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Research on Lightweight Material of FrontalBumperfor Midsize Coach

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Abstract：To estimate the aluminum-alloy bumper compared to steel bumper in lightweight and crash safetyof midsize coach, a numerical simulation model of coach 100% overlap frontal crash with rigid wall was established by using three dimensional explicit finite element analysis software LS-DYNA 3D, based on China's regulation GB11551-2014"The protection of the occupants in the event of a frontal collision for passenger car". Three testingparameters were studied, included the reactive force of crash-box, the drive cab integrity and the acceleration of the coach mass center. The results show that: comparingsteel bumper,the mass of aluminum-alloy bumper system isdecreased 60%，while the system has better absorption crash force curves and crashworthiness of coach body，but the drive cab integrity has become worse.

Key words：coach；bumper；frontal impact；aluminum-alloy material；lightweigh

1.Introduction

As the structure of coach frontalenergy absorption and the impact force absorptionof the outside world, the coach bumper system is a very important component.When collision occurs, it protectsthe coach body and body accessories. It is important for coach safety, especially flat bus. In view of the demand of the coach in both the crashworthiness and lightweight, the safety performance of the lightweight front bumper system was highly valued. At the same time, with the advance of the lightweight process, the new lightweight material is gradually applied to the body parts, such as aluminum-alloy material, which has the similar mechanical properties, and compared original steel bumper,the mash of aluminum bumper system was reduced by 69%, and the energy absorptionof 50%[1]. In recent years, due to the emphasis on energy saving and environmental protection, the car lightweight has become the important direction ofthe major automobile enterprises to improve the competitiveness. And the use of aluminum-alloy instead of steel material is one of the major means of reducing the mass of automotive [2].

In this paper, a new aluminum-alloy bumper system was used to replace the original steel bumper system, and the bumper system was placed on the coach model. Based on the regulations of GB11551-2014[3], the simulation experiment of coach 100% frontal crash with rigid wallwas carried out by comparing the coach model with aluminum-alloy bumper system and steel bumper system along the impact velocity of 30km/h[4].

2. The establishment of the coach 100% frontal crash model

The coach body is typical half a monocoque body. According to the deformation regularity of coach in collision and in order to save time and ensure the accuracy of the calculation results, it appropriately simplified thecoach’s body structure. In order to furtherensure the reliability of the calculation results, finite element model was mainly established by shell element properly[5]. We can simplify the three-dimensional entity model in the CATIA software,and then use the hypermesh/ls-dyna software to establish its finite element model. The related simplification theory of the model can be found in literatures [6-8].

For coach model, the element size is mainly 10 mm in the main deformation area.In the other area, the element size is mainly 30 mm.The whole coach model is made of 339014 nodes, 339014 square elements, 7521 triangular elements and 136 parts.

Car collision deformation research algorithm mainly used the Lagrangian description increment method[9]. The related dynamics theory, the control equation and so on in the calculationcan be found in literature [10].The finite element simulation of coach as follows.

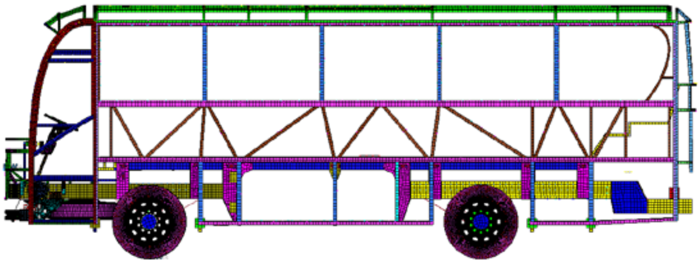


Fig.1 The model of coach 100% frontal crash with rigid wall

3. The selection of coach bumper material

Coach original steel bumper system chosen materials for steel 1 and steel 2，aluminum-alloy bumper system chosen aluminum-alloy1. The material parameters are shown in Table 1.The structure of coach bumper system was shown in Fig.2.

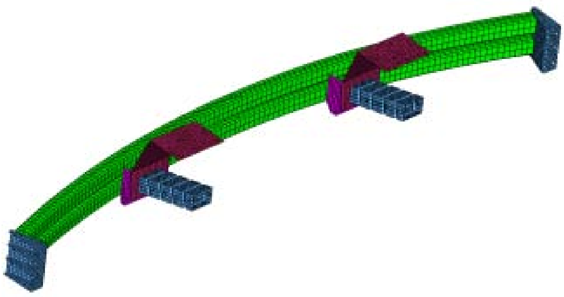


Fig.2The coach bumper systeTable 1Material Parameters

Material	σ s /Mpa	E/Mpa	u	ρ /(kg/m3)	C	P
steel 1	245	210000	0.3	7860	40	5
steel 2	570	54000	0.3	7860	40	5
Al-alloy1	308	54000	0.3	2700	40	5

4. The measuring nodes of coach

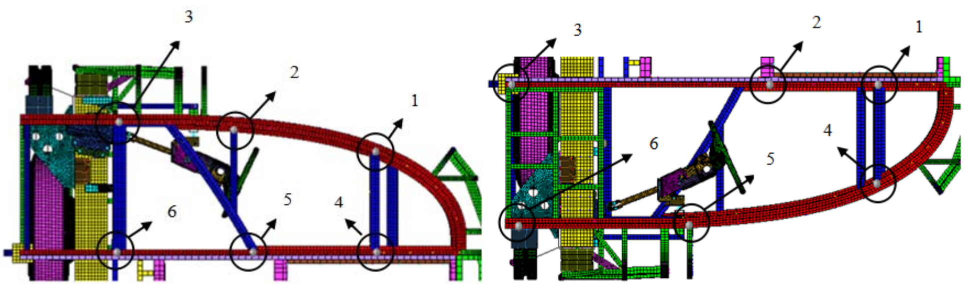
4.1 The 2 measuring nodes in the left crash-box and the right of crash-box

In coach bumper system, crash-box is an important component to pass force and absorb energy. The reactive force of crash-box can characterize collision energybuffering and impact strength of the bumper system in the process of collision .This coach bumper systemconsists a left crash-box and a right crash-box, these two crash-boxes have same structure and material. The specificstructure of two crash-boxes was shown in the figures below.

Fig.3 The left crash-box and the right crash-box

4.2 The measuring nodes of coach's drive cab

To analyze the influence of Lightweight material substitution on the integrity of the coachdrive cab, 12 typical measuringnodes were selected.It contains 6 measuring nodes in the left of coach drive cab and 6 measuring nodes in the right of coach drive cab[11].The max displacements variation of 6 measuring nodes along the initial velocity direction in the left of coach drive cab indicates the maximum deformation of the drive cab structure in its left side in the process of coach 100% frontal impact on rigid wall .The max displacements variation of 6 measuring nodes along the initial velocity direction in the right of coach drive cab indicates the maximum deformation of the drive cab structure in its right side in the process of coach frontal impact on rigid wall . The specific positions of those measuringnodeswere shown in the figures below:



a. 6 measuring nodes in the left of coach drive cab   b. 6 measuring nodes in the right of coach drive cab

Fig.4 12 measuring nodes in the coach drive cab

4.3 The measuring nodes of coach's mass center

In the process of collision， thevalue of accelerationalong the initial velocity direction in the coach mass center indicates the capacity ofenergy absorption and crashworthiness of coach structure [12]. The specific measuringnode position of mass center was shown in the Fig.5.

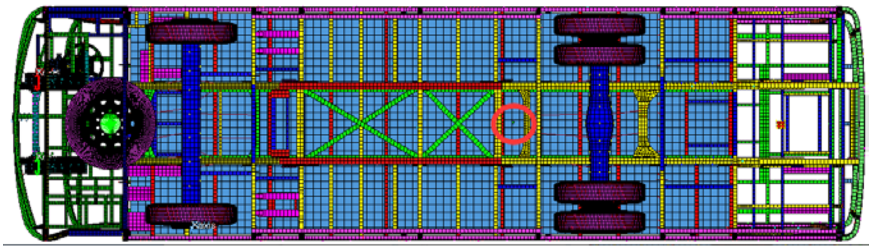
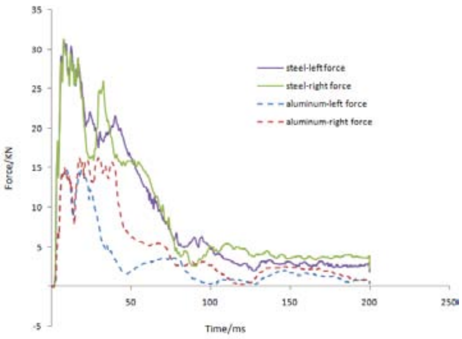


Fig.5 The measuringnode position of mass center

5.The results of crash simulation

By the peak value of the curve in the Fig.6, thereactive force of aluminum-alloy bumper system can reach the maximum 16.2KN, and thereactive force of steel bumper system can reach the maximum 31.3KN. In addition, the two kinds reactive force curve of material bumper system can not coincide with the left and right box, which was due to be asymmetric of the structure of coach. It can be seen that the aluminum-alloy bumper system can buffer the impact force in the process of the impact, which can make the structure of body to has better crashworthiness than the steel bumper system.



From the data of 12 measuring nodes in the left and right of coach drive cab in the Table 3 and Table 4，the max displacement variation of 12 measuring nodes of the coach drive cab with aluminum-alloy materialbumper system was bigger the steel bumper system. It’s shows that aluminum-alloy materialbumper system has worse integrity of the coachdrive cab than steel bumper system.

Table 3　The max displacement variation of 6 measuring nodes in the left of coach drive cab (Unit: mm)

Bumper classification	1	2	3	4	5	6
Steel material	450.46	223.40	217.24	450.14	241.06	219.65
Al-alloy material	454.80	241.95	226.92	454.73	250.44	229.60
D-value	-4.34	-18.55	-9.68	-4.59	-9.38	-9.95

Table 4　The max displacement variation of 6 measuring nodes in the right of coach drive cab (Unit: mm)

Bumper classification	1	2	3	4	5	6
Steel material	507.37	266.47	240.84	506.58	154.58	129.00
Al-alloy material	508.64	278.10	255.18	507.67	159.35	137.65
D-value	-1.27	-11.63	-14.34	-1.09	-4.77	-8.65

From Fig.7 , the peak value acceleration of coachwith steel materialbumper system is24.86g and aluminum-alloy materialbumper system is 24.10g , whose impact buffering time increased by about 7ms than steel materialbumper system . It shows that the coach structure of the aluminum-alloy bumper system has better energy absorption and crashworthiness than the steel bumper system.

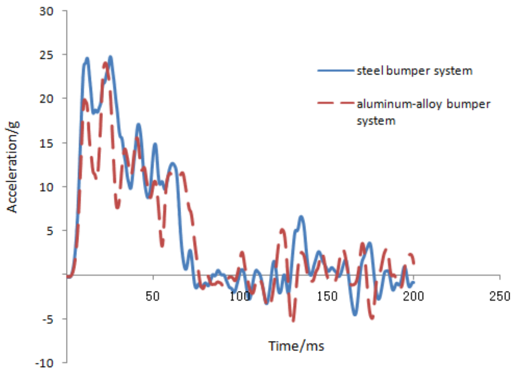


Fig.7 The comparison of acceleration in the coach mass center

6. Discussion and conclusions

1）Compared original steel bumper system, the maximum value of reactive forceof aluminum-alloy crash- box was reduceby 15kN,and itcan better absorb collision force.

2）Compared original steel bumper system, the max displacement variation of 12 measuring nodes of the coach drive cab with aluminum-alloy materialbumper system was bigger，and made the drive cab integrity to be worse.

3) Compared original steel bumper, the peak value acceleration of coach with aluminum-alloy material bumper system was reduced by 4g，and impact buffering time increased by about 7ms.It shows that aluminum-alloy material bumper system made the body of coach to have a better energy absorption and crashworthiness.

4）The mass of aluminum-alloy bumper system was 5.7kg.The mass of steel bumper system was 14-16kg.Compared original steel bumper, the mass of aluminum-alloy was reduced by 60%.

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