A Study of using Different Crash Box Types in Automobile Frontal Collision

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***Abstract* — The automobile crash-box, or crumple zone, is an important part in the safety in vehicle collisions. Good performance of the energy absorbing crash-box results in lighter damage to vehicle and other components with lower repair cost. In this paper, the Finite Element (FE) method is applied to model the structure and material of the crash-box. Modelling and simulation using the software LS-DYNA was carried out. The crash-box is frequently constructed from metal thin walled pipe. Carbon steel with aluminum alloy material pipe is another method of construction. A feasible transversal surface shape of the pipe was seen to give the best 'crash worthiness' in a collision. Five types of transversal surfaces are presented and contrasted. The result in the repair cost of the pipe was shown to be the best when employing aluminum alloy square cross section.**

Keywords- Automobile; Low velocity impact; Crash-box; Frontal collision ;Repair cost; Anti-freeze-thaw strength.

I. INTRODUCTION

The automobile collision is an significant problem in automobile safety, because automobile safety involving life and property of people. For the present, when automobile high velocity impact, the death and injuries often happens, so, people pay attention to the high speed impact. However, the low speed collision always occurs in the crowded city [1, 2]. Low speed collisions usually do not damage, often overlooked. It is therefore, low speed impact research is particularly important. Low speed frontal collision include completely overlap 100%and 40% offset impact(see Fig.1).

Crash-boxes (Fig.2) play an important role in automotive parts. It is not only to protect car occupants and external pedestrian safety, reduce the degree of damage effect, but also to reduce the damage to vehicles and other components [3]. It can also reduce the repair cost of vehicle in the crash occurred.

This text, the motor vehicle crash-boxes in low-speed frontal collision was researched, and repair cost on automobile components is proposed

II. COMPLETELY OVERLAP FRONTAL COLLISION

A. Influence of Different Materials on Repair Cost

1) Model Building

In this paper, crash-boxes were made of thin walled pipe, and FE model was designed by the software Hypermesh [4,5]. Firstly, the circular cross-section pipe (160mm long, Φ90mm diameter and 1.65mm thick) was researched. The mental circular transversal surface pipe, is a ordinary style vehicle crash-box for it is opposite versatile, inexpensive and effective energy absorption [6,7]. The rigid flat plate is1000kg, axially impacted speed of 4.44 m / h on the top of the pipe .With the flat plate at low speed collision the circular cross-section pipe in axial, the circular pipe FE mesh is example in Fig. 3.

Figure1. 100% and 40% frontal collision of vehicle.

2) Main Influencing Factor to Crashworthiness

There are many factors that can influence crashworthiness characteristics of crash-box in collision simulation process, including energy absorbing structure shape, wall thickness, materials and so on, in which material properties has great effects on device characteristics [8].

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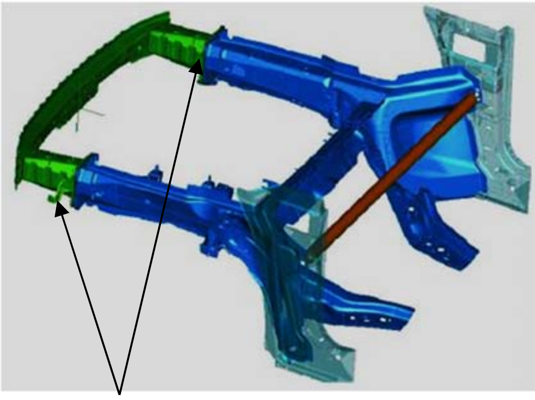

crash-boxes

Figure2. Position of crash-boxes in the vehicle body

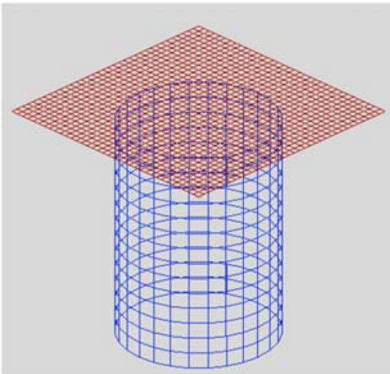

Figure3. The circular pipe mesh model

3） Main Influencing Factor to Crashworthiness

There are many kinds of materials in automobile manufacturing industry, lightweight material has always been a hot spot [9]. Aluminum alloy material is one of the typical lightweight materials.

In this work, the pipe was manufactured using 7075 aluminum alloy and carbon steel. Table 1 provides the main material characteristics parameters .

TABLE I. MATERIAL HARACTERISTICS

	Yield strength (MPa)	*Density(kg / mm)*	*Poisson ratio*	*Young's modulus (GPa.)*
Carbon sheet	430	7.85 x 10^{-6}	0.3	210
Aluminum alloy	455	2.81 x 10^{-6}	0.33	71

4） Crashworthiness Contrast

Imitated Fig.3 FE modeling technique, adopt the same boundary conditions and circumference, aluminum alloy and carbon steel pipe were emulated. Aluminum alloy crash-boxes collision result were shown in Fig.4 and carbon steel collision result were shown in Fig.5. Table 2. is the impact load crest value to pipes with different material **.**The result show that the two materials energy were almost completely absorbed. The crest value impact loads of pipe decreased with aluminum alloy material to 37.34kN.

TABLE II. ENERGY ABSORBING CHARACTERISTICS COMPARISON

	Crest value load (kN)	*Reduction percentage（%）*
Carbon sheet	310.10kN	
Aluminum alloy	272.76kN	12.04

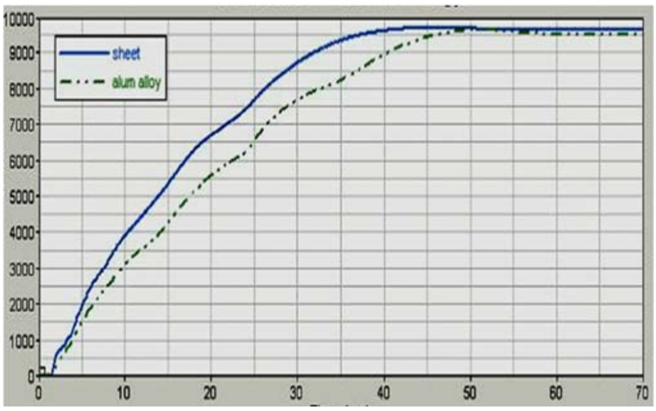

Figure4. Time vs. energy curves .

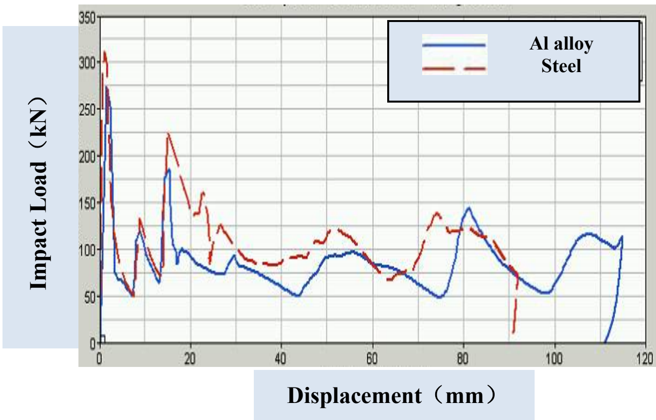

Figure5. Displacement vs. impact load curves

By comparison, the crash-box of aluminum alloy material is better than carbon steel material to absorb energy in completely overlap low speed collision.

B. Influence of Different Structures on Repair Cost

1）Model Building

The ideal crash-box has two indexes in energy absorption characteristics. One, absorbing most of the energy through the plastic deformation itself , this part of the energy is a big proportion In all energy, the other is displacement - impact load smooth curve and no crest load [10,11].

2）Structures Selection

Thin-walled aluminum alloy pipes of five types were compared and researched .The five pipe circumference are equal, Fig. 6 is the mesh model of the five pipes , where, (A) rectangle transversal surface, (B) square transversal surface , (C) circular transversal surface, (D) hexagon transversal surface, and (E) octagon transversal surface.

The five pipes are 1.65mm thick, 120mm long, 280mm circumference, simulated with 7075 aluminum alloy. The 7075 characteristics are showed Table 1.

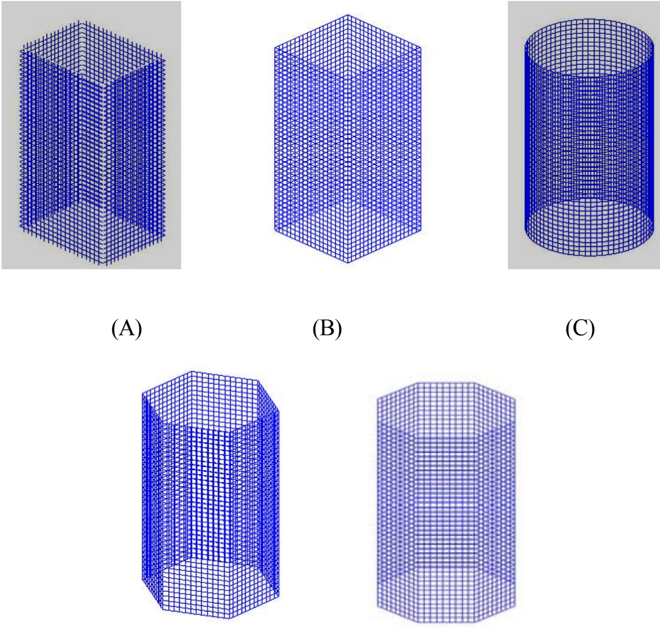

Figure6. Mesh model pipes.

3） Crash-Worthiness Comparison

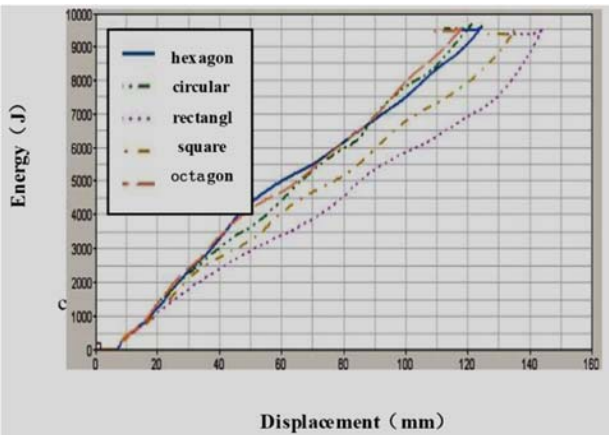

Figure7. Displacement - energy curves.

From Fig.7 (displacement - energy curves), and Fig.8 (displacement - impact load curves), we can find that the shape (B) is the best transversal surface shape. The crest value impact load for five different transversal surface pipe is (rectangle) 238.43kN, (square) 274.67kN, (circular) 273.82kN, (hexagon) 277.28kN, and (octagon) 239.69kN separately. 180kN is permissible value of impact, the crest value of five model is more than the 180kN. The lowest one is square section, among them, Therefore, the shape(B) thin-walled pipe will be optimized farther.

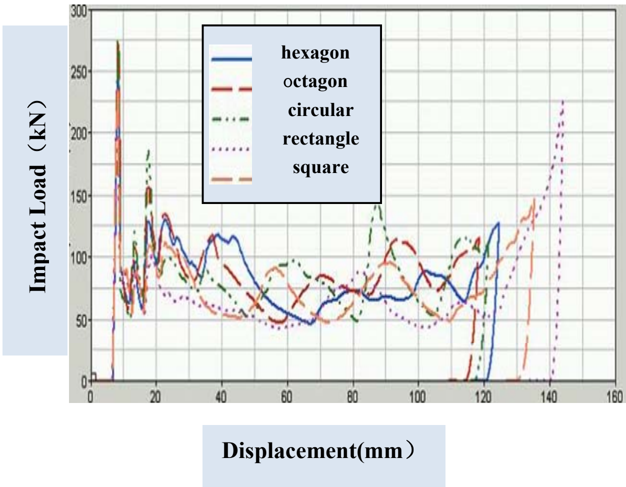

Figure8. Displacement - impact load curves.

III. 40% BIASING FRONTAL COLLISION

A. *Influence of Different Structures on Repair Cost*

1）Model Building

In this paper, 40% Biasing Frontal Collision on the basis of Research Council of Automobile Repairs [12,13], Fig. 9 is the RCAR test regulation. Fig. 10 is FE model of the vehicle impact. RCAR test regulation collision speed is 4.44 m / h, belong to low speed collision.

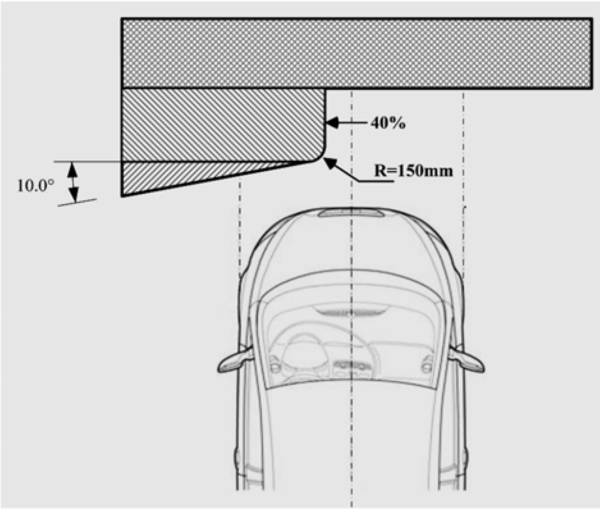

Figure9. RCAR test regulation.

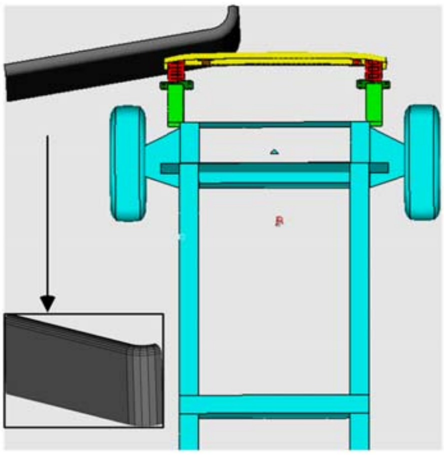

Figure10. The finite element mode of RCAR test regulation

2） Material and Structures Selection

The 40% offset automobile collision , velocity is 4.44 m / h. All the pipes were simulated with 7075 aluminum alloy and same five types of thin-walled pips as 100% frontal collision were compared and researched .

3） Crashworthiness Comparison

Fig. 11.and Fig. 12 are absorption energy value of the five pipes and absorbing energy percentage of five pipes respectively.

On the basis Fig. 11.and Fig. 12, we see that the shape(B), where the energy absorption value is 9412.3J, energy absorption accounted percentage of total energy is 93.23% , and the valve accounted percentage of all internal energy is 97.76%. These three are the biggest .So, in terms of energy, shape (B) is desirable.

Comparing simulation results(time vs. impact load)as illustration in Fig. 13. Fig. 14 is impact crest load of the five pipes.

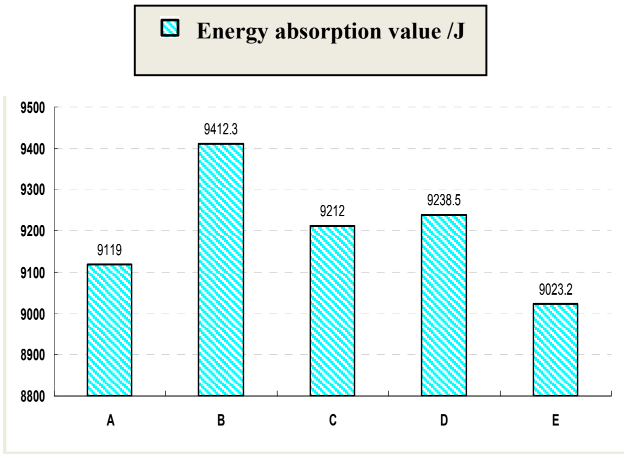

Figure11.The five pipes absorption energy value

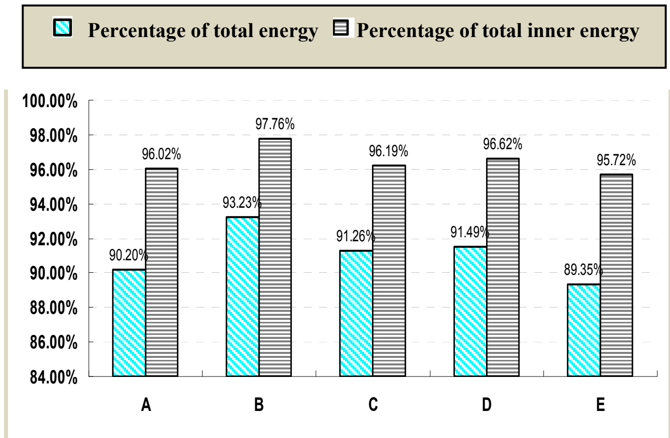

Figure12. The five pipes absorbing energy percentage

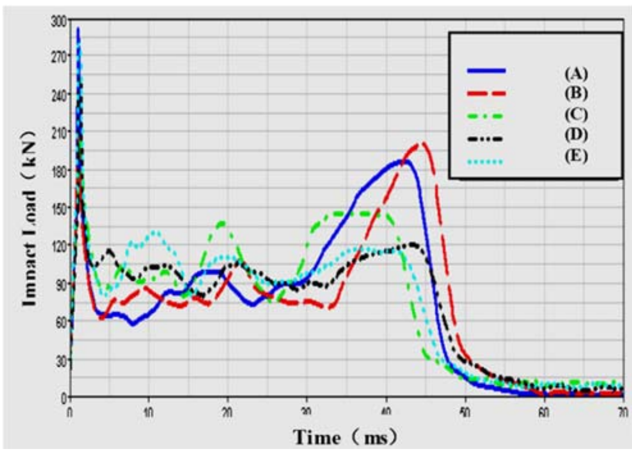

Figure13. Impact load vs. time

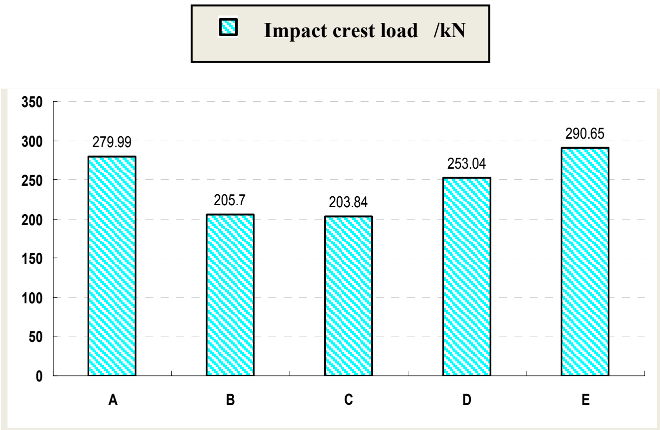

Figure14**.** The five pipes impact crest value

On the basis of Fig. 8 and Fig. 14, we can find that impact crest value load of the shape(E) is the largest , and the shape(B) is the smallest .So, considering of the collision crest value load, the shape(B) is desirable .

So that this square thin-walled pipe crash-box has better than the other four transversal surface shape crash-box .

IV. DISCUSSION

Low speed collision occurs, if the front crash-box crashworthiness is very poor ,vehicle will damage front longitudinal beam. The front longitudinal beam repair costs are usually the bumper and the crash-box component replacement costs several times. The front longitudinal beam repair process is complex, the cost is high, and vehicle safety will be affected after the repair .

So, the crash-box aluminum alloy of square cross section crashworthiness is good , no matter completely overlap 100% or 40% offset impact. The right model selection, will reduce the cost of repair.

V. CONCLUSION

The silica powder concrete compared with conventional concrete, not only the excellent mechanical properties, the freeze-thaw cycle number > 500, but also the durability of the material with good freezing and thawing.

The silica powder improve the internal structure of concrete, which leads to 300 freeze-thaw cycles, the decrease of relative dynamic modulus of elasticity is small. The silica powder improved the properties of concrete itself, increase the adhesive force between materials, limiting the concrete crack propagation, maintains the integrity of concrete.

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