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Analysis of automobile energy-absorbing components using FEM

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Abstract: *In this work, the simulation analysis of automobile energy-absorbing components was carried out using FEM. The numerical simulations were carried out using the software LS-DYNA. Automobileenergy-absorbing components usually were made of a metal thin walled tube. In the paper, several types of materialproperties were studied and compared. Results show that the material properties have influence to automobile energy -absorbing componentscrashworthiness.*
Keywords: *Absorbing components, FEM, material properties, strain rate, yield strength*

I. INTRODUCTION

In cities traffic jam, automotive accident often occurs to low-speed and behind or angle collisions. No attention is paid to the low speed crashed for no personnel injury [1].Therefore, it is quite necessary to study the technical problems of the car involved in low velocity impact.

In low velocity impact accident, the automobile energy-absorbingcomponentisexpectedtobecollapsedwithabsorbing crash energy prior to other body parts so that thedamageofthemaincabinframeisminimizedandpassengers maybesaved[2].

The automobile energy-absorbing component equipped atthe front end of car (see Fig. **1**), is one of the most importantautomotive parts for crashenergyabsorption.

In the present work, the automobile energy-absorbing component (a kind of thin walled metal tube) at low-velocity impact was studied [3, 4], and material properties onautomobile energy -absorbing components crashworthiness were proposed.

II. FINITE ELEMENTMODEL

2.1 Model Building

In case of front allow-speed collision, the automobile energy-absorbing component absorbs impact energy and reduces the peak load of the impact mainly by the plastic deformation [5,6]. The automobile energy-absorbing component comprises a front longitudinal beam, a bumper beam, a crash-box and front and rear flange. The crash-box plays a key role in low-speed collisions, and the structure isgiveninFig. (**2**).

In this paper, crash-box was made of thin walled tubes, and a finite element model was developed using the softwareHypermesh [7]. The axial low velocity impact of the squarecross-section tube (70mm width, 140mm long and1.65mm thick) is studied firstly. The tube finite element mesh is illustrated in Fig. (**3**). A rigid plate of 1000kg, placed on thetop of the tube as shown in Fig. (**3**), axially impacted at the velocity of 4.44 m/h.

Fig.(1). Position of crash-box in the body work.

2.2 Main Crashworthiness Evaluation Parameters

In low-speed collision simulation, the most important crashworthiness evaluation parameters of the crash-box are the total impact energy absorption *via* plastic deformation

Es, the peak impact force *Fp*, the compressed displacement of the tube δ_e, and the average impact load *Fm*. The average impact force *Fm* is given by equation (1),

$$F_m = \frac{E_s}{\delta_e} \quad (1)$$

Where *Fm* is arithmetic average value, with *Fm* increasing, the absorbing energy of the tube will be increased. The greater the *Fm*, the more energy is absorbed, and the better the crew safety. Therefore, in precondition of not more than the permission peak value, the bigger the average impact load is, the better the absorption performance is, and the shorter the compressed displacement is, the better the absorption performance is [8].

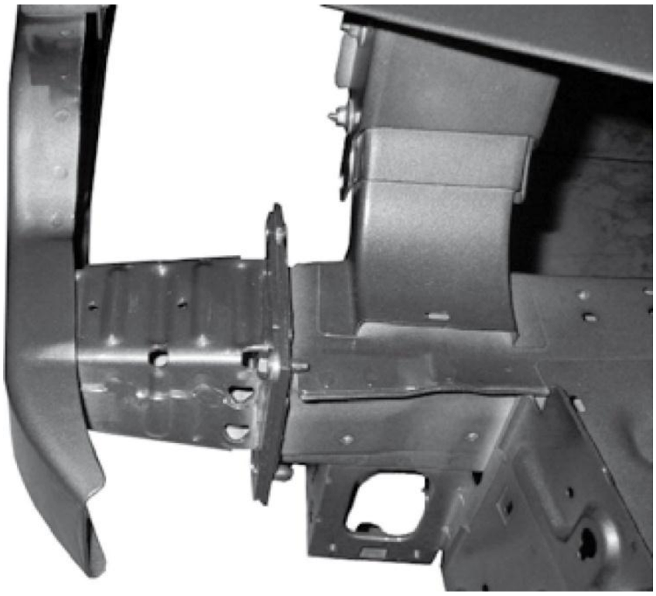

Fig.(2). Structure of crash-box.

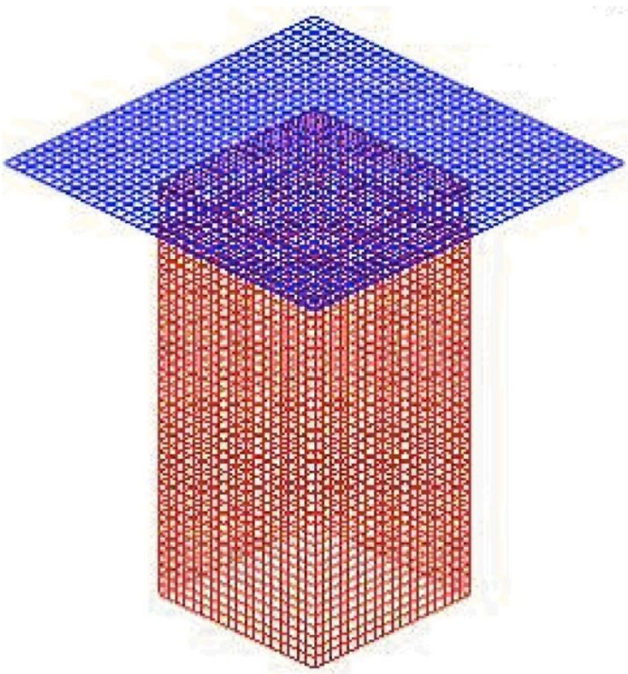

Fig.(3). Mesh model of the tube.

III. MAININFLUENCINGFACTORSTOCRASH-WORTHINESS

There are many factors that can influence crashworthiness characteristics of crash-box in collision simulation process, including crash-box shape, wall thickness, material and soon, in which material properties have great effects on device characteristics. In this paper, influence of material properties to crash-box is chiefly researched.

3.1 Material Strain Rate

Vehicle crash simulation, the effect of strain rate to automobile crashworthiness cannot be ignored.
The energy absorption character of the square cross-section tube on axial low velocity impact is simulated by LS-DYNA. The tube finite element mesh is illustrated in Fig. (**3**). The tube is modeled using steel, yield strength, σy = 430MPa, Density, ρ = $7.85\text{x}10^{-6}$ kg/mm^3, Poisson ratio, v = 0.3 and Young's modulus, E = 210GPa.

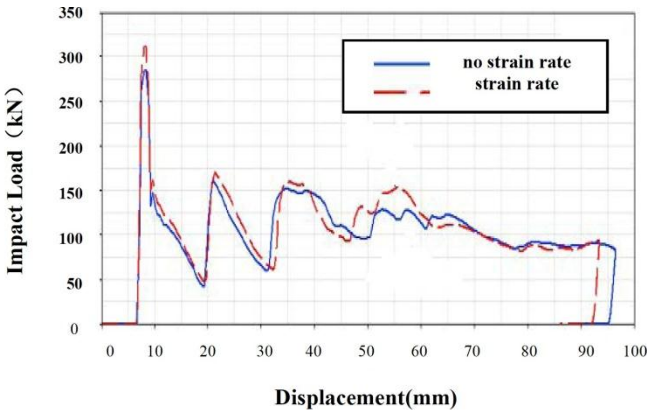

Fig.(4). Impact load-displacement curve of crash-box,

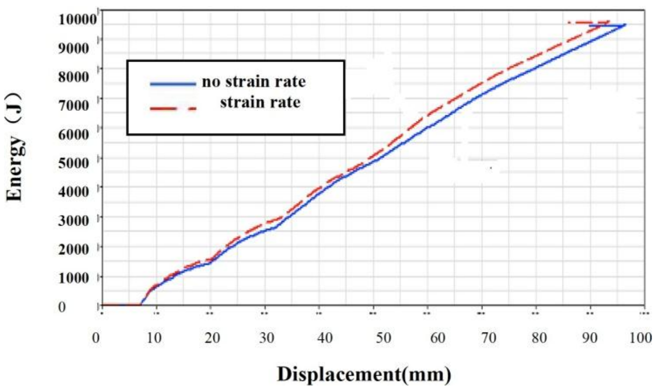

Fig.(5). Energy-displacement curve of crash-box.

The curve of impact load*vs* displacement is shown in Fig.(**4**). The curve of energy *vs* displacement is shown in Fig. (**5**). The curve of energy *vs* time is shown in Fig. (**6**). Table **1** provides a comparison of the main parameters (peak values of impact load for tubes and displacement) obtained by no strain rate and strain rate.
Comparing the simulation results, the energy of the impact is absorbed almost completely for the two conditions, the energy absorption considering strain rate is better than

Not considering the effect of strain rate. But the energy absorbing distance of considering strain rate model is less than that not considering strain rate model, the energy absorption considering strain rate is better than not considering the effect of strain rate.

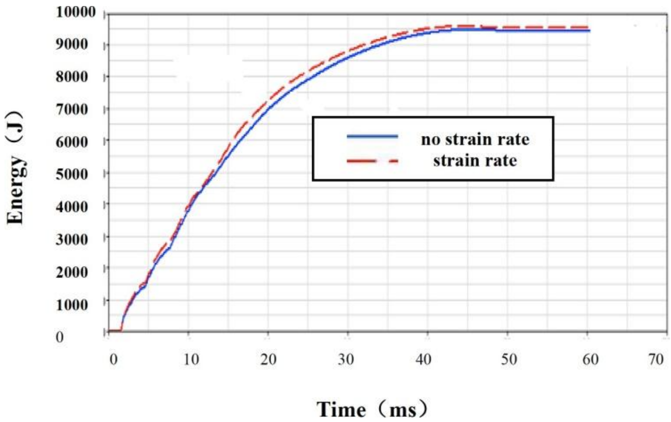

Fig.(6). Energy-timeofcrash-box.

Table1. Comparisonofresultsnostrainrateandstrainrate.

	PeanImpactLoad(kN)	**Displacement(mm)**
Nostrainrate	288.00	97
Strainrate	311.00	93

3.2 MaterialYieldstrength

The tube was modeled using steel, in this paper, Density,ρ = 7.85 x 10-6kg/mm^3, Poisson ratio, v= 0.3 and Young'smodulus, E = 210GPa. Yield strength, σ_y = 430MPa and σ_y =516MPa, on the square cross section tubes were adopted as shown in Fig.(**3**). FE simulation results are shown in Fig.(**7**). The peak values of impact load for tubes are shown inTable**2**.

Results showed that the energy absorption characters of thin-walled tube of square cross section had been increased greatly when yield strength raised. Where the peak value of impact load was 370.1kN, increased about 19% compared with σy = 450MPa, and displacement was 73.25mm, decreased about 27.2% compared with σ_y = 450MPa.

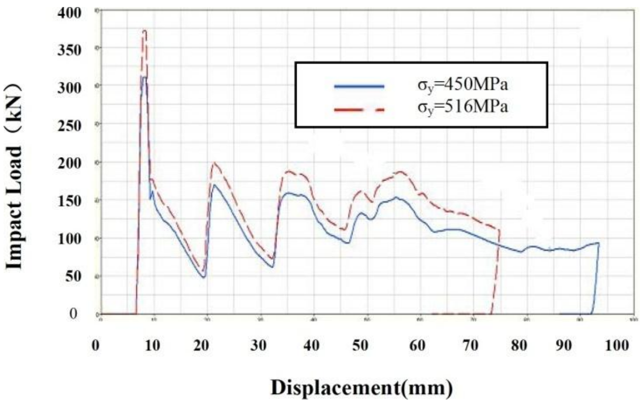

Fig.(7). Impact load *vs* time curve of crash-box.

Table2. Comparison of results energy absorbing characteristics

	Peak Impact Load(kN)	**Displacement(mm)**
σy=450MPa	311.00	93
σy=516MPa	370.1	73.25

3.3 Material Type

There are many types of metal materials; steel is the common type of automobile crash-box, which is used in a wide variety of impact loading applications, since it is relatively cheap, versatile and efficient for absorbing energy. With the rapid development of automobile industry, the light weight materials have been applied in the automobile. Aluminum alloy material through the extrusion forming is subjected to the extensive concern [8].

In this paper, the tube is modeled using steel (Density, ρ = 7.85 x 10-6kg/mm^3, Poisson ratio, v= 0.3 and Young'smodulus, E = 210GPa.yield strength, σ_y = 430MPa) andaluminum alloy (Density, ρ = 2.81 x 10^{-6}kg/mm^3, Poisson ratio, v=0.33 and Young's modulus, E=71GPa. Yield strength, σ_y = 455MPa). On the square cross section tubeswere adopted as shown in Fig. (**3**). Comparison results of collision aluminum alloy and carbon steel crash-box are shown in Figs.(**8**, **9**).

The peak values of impact load for tubes with different material are shown in Table **3**. Results showed that all the energy was almost absorbed by two materials, because the energy curve finally turned to a horizontal line. The peak impact of tubes is fundamentally different when different material is adopted. The peak impact of aluminum alloy tubes decreased 37.34 kN compared with steel, and displacement increased 20mm compare with steel.

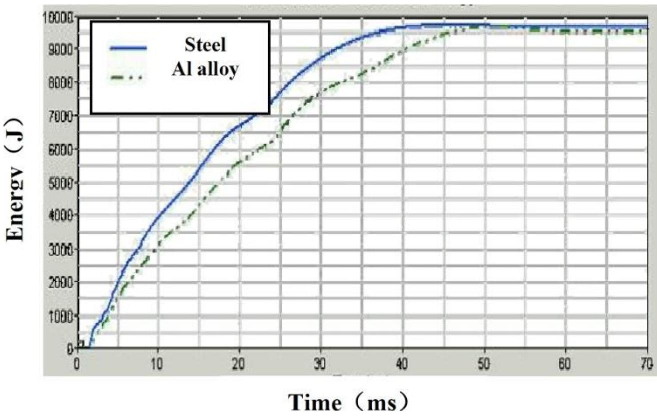

Fig.(8). Energy curve of the tube for the two kind of materials.

IV. CONCLUSION

The automobile low velocity impact is a very complex mechanical problem, and theory analytical solution is quite difficult. So computer simulation is an effective method. Through study models of material parameters, material properties on automobile energy-absorbing components

Crashworthiness has very important influence. Suitable results of the design are obtained by change material parameters. Material strain rate, material yield strength and material type have certain effect to crash worthiness of energy-absorbing component.

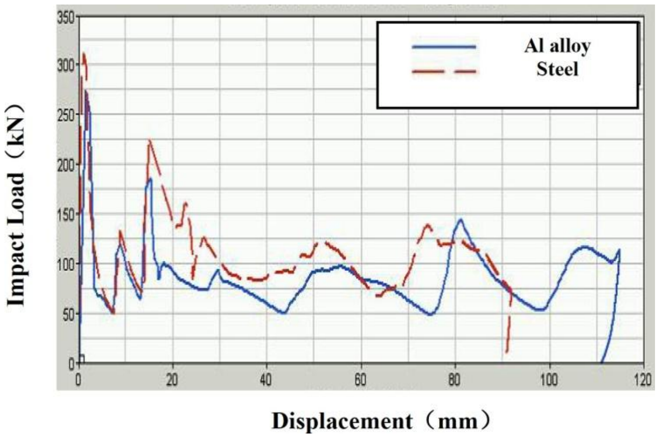

Fig.(9). Impact load *vs* displacement curve of the tube.

Table3. Comparison of results energy absorbing characteristics.

	Peak Impact Load(kN)	**Displacement(mm)**
Carbon sheet	311.00	93
Aluminum alloy	273.66	113

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