A STUDY ON AHOF400 WHICH IS POSSIBLE CAR TO SUV COMPATIBILITY EVALUATION METHOD

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ABSTRACT

Research on the evaluation method for vehicle compatibility has continued among passive safety industries in recent years. NHTSA, which has jurisdiction over automobile safety in the U.S., is studying AHOF400 as a new criteria to evaluate interaction between vehicles to improve compatibility performance. In this paper, the target value of AHOF400 was assumed to be Part581 zone, which is the front bumper height of a passenger car. A basic study was carried out using finite element modeling of an existing vehicle model and a real vehicle crash test in order to determine how to practically modify the vehicle structure of an SUV. As a result, it was determined that the height of the Front Side Member of an SUV should be lower than that of a passenger car in some cases. This is different from the original aiming point that car-to-car interaction would be improved by restriction of AHOF400, which makes the height of front end structures the same level. As a way to solve the concern, an evaluation area of barrier load cells height which is appropriate to calculate AHOF400 was studied

INTRODUCTION

Vehicle safety performance was enhanced by regulations and crash test publication, in addition to continuous effort by car manufactures for many years. Especially Self Protection performance during a crash has been improved very well. In addition, safety concept to reduce the aggressiveness to vehicles and passengers during car-to-car accident is being expanded. And optimization of self protection and partner protection is known as an approach to enhance passive safety performance. This kind of approach is called compatibility generally.
Recently the selling volume of sport utility vehicles (SUV) and light track vehicles (LTV) is being increased, therefore aggressiveness of SUV and LTV against passenger vehicle is pointed out. For example, Mr Kahene reported that LTV is more aggressive than passenger vehicle in case of full lap and offset crash in car-to-car crash, in the report by The National Highway Traffic Safety Administration (NHTSA) in 2003 **[1]**. And compatibility of Car to SUV or LTV is under research by NHTSA **[2, 3 and 4]** and The Insurance Institute of Highway Safety (IIHS).
Generally, basic idea to improve compatibility performance is considered to be followings **[5]**.
1)Increasing interaction of front end structure between vehicles
2)Matching the load between vehicles
Based on this idea, NHTSA is studying 1) Regulation regarding Average Height of Force of front end structure (AHOF400) to increase interaction between vehicles, 2) Front end load (KW400) to match the balance between vehicles as an regulation **[6]**. According to basic research by NHTSA, AHOF400 and KW400 of SUV and LTV are more than the upper limit of criteria which was recommended by NHTSA **[7]**, therefore it is presumed that the additional modification of front end structure of SUV and LTV is needed from now.
From such a background, basic research about AHOF400 was carried out in this paper. Basic study by the FEM simulation using existing car and a vehicle test were carried out to understand how body structure should be modified practically to achieve NHTSA concept, in case of SUV which the aggressiveness against a passenger car is concern especially.

CALCULATION METHOD OF AHOF400 (AVERAGE HEIGHT OF FORCE)[6]

The followings is a summary of the calculation method of AHOF400. AHOF400 is an index which shows the Average Height of Force of the front part of a vehicle when vehicle deformation is 400mm, and it is calculated by using the output value from the barrier load cell on a rigid barrier in 35MPH full overlap crash test. Load cells are set on the rigid barrier in 10 lines and 16 rows, the size of each load

cell width is 125mm by 125mm, the height of lower edge is 80mm and upper edge of load cell is 1330mm from the ground. AHOF400 is computed by using Equitation (1) and (2).

The aiming point is that front structure (i.e. Front Side Member) of various type of vehicle should be in same level of ground height and vehicle interaction can be improved, by limiting upper and lower value of AHOF400. Recently, making the main front end structure distributed around the height of the bumper on passenger vehicles (Part581 zone; 406 to 508mm) is under study. Therefore, target of AHOF400 criteria was assumed to be within Part581 zone, in this paper.

$$AHOF400 = \frac{\int_0^{400} F(s)COF(s)ds}{\int_0^{400} F(s)ds} \quad (1).$$

$$COF(s) = \frac{\sum H_i f_i(s)}{\sum f_i(s)} \quad (2).$$

COF(s) : Center of Force

F(s) : =Σfi(s)

fi(s) : Force on each load cell

Hi : Height of each load cell

BASIC STUDY OF AHOF400 BY FRONTAL CRASH SIMULATION USING FINITE ELEMENT METHOD

The crash simulation was carried out by using FEM model of an existing car to understand how the structure should be modified practically to achieve the assumed criteria of AHOF400, especially in the case of a collision with an SUV. Because the Front Side Member most greatly influences the results, its height was the focus of the study.

PAM-CRASH was used as the solver of the simulation. The model showed in Figure 1. Moreover AHOF400 from physical vehicle test and the above-mentioned crash simulation results were compared to confirm analytical accuracy (Table 1). Because AHOF400 calculated from the FEM simulation are lower than result of vehicle tests as a trend, the numerical value of AHOF was corrected in the ratio of the physical vehicle test results and simulation results, was used in this paper. (Table 1)

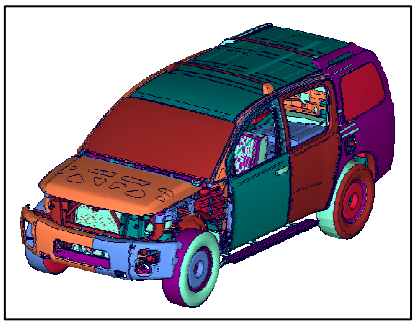


Figure 1. Simulation model.

Table 1.
Difference between AHOF400 calculated from crash test and simulation results

	Experiment	Analysis
AHOF400[mm]	592	578

The relationship between AHOF400 and the height of the Front Side Member by simulation is shown in Figure 2. In the case of the model, where the height of the Front Side Member is higher than Part581 zone in a simulation; the AHOF400 value is much higher than the assumed upper limit (Figure 2-(a)). If the height of Front Side Member is in the middle area of Part581 zone, AHOF400 is still higher than the assumed upper limit (Figure 2-(b)). As a result, height of Front Side MBR has to be lower than Part581 zone to use current AHOF as a recommendation. Figure 3 shows the barrier load distribution when the amount of the body deformation is 400mm. It is understood the main load that influences AHOF400 by the time body deformation is 400mm is generated at the following position; bonnet hood (Figure 3-(a)), front end composition parts in front of the engine (Figure 3-(b)) and Front Side Member (Figure 3-(c)).

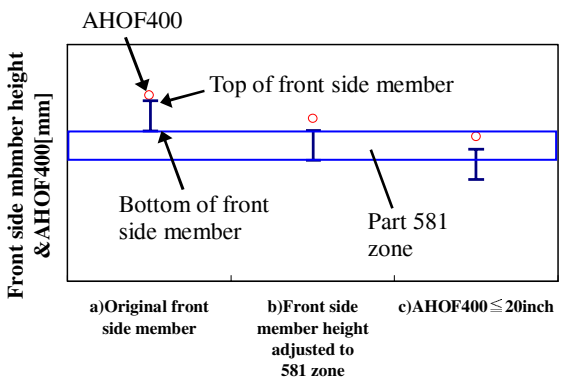


Figure 2. Relationship between front side member height and AHOF400.

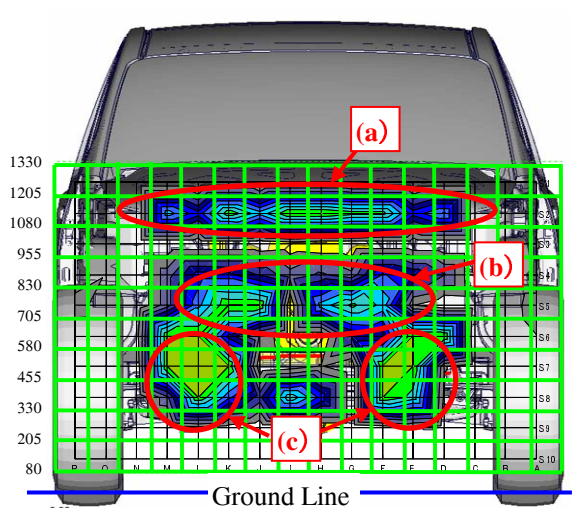


Figure 3. Relationship between barrier load and structure layout

The aim of the AHOF400 restriction is distributing Front Side Member of various types of cars around the Part581 zone to improve the interaction of front end structure between vehicles. This analysis result shows that the Front Side Member becomes lower than Part581 zone in this case, even if it suits the AHOF400 to Part581 zone, unlike the above-mentioned aim (Figure 4). The main cause is considered to be load by the structural element around bonnet hood. Although the load around the hood is low as compared to the Front Side Member load, since road clearance is high, it is presumed as a factor which makes AHOF400 increase (Fig. 3- (a), (c)). Then, in order to check the influence on AHOF400 by the load around the hood, a crash simulation was carried out without a hood, as shown in Fig. 5. As a result, AHOF400 increased 40mm with a hood, and the influence of the hood on AHOF was understood (Table 2).

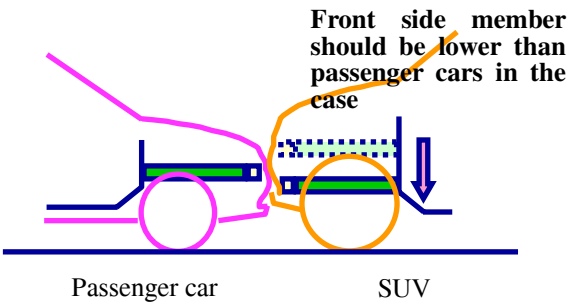
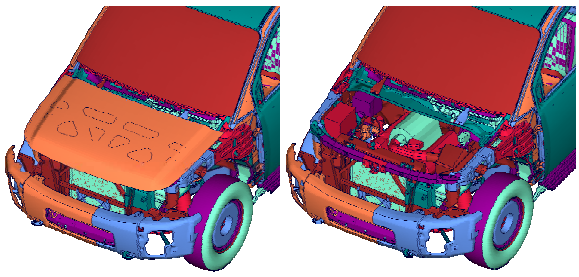


Figure 4. Front Side Member relation between SUV and passenger car to meet AHOF400



a)With hood b)Without hood

Figure 5. Simulation model with/without hood

Table 2.
Difference AHOF400 with and without hood (simulation results)

	With hood	Without hood	Difference
AHOF400 [mm]	489	449	-40

STUDY OF AHOF400 IN CASE OF RESTRICTED BARRIER LOAD CELL EVALUATION AREA

From the basic study about AHOF400 in the preceding chapter, AHOF400 is increased from the influence of structure like as a bonnet hood which position is higher than Front Side Member height. It has been found out that the AHOF400 cannot achieve Part581 zone, if the Front Side Member is not lower than the lower limit of the Part581 zone.
Generally, in a Car to SUV/LTV head-on collision by which the aggressiveness of SUV and LTV is regarded as a concern, the structure around the bonnet hood of SUV/LTV does not overlap the front part of a passenger car in the height direction (Fig. 6), therefore it is hard to think that it has a big influence on the interaction between passenger vehicles and SUV/LTV. It is considered as one of the subjects of AHOF400 that AHOF400 of SUV and LTV increases with such a structural element considered that the influence of the interaction between vehicles is small.

Figure 6. Relation of the front structural element and passenger car and SUV.

In this paper, how to eliminate the load of the structure of an SUV/LTV which is not overlapped with the front end of a passenger car in AHOF400 calculation was studied as a proposal. As a concrete method, the influence of the structure which is not overlapped with the front of a passenger car in vertical direction can be eliminated by making the barrier load cell height lower than 1330mm in AHOF400 calculation. In this paper, new barrier load cell evaluation range is defined from the two following viewpoints.

Height of front part of passenger car

Here, because AHOF400 is calculated at the time of 400mm of body deformation, the front part height of the passenger car was defined as the height of the hood, which is 400mm rearward from the front end of a passenger car (Fig. 7). The distribution of height of the front part of passenger car is shown in Fig. 8. Fig. 8 shows that the height of the front part of passenger car is on 850mm or less.

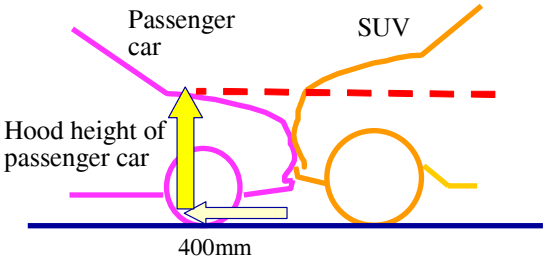


Figure 7. Height of front part of passenger car.

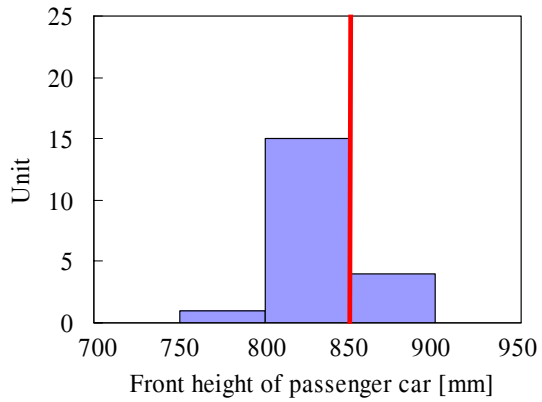


Figure 8. Hood height of passenger vehicles.

Barrier height which imitated the passenger car used in crash tests

Table 3 shows the height of the barrier that imitates passenger cars which are used in the front crash test of North America, the side impact regulation, and the assessment test of each country. It shows that each barrier height is distributed within 800-850mm.

Table 3.

Barrier height used in crash tests in each country

UNIT[mm]	Frontal Impact		Side Impact	
REGION	Regulation	Information Disclosure	Regulation	Information Disclosure
US	850	850	839	839
JPN	-	850	800	800
EUR	850	850	800	800

From the two above-mentioned viewpoints, 830mm (Fig. 4), which is a barrier load cell boundary position between the road clearances of 800-850mm, was made the upper limit of the evaluation area.
AHOF400 calculated by the above-mentioned method is shown in figure 9-(d). In this case, the Front Side Member height that meets Part581 zone, which is the assumed target of AHOF400, was distributed over Part581 zone. This result approached the aim of distributing the frontside member of an SUV over Part581 zone, which is the bumper height of a passenger car. Moreover, the same tendency was seen also in the physical vehicle test result (Fig. 10).

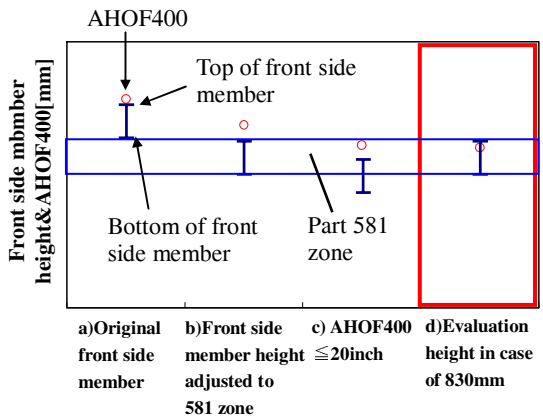


Figure 9. Relationship between AHOF400 and new evaluation method.

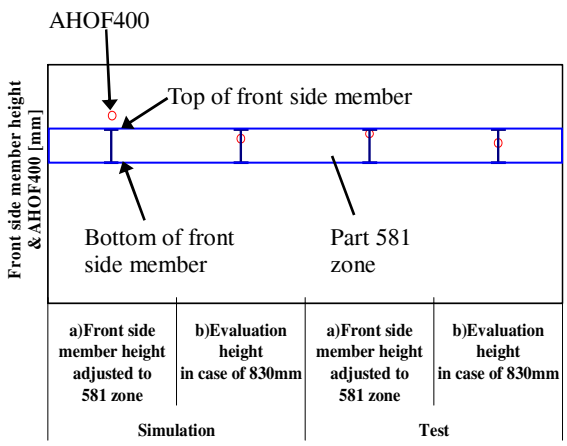


Figure 10. Relationship between AHOF400 and new evaluation method in vehicle crash tests.

CONCLUSIONS

In attempting to achieve the assumed target of AHOF400, which is part581 zone, there are cases where it cannot be achieved if the Front Side Member of an SUV/LTV is not made lower than a passenger car's. This view is different from the original aim, which was to improve the interaction between vehicles by making the height of various types of front structures a fixed height by regulating AHOF400. As a possible cause, the influence of a structure such as the hood, which is not overlapped with the front of a passenger car in the vertical direction, was considered. The upper limit of the AHOF400 evaluation area was restricted to the same height as passenger cars in this study. As a result, it was found out that the original aim can be achieved.

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