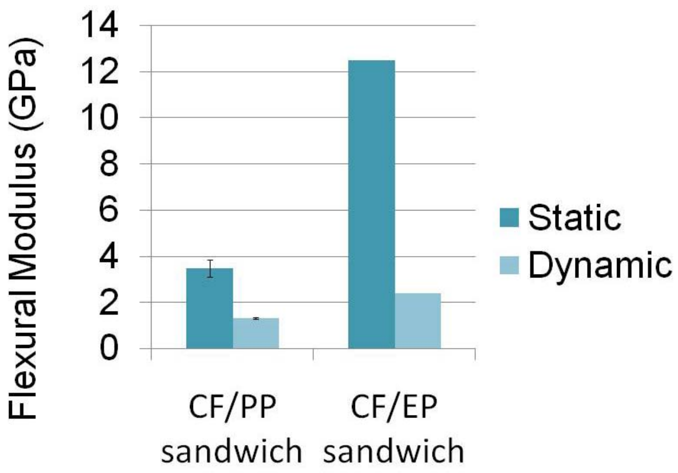

Figure 17 Comparison of static and dynamic flexural modulus.

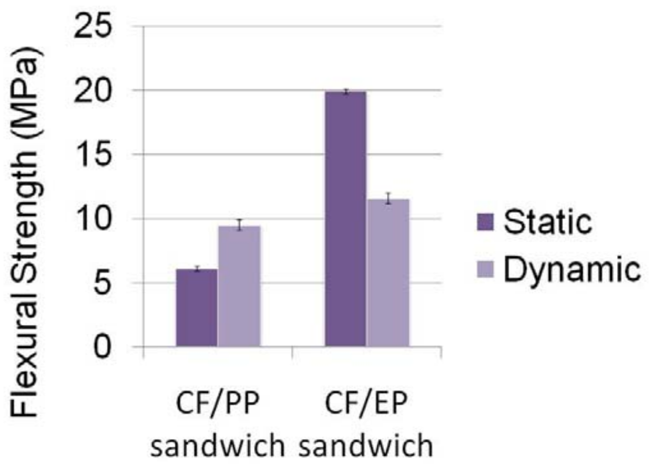

Figure 18 Comparison of static and dynamic flexural strength.

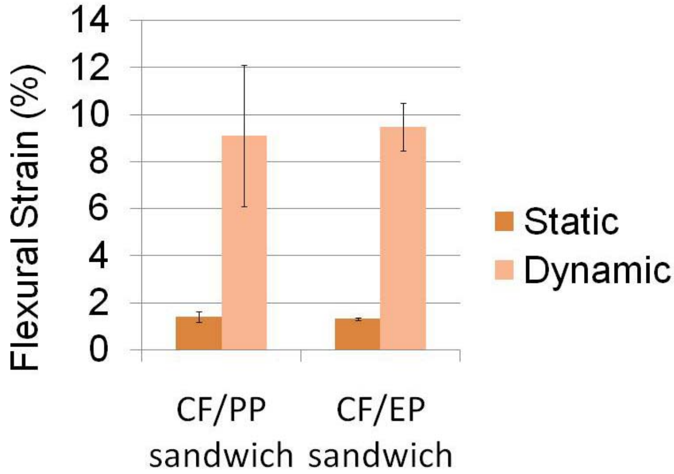

Figure 19 Comparison of static and dynamic flexural failure strain.

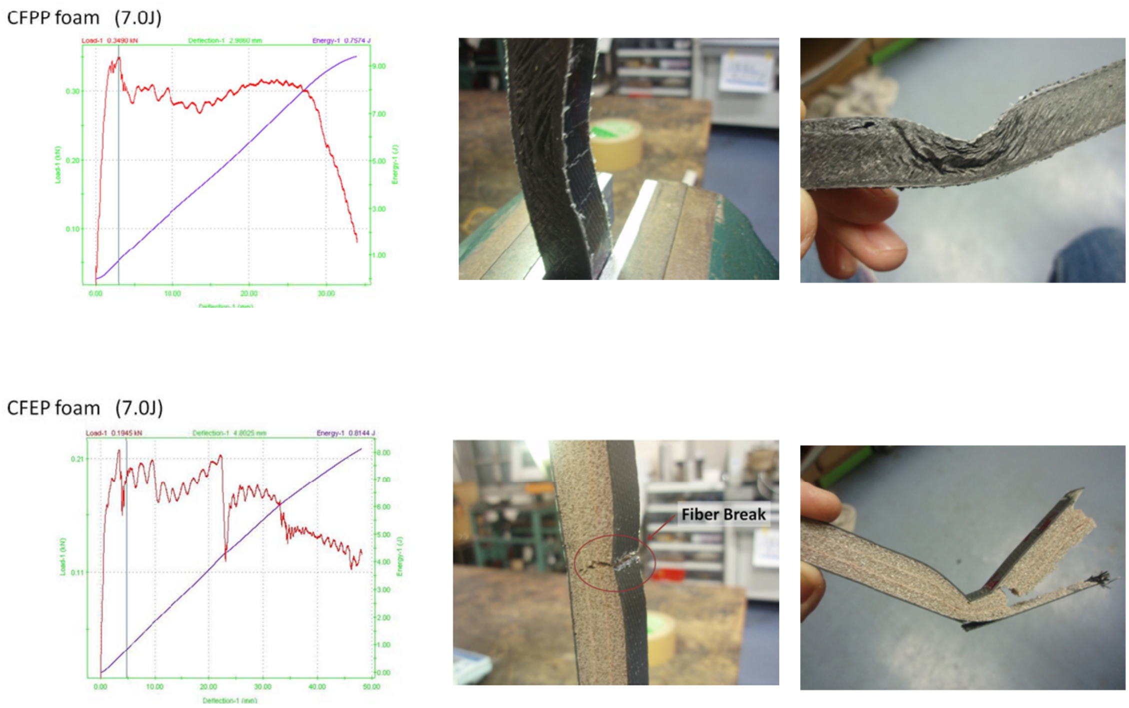

Figure 20 Experimental results of dynamic three points bending test of CF/PP and CF/EP form sandwich.

FINITE ELEMENT SIMULATION OF CFRTP SANDWICH BONNET

Finite element fracture simulation is performed by using material properties obtained in the above experiment. In case of small damage which corresponds to denting feature, such as a collision by small stone, CF/PP form sandwich bonnet has no damage when plastic deformation remains in steel bonnet. Then figure 21 and table 2 shows the result of head impact simulation, which show that both maximal acceleration and HIC of CF/PP sandwich bonnet become half of steel bonnet. And the weight of CF/PP sandwich panel is also about half of steel one.

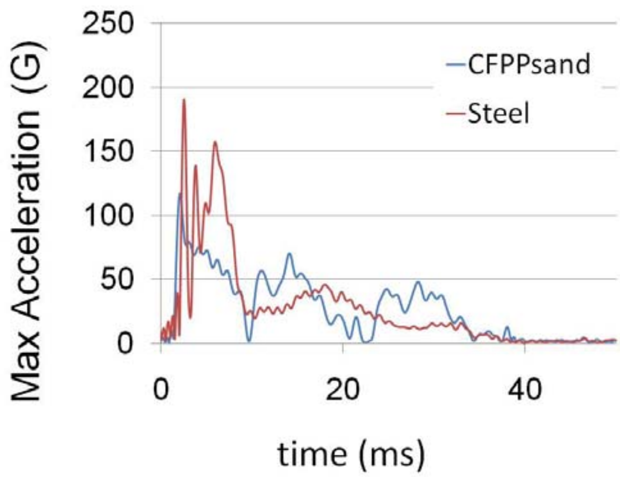

Figure 21 Acceleration curves of CFRTP and Steel bonnet.

Table 2 Comparison of analytical results between CFRTP and Steel bonnet.

	HIC	Peak Acceleration (G)	Deflection (mm)
CFRTP model	295	112	-55.01
Steel model	589	192	-49.17

CONCLUSIONS

As a result of dynamic finite element analysis, it is observed that material substitution and structural change have the effect to prevent fatal damage to pedestrian head. Of course, the requirement of bonnet includes not only safety but also other properties such as dent, fatigue and corrosion resistance; however, enhancing safety of automobile is the issue that directly concerned to human life so that should be immediately achieved without any other functional degradation of automobile. In this study, dent, repairability and recyclability of CFRTP bonnet are also shown to be very good compared to those of steel one.

ACKNOWLEDGEMENTS

This study was partially supported by NEDO (New Energy and Industrial Technology Development Organization, Japan).

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