Study on Aluminium Alloy Bumper of Benchmark Car Using LS-DYNA Simulation Analysis on In-Flight Collision

Jintao Su¹, Jianping Lou², * and Xiaolu Jiang²

¹SAIC Commercial Vehicle Technology Center, Shanghai, China
²Saic-iveco Hongyan Commercial Vehicle Co., Ltd, Chongqing, China

*Corresponding author e-mail: jianping_lou@hongyantruck.com

Abstract. At present, aluminum bumper has been used in the field of passenger cars. In order to provide technical reference for the aluminum alloy bumper to be developed, and to better develop the aluminum alloy bumper, this project analyzes the material and process of an existing aluminum alloy bumper from the perspective of mechanical properties, material composition, and the connection method between each component. Through crushing, static pressure, collision test and simulation technology, the performance of aluminum alloy bumper of benchmarking car is analyzed.

Keywords: Aluminum Alloy, Bumper, Benchmark.

1. Introduction
Reducing fuel consumption, reducing emissions and improving safety are the problems that the global automobile industry must face today. Automobile lightweight is an effective means to solve the above problems. Research shows that the mass reduction effect of typical aluminum parts can reach 30% ~ 40% in the first step, and 50% in the second step, and the fuel saving can be realized by 6% ~ 8% for every 10% reduction of mass in automobile [1]. Bumper system is the most important load bearing system in low speed collision the energy absorbing component plays a vital role in protecting the safety of other automobile parts and occupants. On the basis of meeting the functional requirements, the development of aluminum alloy bumper with lighter quality is getting more and more attention from automobile manufacturers and researchers [2]. According to the SAEJ2319 standard, the pendulum impact test device and simulation analysis model are established to study the low-speed collision performance of car bumper. Through computer simulation analysis and experimental research, the validity of the pendulum low-speed impact test is verified. In Literature [3], 7075 aluminum alloy was applied to automobile bumpers, and LS-DYNA was used to conduct simulation analysis on in-flight collision of bumper models with different thicknesses, which met the safety requirements while realizing lightweight.

2. Crushing test and simulation of energy absorbing box
Static crushing tests on individual energy-absorbing box components can better study the compression deformation mode, energy absorption and cross-section force variation in the process, and provide a basis for the establishment of design indexes in the subsequent design of energy-absorbing box. The static crushing test was carried out under normal temperature and pressure, and the test equipment was
material tensile testing machine. The pressure head is a rigid disc, and the specimen is rigidly fixed with the rigid platform, as shown in Fig. 1:

![Diagram of static collapse test of aluminum alloy bumper energy absorbing box for benchmark car](image1)

**Fig.1** Diagram of static collapse test of aluminum alloy bumper energy absorbing box for benchmark car

At the beginning of the test, the sample of the energy absorption box is placed on the test table, the pressure head is moved down to the cross section of the energy absorption box just to contact, the parameters of the loading software are set, and the test begins. In the test, the loading speed was 5mm/min, and the loading distance was determined according to the length of the energy absorbing box. In this test, the loading distance was set as 63mm according to the length of the energy absorbing box. Figure 2 is the static collapse test process diagram of the aluminum alloy energy absorbing box of the benchmark car.

![Static Crash Test of Aluminum Alloy Bumper Energy Absorption Box for Benchmark Car](image2)

**Fig.2** Static Crash Test of Aluminum Alloy Bumper Energy Absorption Box for Benchmark Car

The static collapse model of the energy absorbing box, with the required load and boundary conditions imposed on the simulation, was imported into ABAQUS for calculation, and the bumper displacement cloud map of the benchmark car as shown in Figure 3 and 4 was obtained.

![Pole car aluminum alloy bumper energy absorption box displacement cloud image](image3)

**Fig.3** Pole car aluminum alloy bumper energy absorption box displacement cloud image
Figure 4 for benchmarking car aluminum alloy endergonic box static crushing of deformation and simulation experiment contrast effect, can be seen from the diagram, benchmarking car aluminum bumper can suction box static crushing test and simulation of the deformation in the local place only slightly different, in general, model test and simulation of deformation and deformation process are basically identical. By analyzing the stress of the energy absorbing box, it can be seen that the maximum stress of the energy absorbing box in the static crushing process occurs in the maximum bending area of the plastic hinge, and the maximum stress is 241MPa, which does not exceed the strength limit of the material (270MPa), so there is no fracture phenomenon, which is consistent with the test results.

3. Strengthen static pressure test and simulation of beam

An important function of the reinforced beam lies in that it can transmit the collision force backwards along the left and right energy absorbing boxes as evenly as possible under either 100% frontal overlap collision or various forms of offset collision conditions, so as to reduce the serious damage caused by the one-side parts of the car and play the due protective role. Therefore, some requirements are put forward for the stiffness performance of the bumper reinforced beam. Through the three-point static pressure test of the reinforced beam, the support reaction force of the beam in the static pressure process can be accurately measured, which can be used as an important index to evaluate the stiffness performance of the beam, and as an important basis for the subsequent design of the reinforced bumper beam. The test was carried out under normal temperature and pressure, and the test equipment was PLS-L50B4 electro-hydraulic servo component test system (loading device thrust > 25kN, BBB>kN) and YE2539 high-speed static strain gauge. The radius of the pressure head is R152mm, and the specimen is rigidly fixed with the rigid platform. Before the start of the test, the two mounting flanges of the bumper are fixed on the workbench, and strain gauges are affixed to the middle part of the strengthening beam near the lower part and the side of the energy absorbing box. The loaded cylinder head moves down to contact the middle part of the strengthening beam. After the start of the test, the loading speed was 0.001m/s, and the loading stopped when there was obvious damage. If there was no obvious damage, the loading stopped when the loading distance reached 100mm. Fig. 5 is a diagram of the three-point static pressure test of the bumper.
Figure 6 shows the stress cloud diagram of the aluminum alloy bumper of the benchmark car. It can be seen from the figure that the stress distribution at the left and right symmetrical points is basically the same after the bumper bears the load, because the bumper has a symmetrical structure. When the bumper bears the above load, the maximum stress appears in the middle of the bumper strengthening beam, and the maximum value is 333.9MPa. Because the reinforced beam is made of 6 series aluminum alloy, the maximum stress value of simulation analysis does not exceed the strength limit of the material (341-357MPa), and the stress of the other parts is below 200MPa, so there is no fracture phenomenon, which is in accordance with the test results.

4. Conclusions
The static collapse test of the aluminum alloy bumper energy absorbing box of the benchmark car and the three-point static pressure test of the reinforced beam are carried out, and the important basis of evaluating the energy absorbing performance of the aluminum alloy bumper box and strengthening the beam strength by the static compression reaction force is put forward, and the performance parameters are determined for the subsequent design of the aluminum alloy bumper of the target car.

Acknowledgements
The research was financially supported by the National Natural Science Foundation of China (51275541).

References
[1] Kim Sang-Ha. Hoon Myung. Ha Sung Kyu. Design and Structural Analysis of Bumper for Automobiles[C]. SAE Paper 980114.
[2] Kim Soo-Sang. Lee Kang-Wook. Lee Dong-Hyun. et al. Bumper System Development to Meet New IIHS Bumper Test Using CAE and Optimization[C]. SAE Paper 2009 — 01 — 0962.
[3] Ge Ruhai, Wang Qunshan. Low Speed Crash Test and Simulation of Buffer Energy Absorbing Bumper [J]. Transactions of the Chinese Society for Agricultural Machinery. 2006. 37(2):29 – 32.