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EXPERIMENTAL INVESTIGATION ON THE MAXIMUM AXIAL FORCE OF AN ALUMINUM SQUARE COLUMN

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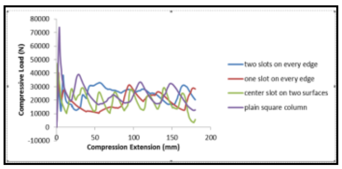
Graphical abstract



Abstract

Energy absorption is one of the characteristics that must be included especially in transportation systems. This property dissipates kinetic energy during collisions. Normally, industries use thin wall structures because of their ease of fabrication, high performance, and low cost. This study determines the first peak force and energy absorption of an aluminum square column. The square columns prepared with various design patterns exhibited different results. The designs showed favorable results in terms of increasing the specific energy absorption and reducing the initial peak force. To achieve the project objective, this project conducted two types of analyses using INSTRON 3382 for the experimental analysis.

Keywords: Crush, quasi-static and compressive load, specific energy absorption, initial peak force, thin-walled column

1.0 INTRODUCTION

In this project, a hollow square column made from an aluminum alloy material was used as a structure specimen. The aluminum structural material has gained much popularity in its application to the automotive industry, especially applications that involve energy absorption combined with low weight. In fact, European car manufacturers such as Lotus, Audi, and Renault use many aluminum structures in their cars [1]. The hollow square column effectively serves as an excellent kinetic energy absorber of the structures by conducting plastic deformation during a crash, and it also has important components that improve a vehicles crashworthiness [4].

This study aims to determine the initial peak or maximum force. According to the injury criteria, the increased value of maximum force of the initial peak force may cause serious damage or injury to passengers. The maximum force restriction ensures that the minimum elastic capacity of the structure does not exceed to prevent damage.

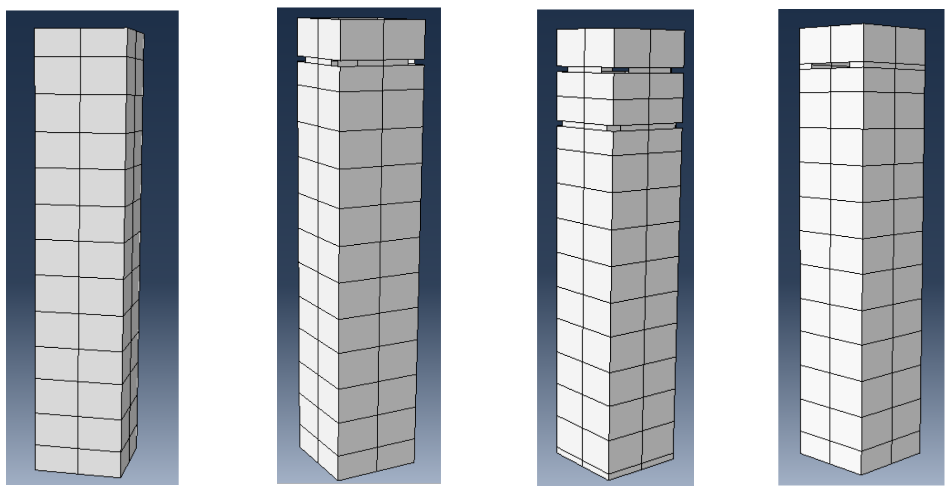
1.1 Experimental

The material selection for this study is made from aluminum alloy (aluminum6063 T5). Its mechanical properties are shown in Table 1. The materials were obtained from Faculty of Mechanical Engineering workshop, UiTM Shah Alam. The type of specimen selected was a hollow square column in a specific dimension obtained from the workshop. The dimensions of the column are 250mm in length, 50mm in width, and 1.7mm in wall thickness. The mechanical properties of this aluminum alloy are shown as follows.

Table 1 Mechanical properties of aluminum 6063 T5

Young's Modulus	Poisson's Ration	Density [kg/m³]	Yield Strength	Ultimate Strength
70 GPa	0.33	2700	214 MPa	241MPa

The specimen was cut manually using a hand saw according to the specimen dimensions. The finishing process was then conducted to increase the surface performance. This process ensures that both surfaces of the specimen are perpendicularly straight to the surface to obtain more accurately results during the testing process. To obtain the slot design, a milling machine with a shank milling 3mm in diameter was used. Figure 1 shows the specimen design with and without slots for analysis.



(a) (b) (c) (d)

Figure 1 Structural Model (a) Plain square column, (b) One slot on every edge, (c) Two slots on every edge (d) Center slots on two surfaces

1.2 Analysis Result

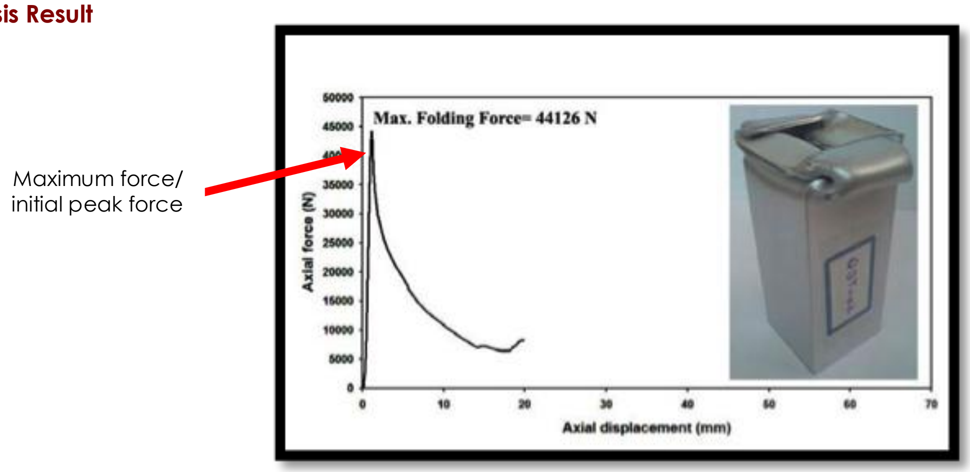


Figure 2 Load displacement curve

As shown in Figure 2, at the beginning, the structure of the curve shows an increase in slope due to the elastic compression of the specimen until it reaches the highest load value. At this point, it is called the maximum force (Pmax). The micro-cracking of the structure that causes a dramatic drop in the curve is observed, and it indicates that the specimen starts folding. Afterwards, the curve increases, decreases, and then fluctuates because of the multiple failures in the structure until the end of the test.

2.0 RESULTS AND DISCUSSION

This section discusses in detail the results of the experiment and the finite element analysis. The results show a load–displacement curve to analyze the characteristic behavior of the structure.

Table 2 shows the experimental square column specimen before and after compression by the INSTRON machine. The compression was performed by a quasi-static force on the top plate, which represents the impact and discrete rigid-body. Figure 3 shows the results illustrated by the load–displacement curves from the experimental analysis.

Table 2 Before and after compressionof the specimen in theexperimental analysis

Specimen Characteristics	Before Compression	After Compression
Plain square column		

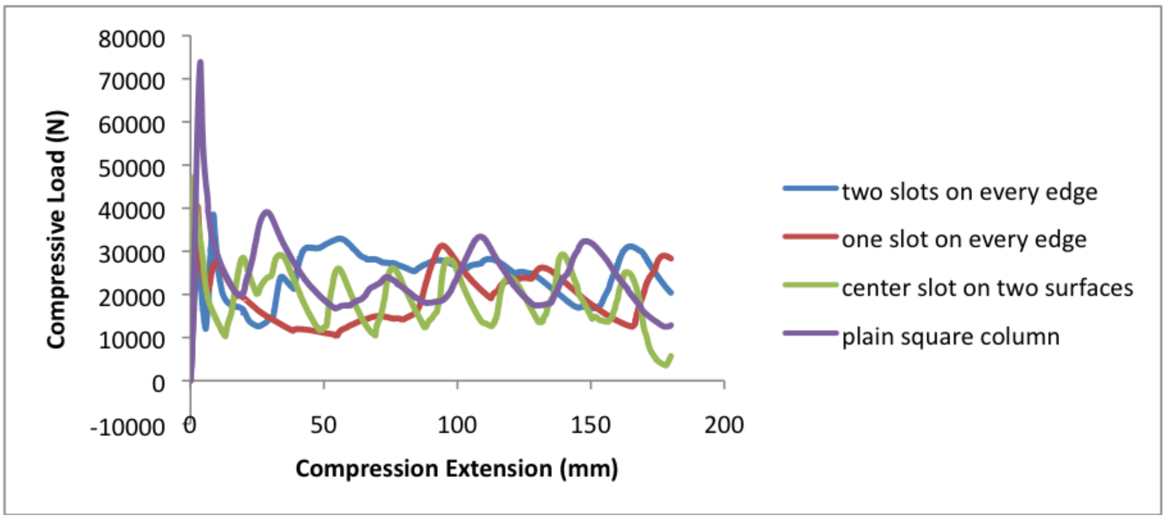


Figure 3 Compressive Load vs. Compressive Extension Curve for (a) Plain square column, (b) One Slot on Every Edge, (c) Two Slots on Every Edge, and (d) Center Slots on Two Surfaces

Table 3 Decrement percentage of peak force for all specimen in experimental analysis

Design	Design Characteristics	Initial Peak Force (N)	Decrement (%)
Specimen (a)	Plain square column	73892.266	0
Specimen (b)	One slot on every edge	40422.227	45.30
Specimen (c)	Two slots on every edge	38532.664	47.85
Specimen (d)	Center slots on two surfaces	47304.577	35.98

In consideration of the physical behavior, the folding force increased from a minimal value as it started to fold (Figure 3). Then, it decreased rapidly when the folding was completed [18]. Afterwards, the increasing and decreasing cycle followed at the next fold. The graph above presents the theoretical relations in predicting the peak force and energy absorption. The peak force values on the load displacement curves for each design have different values with each other. The reason is that the different designs for the square column give different results for the analysis. The highest initial peak force recorded is for specimen (d), which has center slots on two surfaces. As shown in Table 3, the maximum compressive load applied to this specimen is 47304.578 N. The lowest decrement percentage compared with specimen (a) (plain square column) is the decrement of 35.98%. The lowest initial peak force is for specimen(c) (two slots in every edge), as shown in Table 3,with the compressive load value of38532.664 N. This design has the highest percentage decrement of 47.85% compared with that of the plain square column specimen. The results show that the range of values for the peak force in all designs is 38532.664 N to47304.578 N. Therefore, the effects of the slots cause great changes to the specimen's physical behavior. Unlike in the plain hollow square, a greater descent to the initial peak force value occurred, decreasing from 73892.266N to 38532.664 N for the lowest maximum load.

3.0 CONCLUSION

The objective of the study was successfully reached at the end of the experimental and finite element analyses. All the values obtained were translated to words. The slot design of the square column gives many decrement values compared with the plain square column structure. This decrement is presented through the peak force values and specific energy absorption calculation based on the experimental and finite element analysis results. A high decrement of 45% compared with that of the plain square column shows that the presence of slots in the structure can reduce the initial peak force of the axial compression force. It is consistent with the purpose of the study, that is, to effectively produce a positive impact on the structure especially during a car crash. A low maximum force during a crash transfers less impact to the occupants and indirectly produces optimum safety from serious damage for the occupants.

Acknowledgement

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