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CRASH ENERGY ABSORPTION OF MULTI-SEGMENTS CRASH BOX UNDER FRONTAL LOAD

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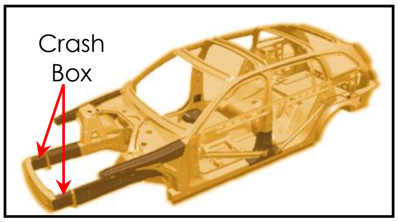
Graphical abstract



Abstract

Crash box designs have been developed in order to obtain the optimum crashworthiness performance. Circular cross section is first investigated with one segment design, it rather influenced by its length which is being sensitive to the buckling occurrence. In this study, the crash box with multi-segments design is investigated and the deformation behavior and crash energy absorption are observed. The crash box modelling is performed by finite element analysis on cylindrical crash box with multi segments design. The numbers of crash box segments used in this investigation are two segments, three segments with a sequence diameter and three segments with alternating diameter. The crash test components were impactor, crash box, and fixed rigid base. Impactor and the fixed base material are modelled as a rigid, and crash box material as bilinear isotropic hardening. Crash box length of 100 mm and frontal crash velocity of 16 km/jam are selected. Crash box material of Aluminum Alloy is used. Based on simulation results, it can be shown that three segments crash box with alternating diameter design has the largest crash energy absorption. From deformation pattern has showed that three segments crash box absorbs low energy at the beginning of crashing. Energy absorption start increased at the boundary area of the first, second and three segments as a result of increasing inertia where critical load has increased hence buckling phenomenon could be minimized.

Keywords: Ccrash box, multi segments, frontal load

1.0 INTRODUCTION

The crashworthy systems utilize crash box which is mounted between bumper and front frame of the car. Crash box has function to absorb energy resulted of the crash during frontal collision. The impact energy absorbed will cause deformation of the crash box itself, thereby reducing the impact to the passenger. Study on the various cross-sectional of crash box has been carried out to obtain design with high impact energy absorption ability. There are square [1], rectangular, hexagonal and octagonal cross-section tube design [2]. Higher specific energy absorption resulted in circular tube design compared to square and rectangle tube [3]. Some investigations on bumper structure with the cross-sectional variation of crash box provide information on the proportion of energy that is absorbed by the bumper and the crash box [4].

There are many researches on crash box design were performed using one segment of tube. With one segment, the crash box length dimension is very sensitive to the occurrence of buckling. The aim of this study is to get energy absorption characterization on multi-segment of crash box by observe the deformation behavior and the ability to absorb crash energy. Deformation patterns associated with the possibility to get a reduction in Peak Crushing Force and increasing of Crushing Force Efficiency. The crash box design allows the development of different materials in each segment and is expected to provide an increase in the acceptable of critical load limits.

2.0 LITERATURE REVIEW

Crash boxes are a thin walled structures mounted between automotive chassis and bumper which are used as energy absorption during crash event (Figure 1). These elements are part of the crashworthy system used to reduce the severity of accidents due frontal crash. These structures play important role to absorb the impact energy of the frontal crash by plastic deformation to protect the occupants. Crash box is desirable to be deformed by absorb impact energy before striking another vehicle parts such as frames and cabins to ensure the overall integrity of chassis, hence passenger safety. During crushing, these structures will exhibit plastic deformation by collapse and sequential folding process. Therefore, the plastic deformation process must be controlled to absorb as much energy as possible thus the severity of injury could be minimized. Thus, there have been many studies on investigating the behavior of crash boxes to improve energy absorption under frontal crash.

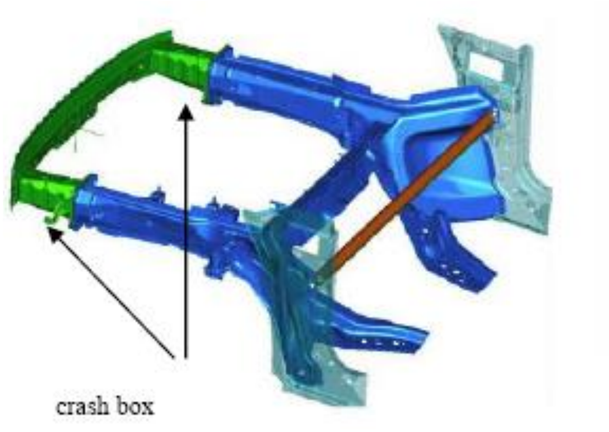


Figure 1 Crash box placement on chassis [6]

3.0 METHODOLOGY

The investigation on multi-segments of crash box was performed by using finite element method-based program ANSYS 14.5. Crash box design with a length of 100 mm has rectangular and circular cross-section was simulated with frontal crash direction. The numbers of crash box segments used in this study are two segments, three segments with a sequence diameter (type 1) and 3 segments with alternating diameter (type 2) as show in the Figure 2. Each segment was connected as press-fit. The crash test components were impactor, crash box, and fixed rigid base (Figure 3). Impactor and the fixed base material are modelled as a rigid, and crash box material as bilinear isotropic hardening. The velocity of frontal load 16 km/hour is selected and the material of Aluminum Alloy is used. From examination the energy absorbed was recorded and the deformation pattern was observed.

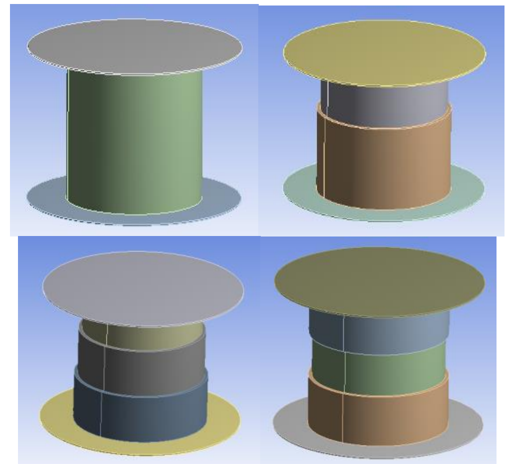


Figure 2 Crash box model: 1 segment, 2 segments, 3 segments (type 1) and 3 segments (type 2)

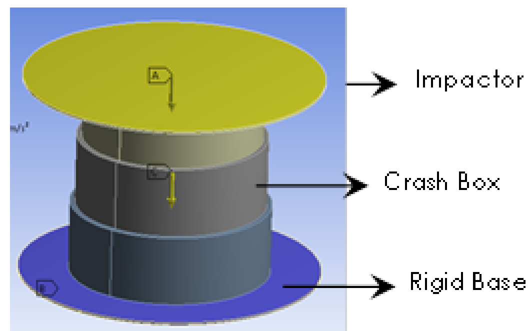


Figure 3 Crash box modelling component

4.0 RESULTS AND DISCUSSION

4.1 Energy Absorption

The deformation behavior of circular multi-segments after crash was observed. The difference result between one segment crash boxes was verified. From simulation result as shown on Figure 4, it can be pointed out that crash box design with 3 segments of alternating diameter (type 2) has better ability to absorb energy. While crash box design with 1 segment and 3 segments of sequence diameter (type 1) have shown lower crash energy absorbed during frontal test simulation.

In the beginning both multi-segments crash box design with 2 segments or 3 segments have slight increasing of energy absorbed. The dramatic increase in energy absorbed was occurred in middle of collision for multi-segments models as shown in high steep slope. This fact was the characteristic of multi-segments cashbox design. Deformation has started to occur at the first segment, then continue penetrated to the second segment with typical deformation pattern. The high energy absorbed in this step was due to the increase of critical load related to the increase of inertia of crash box. All this process was take place in the boundary between first segment and second segment.

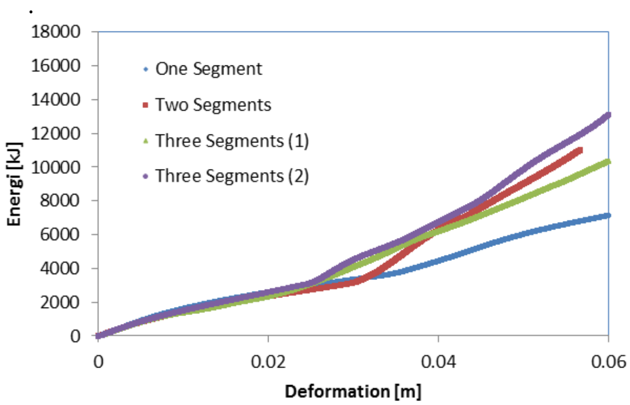


Figure 4 The relation between energy absorbed with deformation for all models of crash box

4.2 Deformation Pattern

The deformation occurred during collision was obtained trough deformation pattern observation. Figure 5, Figure 6, Figure 7 and Figure 8 show the feature of folding mechanism for all models, crash box with one segment and multi-segments. In general, deformation was occurred in axial mode with a typical collapse shape named as concertina. During collision, the thin wall of crash box is suffering a high impact load. Crash box structure is pushed under axial compression which leads to the structure collapse. Plastic deformation was occurred since crash box structure could not resist the high impact load by fold its wall. Alteration in the shape does not occur in Euler buckling and this affected area undergo lateral deflection which are symmetrical with respect to the axis of crash box. During this fold mechanism pointed out that the impact energy is absorbed by crash box structure [7, 8].

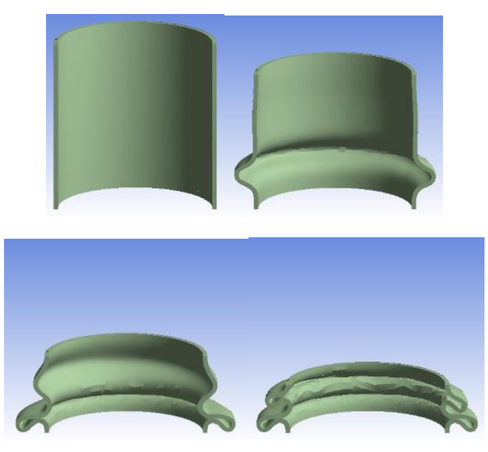


Figure 5 Deformation sequence of one segment crash box

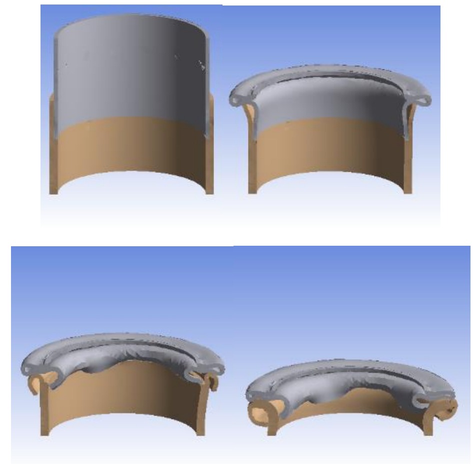


Figure 6 Deformation sequence of two segments crash box

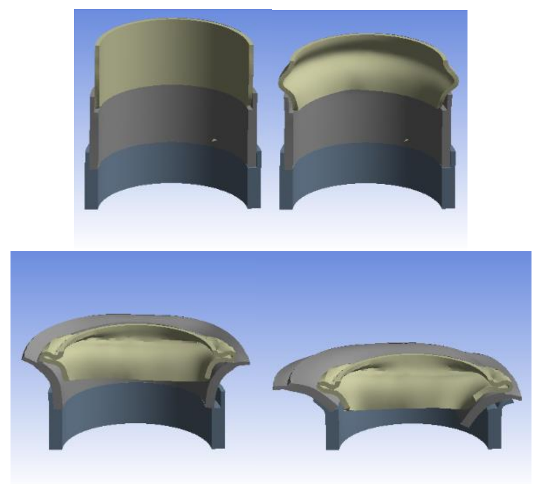


Figure 7 Deformations sequence of three segments crash box (type 1)

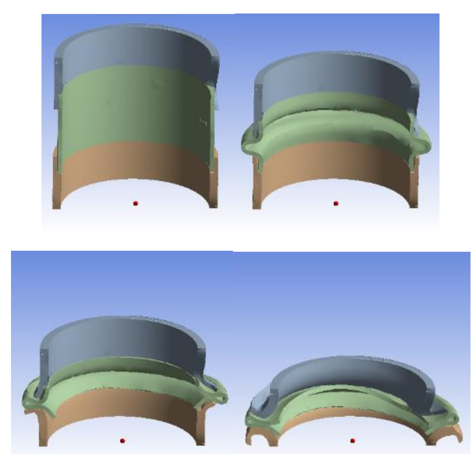


Figure 8 Deformation sequence of three segments crash box (type 2)

The deformation results revealed that the deformation pattern is correspond with energy absorption as depicted on Figure 4. One segment crash box on Figure 5 shows a constant in increasing of energy absorbed which is related to the folding occurred. While multi-segments crash box has increase of energy absorbed when the first segment tries to penetrate into the adjacent segment result in a number of folding occurred as shown on Figure 6-8. This deformation pattern is increase due to crash box structure deformed to absorb the frontal load.

The curve plotted on Figure 4 indicated that 3 segments crash box (type 2) has the highest energy absorption capability compared to other models. Within three segment crash box models, type 2 is better than type 1 since a buckling was occurred at the last folding process due to asymmetric deformation. Deformation with buckling has become the cause of decreasing of energy absorbed. It is known that energy absorbing device is subjected to axial load; plastic deformation occurs within the shape parameter crash box control and stabilizes collapsing of the whole structure [9].

5.0 CONCLUSION

Crash simulation under frontal load was carried out on circular crash box design with one segment and multi-segments. Variation on segment combinations was intended to obtain the better performance in crash energy absorbing. Deformation pattern for all models were occurred axially in concertina mode. The folding mechanism is corresponds to the impact energy absorbed. Multi- segments crash box design with three segments of alternating diameter (type 2) has better ability to absorb energy. The high increasing of energy absorbed was occurred in the middle of collision when the deformation flow started to penetrated into the adjacent segment. Buckling phenomenon was occurred in three segments with sequence diameter (type 1) model and has become the cause of decreasing of energy absorbed.

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