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# Modified Aluminium Tube Profile to Enhance the Performance of Impact Energy Absorption

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## ABSTRACT

The use of thin-walled structures as impact energy absorbers are well known. The thin aluminum cylinder tube is a good impact energy absorber. However, the energy-absorbing design must also have sufficient toughness. In this research, we made modifications to improve the performance of the thin aluminum tube. The thin aluminum cylinder's modification is prepared by adding four grooves along the wall in the axial direction. Numerical modeling was carried out using the finite element method. The impact test is carried out by applying a high speed of 50 m/s to a hammer that hits the axial direction's specimen. Explicit dynamic analysis is used in this modeling. The reaction force is obtained by measuring fixed support at the end of the tube. The total energy as a function of time is received in this simulation. The explicit dynamic simulation results show that the toughness of the modified specimens increased compared to the original model. The amount of energy per unit time at the start of the collision appears to be higher. Likewise, the total deformation in the modified specimen is shorter than in the original specimen. Thus, until the collision's end, the modified thin aluminum tube specimen provides better performance and absorption of impact energy.

Keywords: Aluminum cylinder, Deformation, Energy absorbing, Explicit dynamic, Thin-walled structure

## ABSTRAK

Penggunaan struktur berdinding tipis sebagai peredam energi impak sudah dikenal luas. Tabung silinder aluminium tipis merupakan penyerap energi benturan yang baik. Namun demikian desain penyerap energi juga harus memiliki ketangguhan yang cukup. Pada penelitian ini dilakukan modifikasi untuk meningkatkan kinerja tabung aluminium tipis. Modifikasi tabung aluminium tipis dibuat dengan menambahkan empat alur sepanjang dinding dalam arah aksial. Pemodelan numerik dilakukan dengan menggunakan metode elemen hingga. Uji impak dilakukan dengan menerapkan kecepatan tinggi 50 m/s pada palu yang mengenai benda uji arah aksial. Analisis dinamik eksplisit digunakan dalam pemodelan ini. Gaya reaksi diperoleh dengan mengukur tumpuan tetap di ujung tabung. Energi total sebagai fungsi waktu diterima dalam simulasi ini. Hasil simulasi dinamik eksplisit menunjukkan bahwa ketangguhan spesimen yang dimodifikasi meningkat dibandingkan dengan model aslinya. Jumlah energi per satuan waktu pada awal tumbukan tampaknya lebih tinggi. Demikian juga deformasi total pada spesimen yang dimodifikasi lebih pendek dari spesimen aslinya. Jadi, sampai akhir tumbukan, spesimen tabung aluminium tipis yang dimodifikasi memberikan kinerja dan penyerapan energi tumbukan yang lebih baik.

Kata kunci: Silinder aluminium, Deformasi, Penyerap energi, Dinamis eksplisit, Struktur berdinding tipis

## INTRODUCTION

Energy impact can be absorbed by using a suitable structure. The use of thin-walled structures as impact energy absorbers are well known. The thin aluminum cylinder tube is a good impact energy absorber. However, the energy-absorbing design must also have sufficient toughness. In this research, we made modifications to improve the performance of the thin aluminum tube.

Many previous researchers have modified thin-walled structures to increase the ability to absorb the impact energy (Alghamdi, 2001). Various methods are performed with standard shapes, including circular tubes, square tubes, frusta, struts, honeycombs, and sandwich plates. Modification deformation modes for circular tubes include axial crushing, lateral indentation, lateral flattening, inversion, and splitting.

The structure's shape was modified by comparing the tapered tube with a straight tube to determine the impact energy absorption (Nagel, 2005). Likewise, research on thin tubes' behavior when receiving high-velocity impacts shows differences in response characteristics of the tube. A structure can absorb impact energy and must be challenging when subjected to prior bending loads. It can be prepared by modifying the affected part of the car (Witteman, 1999). The difference in cross-section affects the ability to absorb energy. The reaction force of the supports on the system is also different (Hardi, 2021a) The results of the experiment showed that the larger the radius of the tube with the same thickness, the greater the maximum force required (Hardi, 2018).

Often, the thin tube is filled with rubber to increase its capacity. Filler modifications, including the end cap cover, were investigated to obtain the optimum energy absorption design (Ghamarian & Tahaye, 2011). The honeycomb-type energy absorber structure was investigated by finite element methods to obtain conclusions about the effect of the charging arrangement on the energy absorption capacity (Nakamoto et al., 2009). The effect of aluminum tube length with maximum deformation, maximum reaction force, and plastic energy on high-speed impact loading has been investigated. The results showed that the longer the specimen, the smaller the deformation. The reaction force is also getting smaller. Energy due to plastic deformation does not change significantly. (Hardi, 2021b).

There is a significant effect on the thin aluminum circular tube applied rib to its wall. The distance between the ribs and the total number of ribs affects the deformation pattern and its ability to absorb energy. The research revealed the critical distance of the ribs to change the deformation mode from Axisymmetric to non-axisymmetric. The axisymmetric mode has a mean crushing force approximately 1.3 times larger than non-axisymmetric. (Adachi et al., 2008).

This research aims to improve the toughness and ability to absorb impact energy by changing the cross-section, which was initially circular, into another shape to form a groove in the tube's axial direction. Another result of this research is to find the difference in deformation, reaction force, and total energy absorbed in the original condition without the grove and using the grove. This groove is expected to improve the thin-walled structure's impact performance.

## METHODOLOGY

Modeling is prepared numerically using Analysis of System (ANSYS) 2020 explicit dynamic. ANSYS is the finite element methods software for crushing analysis. Flowchart of this research can be seen in Figure 1.

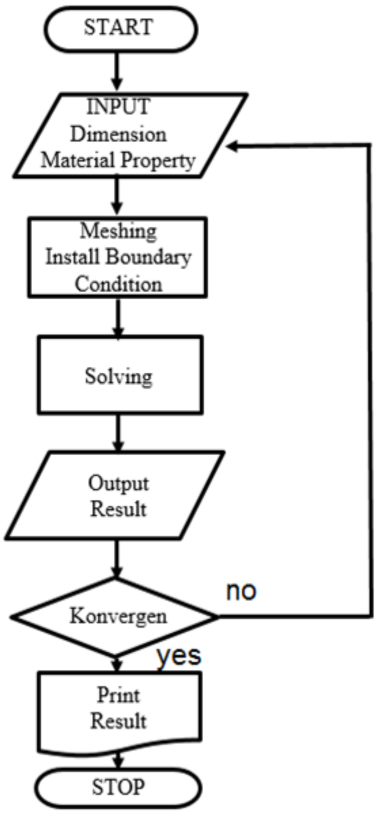


Figure 1. Flowchart of research

**Modeling**

Figure 1 explains the steps of Finite element methods. Modeling using the ANSYS design modeler and then introducing aluminum on the specimen and steel on the impactor. There are two types of specimens being tested: the regular type and the grooved tube. The length of the specimen is 200 m, the cross-section diameter is 50 mm, and the thickness is 1 mm. Four groves were made along the tube wall in the axial direction, as shown in Figure 2.

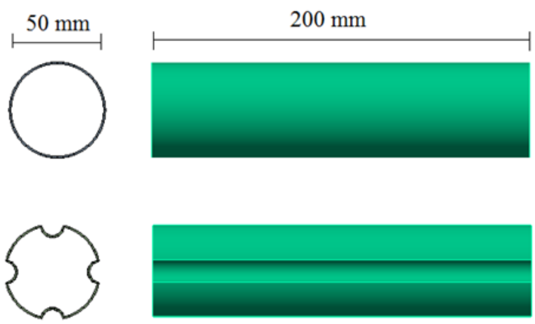


Figure 2. Specimens

**Material Properties**

The material properties of the specimen and impactor are as shown on Table 1.

Table 1. Material properties

| Material | Specimen | Impactor |
|---|---|---|
| | **Aluminum** | **Steel** |
| Density (kg/m$^2$) | 2770 | 7850 |
| Poisson ratio | 0.33 | 0.33 |
| Modulus of elasticity (Pa) | 7.1 x $10^{10}$ | 2.0 x $10^{11}$ |
| Bulk Modulus(Pa) | 6.9608 x $10^{10}$ | 1.6667 x $10^{11}$ |
| Shear Modulus (Pa) | 2.6692 x $10^{10}$ | 7.6923 x $10^{10}$ |

**Meshing**

Meshing is carried out in a moderate size, 1 mm. The smaller the element, the more accurate the calculation, but it will take longer (Zienkiewicz & Taylor, 2000). Then the boundary conditions are determined, namely the impact speed and fixed support. After loading and completion, the results can be taken from post-processing.

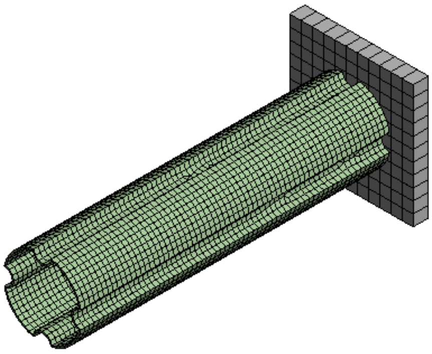

Figure 3. Meshing

**Testing Result**

The test results can be shown in Figure 4.

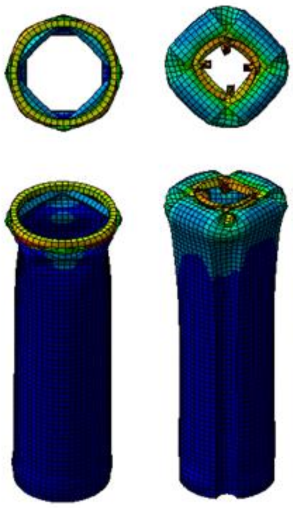

Figure 4. Test result

## RESULTS AND DISCUSSION

The simulations carried out on the specimens get the following results. The standard 34.41 mm tube's maximum deformation is slightly larger than the 33.51 mm modified tube. In other words, there was reduced deformation of the modified tube.

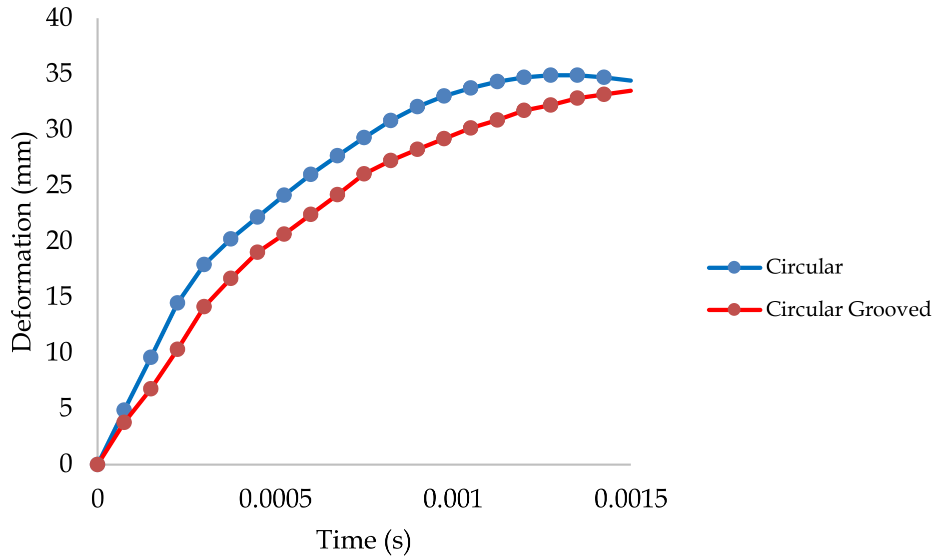


Figure 5. Total deformation

Figure 5 shows the deformation history of both specimens. Over time, the deformation was smaller than the standard specimen in the modified samples.

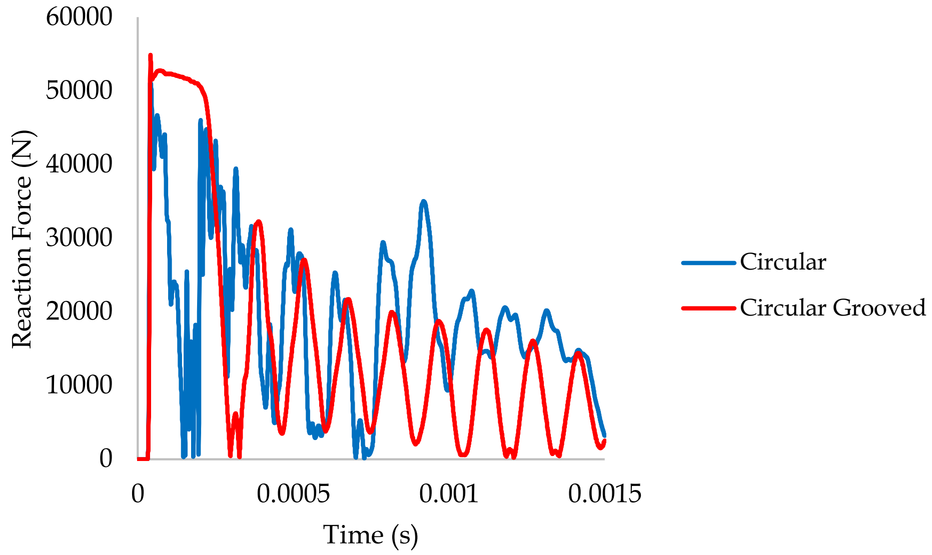


Figure 6. Reaction Force

Figure 6 shows that the maximum reaction force in the modified tube is higher than the standard. Besides, the modified tube's wrinkle formation process is less, and the area under the curve is more extensive than the standard specimen. The figure above also shows that the time required to deform the modified tube is shorter than the standard. This picture shows that the energy absorbed per unit of time is more incredible than the standard. This follows the study of adding ribs to thin tubes, which can increase the mean crushing force (Adachi et al., 2008).

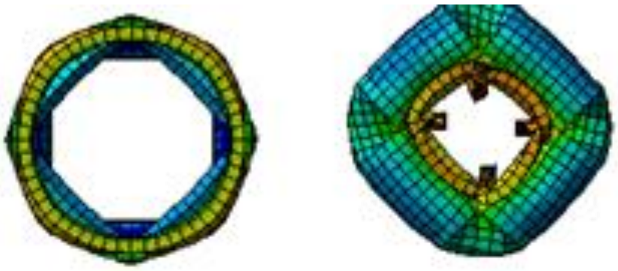

Figure 7. Deformation mode

The deformation mode in the grove tube is more complex than in the initial specimen as shown in Figure 7. The grove proposed the deformation mode.

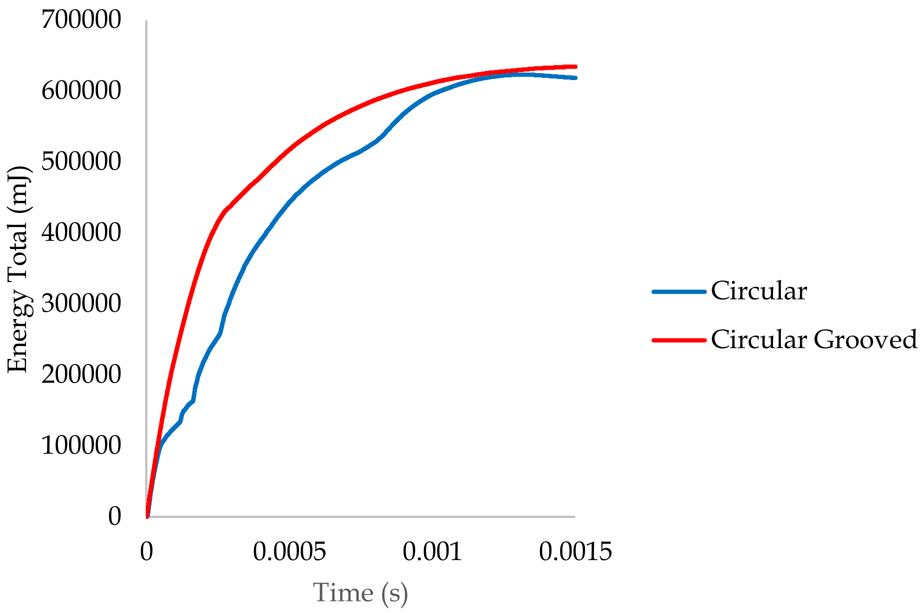


Figure 8. Energy absorbed

The total energy absorbed by the system is, in principle, the same because all the kinetic energy will be absorbed until it runs out as shown in Figure 8. However, both have different responses. At the beginning of the deformation, the energy absorbed by the modified tube is higher than the standard, and the time required is greater than the standard tube. The provision of a grove increases energy absorption due to a change in the deformation mode from full axisymmetric to mixed mode. The approximate equation between the two types of deformation modes is different (Shinde & Mali, 2018).

Total energy per deformation length is shown in figure 9 and figure 10. The circular groove's performance is better than the circular cross-section. Grove is introduced to control plastic deformation, and it will improve the ability to absorb impact energy (Mat et al., 2012).

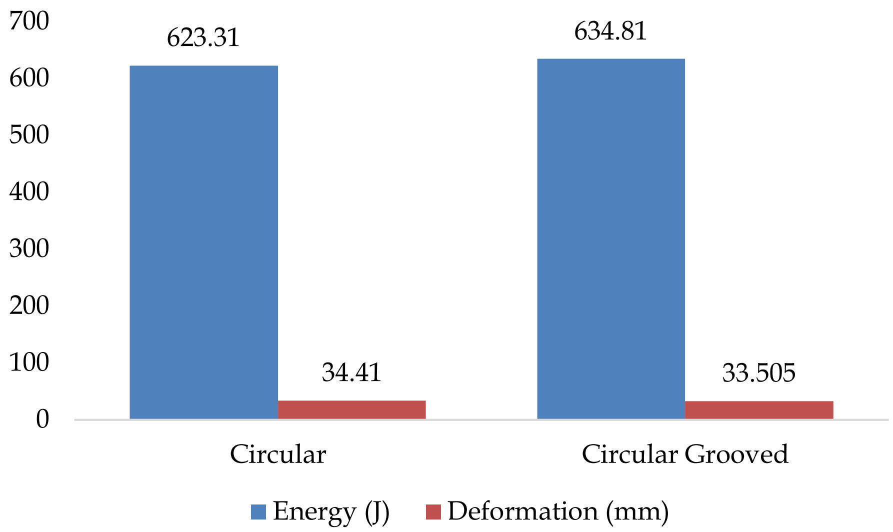


Figure 9. Total energy and deformation

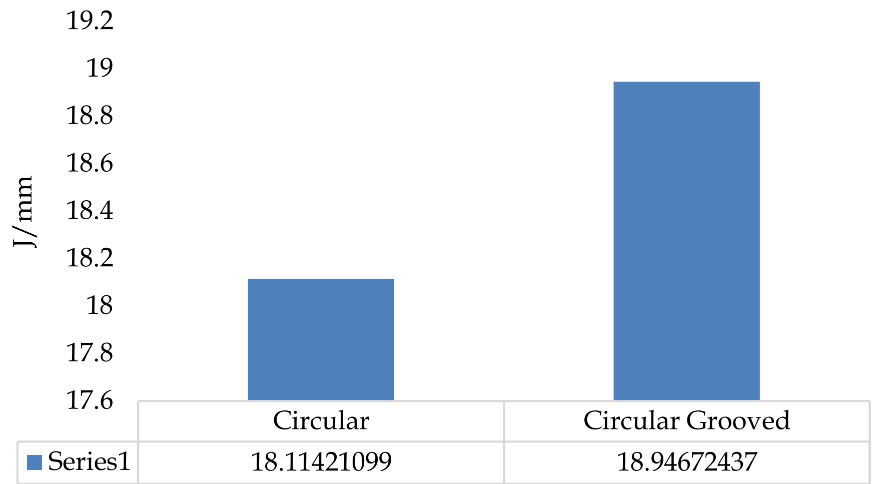


Figure 10. Energy per deformation

## CONCLUSION

We have compared the two specimens' responses when subjected to axial forces at a high velocity of 50 m/s. Groove modification on the tube has reduced the specimen's total deformation and can also increase the ability to absorb energy per unit time at the start of the collision. The number of wrinkles formed on the modified tube is less than the standard. The toughness of the structure is maintained, and the maximum reaction force is slightly increased. Modifying the cross-section on thin aluminum tubes can be done with various other forms so that the structure can absorb energy and has sufficient strength and toughness.

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