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DEVELOPMENT OF CRASH-BOX FOR PASSENGER CAR WITH HIGH CAPABILITY FOR ENERGY ABSORPTION

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Summary. *A new design scheme of cross sectional shape of a crash box to ensure high crash energy absorption has been proposed. By the new design, not only high and stable deformation load but also detailed wrinkles generated during axial collapse have been acquired.*

1 INTRODUCTION

Crash box, with which a car is equipped at the front end of its front side frame, is one of the most important automotive parts for crash energy absorption. In case of frontal crash accident, for example, crash box is expected to be collapsed with absorbing crash energy prior to the other body parts so that the damage of the main cabin frame is minimized and passengers are saved their lives. Conventionally, a crash box is equipped with several ditches as shown in figure 1, called "crash beads", so that those crash beads may initiate buckling deformation and make the crash box easily collapse. Recently, it has been strictly required to satisfy both reduction of body weight and improvement of crash worthiness and thus, regarding crash box, it is required to ensure high energy absorption using sheet as thin as possible. However, there is often the case that the crash beads do not work as designed when a thin sheet is applied as the material for a crash box and thus, it has become difficult to acquire sufficient energy absorption only by the crash beads.

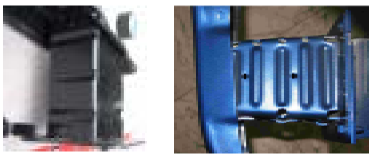


Fig.1 Crash beads.

In this report, attention is focused upon finding an optimum cross sectional shape of a crash box to ensure high capability for energy absorption without crash bead. By making use of FEM, first a mechanism through which a body part absorbs crash energy in axial collapse was clarified and then, the influence of cross sectional shape of the part on energy absorption was quantitatively revealed. Finally, a new design scheme of cross sectional shape of a crash box was proposed.

2 ESTABLISHMENT OF FUNDAMENTAL THEORY

2.1 Crash deformation control by cross sectional design

First of all, axial collapse analysis of a hat channel, which was chosen as a representative shape of an automotive part, was carried out in order to clarify fundamental phenomena caused throughout crash deformation. As shown in Figure 2, first, crash deformation is initiated at a certain area of the ridge lines where compressive strain is locally accumulated, as the ridge lines have higher rigidity than the other portions. Then, plastic buckling arises at the above area and thus bending is caused at the plane between the ridge lines, that is a wrinkle. Finally, after the wrinkle is folded, a new plastic buckling is caused at another area of each ridge line just below the above wrinkle. The relationship between those phenomena and deformation load can be explained by Figure 3. From the start, the load increases until the initial plastic buckling is caused and reaches the maximum value point. Then after the buckling, the load decreases to the minimum value point when the wrinkle is completely folded. The same applies to the following deformation and thus, the load fluctuates throughout the collapse.

In summary, the main points to improve the impact energy absorption can be concluded in three points;

(1) ensuring high buckling load at the ridge lines,
(2) minimization of buckling cycle time, and
(3) minimization of load fluctuation.

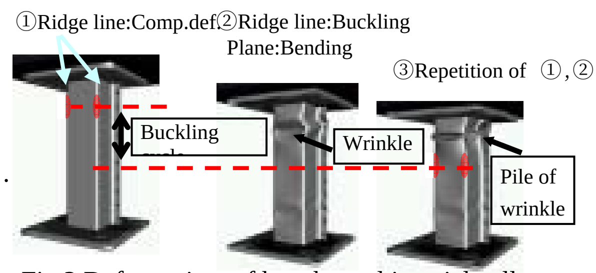


Fig.2 Deformation of hat channel in axial collapse.

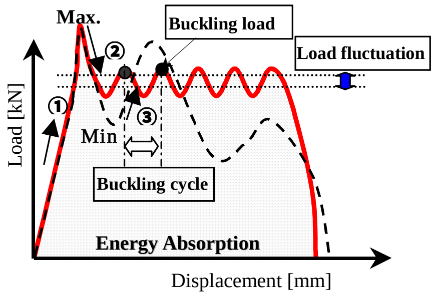


Fig.3 Schematic illustration of deformation load curves.

2.2 Examination of design parameter for controlling plastic buckling

In order to clarify the influences of cross sectional shape on the load and the mode of crash deformation, fundamental analysis was carried out with various polygons, the diameters of the circumscribed circles of which were varied as 60,120 and 240mm, as shown in Figure 4.

Figure 5 shows the analytical results

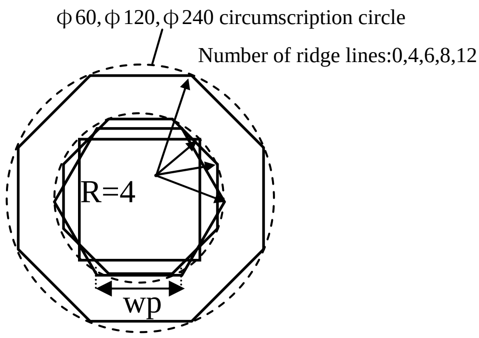


Fig.4 Cross sectional shape of fundamental analysis models.

of square, hexagon, octagon and dodecagon when 120 mm was chosen as the diameter of each circumscribed circle. Ordinate '$P_{std.}$' indicates (or denotes) standardized load which means the deformation load divided by the circumferential length of the cross section of each model.

As clearly shown in the figure, the larger is the number of ridge lines, the higher the maximum 'Pstd' when plastic buckling occurs becomes and also the larger the number of the maximum 'Pstd' points becomes, which means the buckling cycle time becomes smaller. On the other hand, the influence of width of plane between ridge lines on crash deformation is shown in figure 6. The ordinate "Pstd. ave" indicates divided average load from 0 to 160mm displacement by the circumferential length of cross section of each model and another ordinate "Nb" means the number of bucklings generated throughout the crash deformation. The shorter is the width of plane, the higher "Pstd.ave" becomes and the larger "Nb" becomes.

As a result, it can be concluded that in optimising cross sectional shape for ensuring crash capability for energy absorption, the width of plane is much more important design parameter than the number of ridge lines.

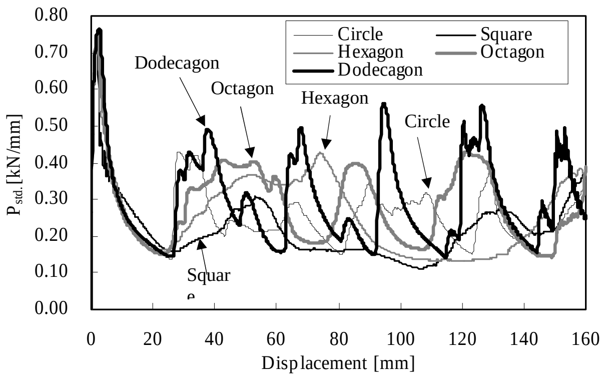


Fig.5 Analytical results (circumscribed circle =ϕ120).

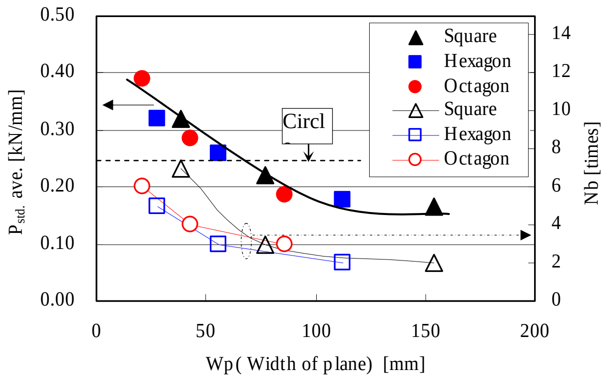
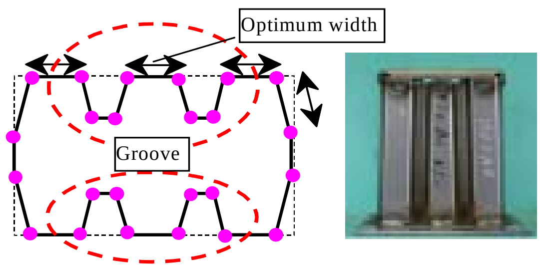


Fig.6 Effect of Wp on P_{std}. ave. and Nb.

3 NEW DESIGN OF CRASH BOX

3.1 Application of theory based on analytical results to actual part design

As shown in Figure 7, in designing a new crash box, the important design parameters discussed in the previous section were carefully examined and a new design of the cross sectional shape was established by which four grooves were adopted to its cross section for ensuring optimum width of plane. As a result, the crash box has as many ridge lines as 24 and thus, not only high buckling load can be obtained, but also plastic buckling can be easily caused by impact load in optional direction.



(a) Cross sectional shape (b) Appearance

Fig.7 Design for new Crash box.

3.2 Crash performance of developed crash box

In order to evaluate the crash performance of the developed crash box, both weight drop experiment and FEM analysis were carried out in which the crash box, made of 590MPa HSS, was collapsed in axial direction at a speed of 25km/h. As shown in Figure 8, not only high and stable deformation load but also fine detailed wrinkles were obtained. As clearly shown, moreover, the analytical result showed good agreement with the experimental result.

Figure 9 shows the comparison of energy absorption between the new and conventional crash boxes made of 440MPa HSS. The right ordinate Pave is the average deformation load and the left ordinate EP is the divided value of Pave by the part's weight. As clearly shown, the developed crash box can absorb twice the impact energy of the conventional one which means that the weight of a crash box can be drastically reduced with ensuring high crash worthiness by applying the developed design to the part.

As a result, it can be concluded that the newly developed design scheme of cross sectional shape is effective both in improvement of crash capability and in reduction of part weight.

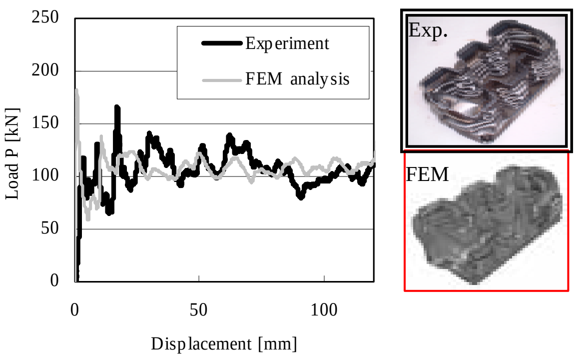


Fig.8 Crash performance of new crash box.

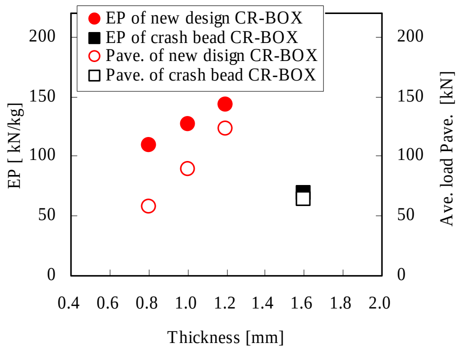


Fig.9 Comparison of energy absorption efficiency between new and conventional crash boxes.

4 CONCLUSIONS

An innovative philosophy of crash box design has been successfully proposed. High crash energy absorption can be achieved. As the most important design parameter, the influence of the width of plane between ridge lines on crash deformation was quantitatively clarified. A new design scheme was successfully adopted to a real crash box by applying grooves to cross sectional shape to ensure the optimum range of the width of plane. As a result, the new crash box satisfies the both demands for improvement of crash worthiness and reduction of part weight. The new design philosophy can change the whole design of automotive parts for crash energy absorption, and definitely contribute to drastic weight reduction of steel parts.

REFERENCES

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