Design a Corrugated Tube for Energy Absorption

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Abstract - *The focus of studying energy-absorbing structures is to analyze their behavior under impact and compression. Impact characteristics are influenced by geometric factors, which also apply to dynamic loading scenarios. Peak crush load, denoted by Pmax, represents the maximum axial load experienced during compression, usually at the beginning. The magnitude and occurrence of Pmax can be altered by adding holes. The objective of the finite element analysis performed using ANSYS 15.0 with the tool EXPLICIT DYNAMICS is to determine the energy absorption of two types of tubes and compare their effectiveness in absorbing energy smoothly and efficiently. By analysing the impact loading, the solution obtained from the ANSYS test can provide insights into the energy-absorbing capabilities of the structures being tested. Key word energy-absorbing structures, impact analysis, compression, geometric factors, dynamic loading, peak crush load, Pmax, finite element analysis, ANSYS , EXPLICIT DYNAMICS, energy absorption, tubes, smooth deformation.*

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1. INTRODUCTION

As the world population grows, the demand for new cars increases from year to year. According to the International Energy Agency, by 2035 the number of cars will reach 1.7 billion. As the number of vehicles in traffic increases, the number of accidents also increases.

According to the World Health Organization (WHO), the total number of deaths in railroads is still incredibly high at 1.2 million per year. People living in cars make up about 50% of this figure. Automotive engineers play an important role in the design of cars to solve this problem by providing maximum safety for passengers. This can be done through safety measures, in which the structure of the car is designed to provide greater protection and safety in the event of an accident.

The first car structure responsible for absorbing the collision energy in a frontal collision are the front rails, also called the side rails (see Figure 1). Side members are thin-walled hollow tubular structures of rectangular or square cross-section that dissipate energy loss from plastic deformation. Thin-walled systems are frequently used in collision avoidance and energy absorption applications due to their light weight and high energy absorption efficiency. Strict vehicle safety standards force engineers to have strong suction power to avoid affecting the entire weight of the vehicle. Many studies have been published on the study of energy absorption in metallic tubular thin-walled structures.

These studies can be classified as follows:

(1) investigates the effect of different geometries and configurations.

(2) investigates the effect of foam.

Extensive work has been done to investigate different geometric modifications and configurations of thick tubes designed to improve energy absorption in thin tubes. Most of the work published in this area focuses on simple tubular structures visible from the fabrication process. One of these modifications is the splitting of thin walls into simple extruded multicellular profiles that can be partially or completely tubular. Tang et al. investigated the energy absorption properties of multicellular cylindrical tubes and found that different cell geometries improve energy absorption.

Other studies on various cell geometries have investigated the effect of thin-walled tubes with different cross sections on energy absorption. Changing the thickness of the tubular structure is another geometric change researchers are investigating to improve energy absorption and reduce weight. Similarly, the effect of varying the thickness of various tubular structures was investigated. Custom-made tubular structures have also been studied as potential energy absorbers with different thicknesses. Expanded metal tubing is another method researchers use to improve energy absorption and reduce weight in thin layers.

Other researchers investigated the effect of polygonal tubular structures on energy absorption, while others investigated the energy of double pipes and nested.

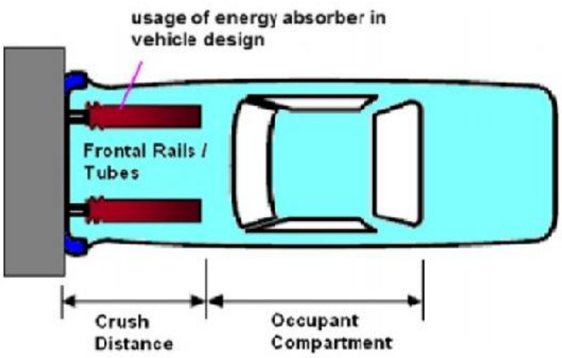


Figure 1. Longitudinal thin-walled cabinet front structure.

Other researchers have studied the effect of steel foam on the pipe. Foam is considered an attractive energy absorber due to its low load resistance and sustained load plateau.

To get the best combination of foam and tubular structures, you must consider the foam density, line width, thickness, and cross-section profile, as well as the material. Some researchers have studied non-porous foams, while others have studied foams. He found on the principle that if designed correctly, foams can improve shock, functionally graded foams. Solutions are often limited to the fabrication methods used to create thin walls. Even recent research in crash-resistance applications has focused on simple geometry.

With advances in additive manufacturing (AM), it is now possible to create complex geometries that can be integrated into thin layers. The main purpose of this study is to numerically investigate the energy absorption properties of thin walled geometries. This numerical study is a preliminary study to evaluate the energy absorption capacity of complex geometries. The next step in this research is to perform dynamic extrusion tests to numerically select the best design for further production and evaluate the potential for energy use of the thin film process.

2. Literature Review

K. Yamazaki and J. Han This article is about the development of methods for maximizing the impact strength of tubular structures and their application to the problem of axial extrusion of cylindrical and square tubes. In the program proposed in this study, the latest finite element code DYNA3D is used to simulate the complex damage behavior of tubular structures. Use response surface approximation techniques to construct a design problem in a predesigned environment using a test model.

Approximation problems are solved by traditional mathematical methods. This optimization process is repeated until convergence is achieved. Also, the comparison of crushing energy absorption of cylindrical and square pipes is discussed

Upkar Mane, Prof. SS Mashyal Thin wall energy absorber tubing is widely used as energy absorber in many automotive and aerospace applications due to their higher energy absorption. The exhaust pipe is connected between the front bumper and the dashboard.

It is one of the members of the structure that absorbs the high energy in a frontal collision so that the impact force is not transferred to the driver/passenger.

Consider the absorption of electricity by the dynamic pulse, pulse velocity and pulse energy are interrelated factors. Tests are done semi-statically, while some are done dynamically. The energy absorption pipe length and pipe cross section ratio, with the great influence of friction, such as the effect of friction and specific energy absorbing contact time, maximum energy and collision distance. Suppose the pulse is constant at 15 m/s.

Aluminum pipes with various cross-sections are defined by precise analysis. After providing the necessary interaction and meshing functions, all models are run with dynamic open code using LS DYNA.

Arameh Eyvaziana, Meisam K. Habibia, Abdel MagidHamoudaa and Reza Hedayatib, This study, conducted explores the effect of fluctuations on energy absorption, fracture behavior and failure of aluminum pipes under axial compression load. The researchers tested five different tube types and simple tubes of various sizes and orientations. They also introduced new solutions for music production. The study found that the direction of the grooves improves performance and control performance, which is important for the reliable design of the shock absorber. The test results provide recommendations for improving how the bike bumps, controls and crashes under axial loads.

Javad Marzbanrad1, Mehdi Mehdikhanlo, Ashkan Saeedi Pour The energy absorption values of thin pipes with different geometries were investigated with detailed simulations. Square, round and oval steel and aluminum tubes are used to compare the absorption power. The results of the load-bearing test used for the analysis of square steel pipes are recommended. The 3D simulation was done using the finite element method, when the impactor collided with one side of the tube while the other remained rigid. Square pipes of 2 different thicknesses and 2 widths were also compared.

In addition, 2 cross-sections such as circular and elliptical with the same area were studied for comparison at the beam transition. The results show that the elliptical cross section has more absorbing power than the other two. In addition, as the thickness increases in pipes with small cross-sections, the amount of energy absorbed will also increase.

F Tarlochan*, Sami AlKhatib Thin-walled structures were used in the energy absorbing area at the time of the accident.

Numerous studies have been carried out on tubular structures. Complex geometries are excluded from solutions due to manufacturing limitations. Complex geometries can be achieved with advances in additive manufacturing. As motivation, the aim of this study is to analyze the collision behavior of complex tubular structures.

Five models were evaluated. The complex geometry was found to be more effective than the currently used tubular structure.

J. Han and K. Yamazaki conducted a study using the finite element method to investigate the axial crushing behavior of grooved and smooth square pipes. They compare the mean axial extrusion force between numerical and theoretical predictions and also compare and discuss folding patterns derived from numerical simulations and experimental observations. Through numerical analysis, they obtained a method to maximize the effect of tubular structure, and used the surface method and various mathematical concepts to solve the problem of maximum energy absorption of ribbed and non-ribbed square tubes.

In addition, the crushing energy absorption capacities of cylindrical pipes and ribbed and non-ribbed square pipes were compared.

2.1. Objective of Project

❖ Use AutoCAD software to create thin walls.

❖ Perform finite element analysis using boundary conditions and specific loads.

2.2 Project Scope

❖ Energy Absorber Tube Study.

❖ Energy Absorber Tube Design.

❖ Finite Element Networks, Loading, Boundary Conditions, etc.

❖ Finite Element Analysis.

3. METHODOLOGY

The aim of this study is to investigate the effect of complex geometry and structure on the collision of tubes. To achieve this aim, two different competition designs were created as shown in figures 2 and 2.1. Modify a parameter for each model to create a configuration file for each model to examine the effect of each parameter on the extrusion scale. Profiles were modeled using both steel and aluminum materials to examine the factors affecting the response of each profile.

Numerical simulations included an axial impact using an impactor weighing 1.7 kg and an initial velocity of 25 m/s.

All profiles in this study are thin-walled pipes with a cross-sectional area of 292,168 mm2 and a thickness of 2 mm. Select a profile from the printout using multiple decision methods. The first step in the multivariate decision-making process is to choose a functional model.

Performance evaluations are used in both evaluations. The main category includes defined performance indicators, while the other category includes basic production. After the performance criteria are selected, a digital logic (DL) algorithm is used to generate weights for each parameter.

3.1 Simple thin-walled tube

The design of simple thin-walled tube is made as follows;

Table -1: Specifications

Length	100 mm
Diameter	44.5 mm
Thickness	2 mm
Material	Aluminum Alloy

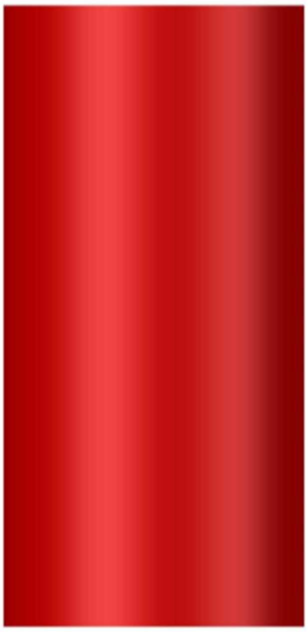


Figure 2. Simple tube

3.2 Corrugated Tube

The technical specifications for designing the bellows are outlined below:

Table - 2. Specifications:

Length	100 mm
Diameter	44.5 mm
Thickness	2 mm
Material	2090 Aluminum Alloy

Table -2.2 Corrugations:

Number	8
Wavelength	12.5 mm
Amplitude	1 mm

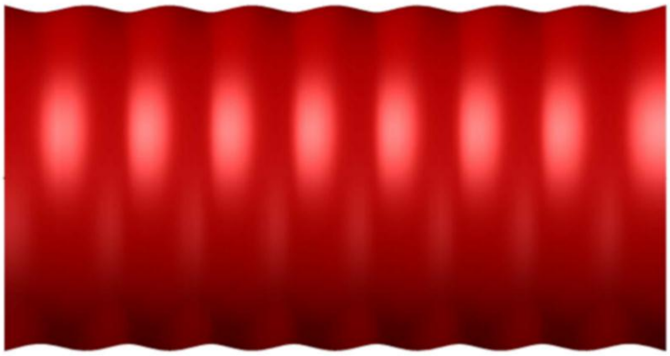


Figure 2.1 Corrugated tube

3.3 Modelling of Corrugated Tubes

Generatrix of the corrugated surface of a diameter D pipe:

$$y = \frac{D}{2} + A\left(\frac{x}{L}\right)^{k_1} \sin\left(2\pi n\left(\frac{x}{L}\right)^{k_2}\right)$$

where A = amplitude of sinusoidal corrugation
x = arbitrary distance selected along pipe length
L = length of pipe tube
k1 = 0, 1 & 2 (constant, linear and quadratic amplitude variation)
k2 = 0, 1 & 2 (constant, linear and quadratic amplitude variation)
n = number of fluctuations along the pipe length
For sinusoidal corrugated pipe (groove) k2 = 0)

$$y = \frac{D}{2} + A\sin\left(\frac{2\pi n x}{L}\right)$$

4. Research and Analysis

Research into the behavior of electrical structures begins with impact tests and compression tests. Shock properties include large geometric effects that also occur under dynamic loads. Peak breaking load is the maximum load to which the specimen is subjected in the axial direction. It is usually encountered at the start of compression.

The size and appearance can be changed by adding holes. It is represented by Pmax. The main purpose of this final analysis is to find the power absorption of the two pipes and then compare them to get the more uniform pipe power absorption. In ANSYS 15.0, finite element analysis, analysis of impact load, is performed to obtain the following solution. This impact analysis was performed in ANSYS using the EXPLICIT DYNAMICS tool.

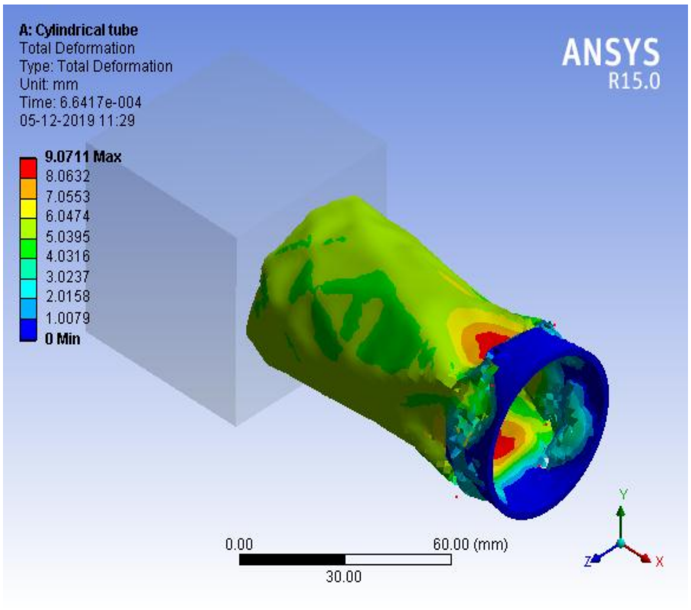


Figure 3 Total deformation of simple tube

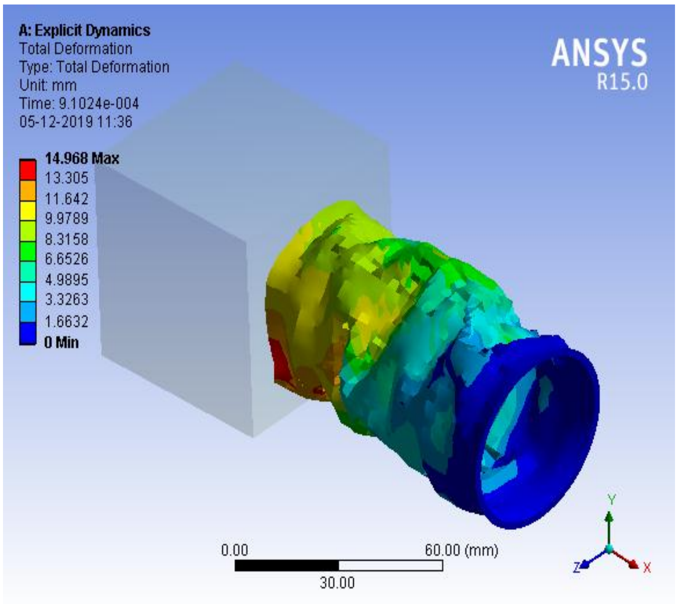
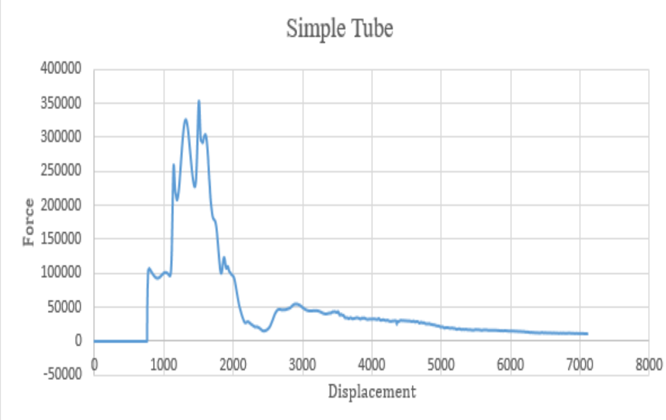


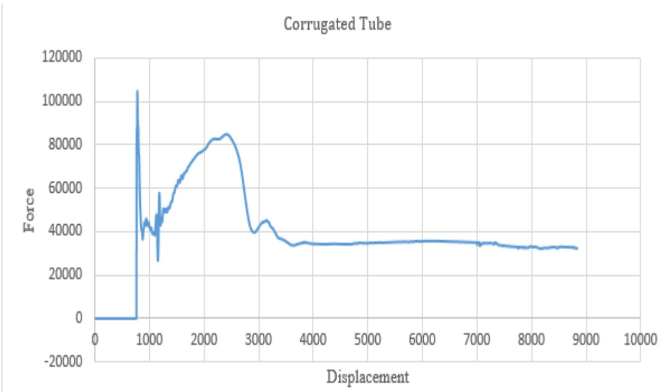
Figure 3.1 Total deformation of corrugated tube

4.1 Absorption energy of Simple Tube



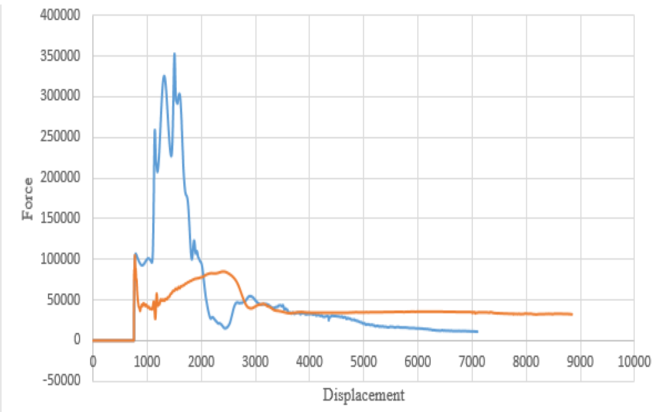
Graph 1 Absorption energy of Simple Tube

4.2 Absorption energy of Corrugated Tube



Graph 1.1 Absorption energy of Corrugated Tube

4.3 Comparison of energy absorption of both tubes



Graph 1.3 Comparison of energy absorption of both tubes

4.4 Conclusion

After the final analysis, we got the change in contact force and time versus time for the two tubes. As we talked about performance measurement, we can see that the energy absorption of objects can be calculated from force and displacement. Therefore, we prepared a picture of the energy and motion of the two pipes and compared the two pictures to study the energy absorption of the two tube shows the difference in strength and smoothness of the stomach deformation.

Therefore, the suction effect is better and the deformation is softer after a certain inertia force is applied to the bellows.

5. LIMITATIONS

Features: Although 2090 aluminum alloy has many advantages, it may not be suitable for all applications. For example, it may not be suitable for hot applications.

Corrosion: Aluminum alloys are susceptible to corrosion in some areas that can affect the performance of the pipe.

Production limitations: Vacuum design must take into account the limitations of the materials used to manufacture it. For example, the capacity of the product will limit the depth of the grooves.

Structural Stability: The pipe should be designed to retain its structural stability during and after deformation so that it can absorb energy well.

Test: Testing is required to ensure pipelines meet performance standards. However, this can take a long time and add to the overall cost of the project. When designing a pipe made of 2090 aluminum alloy material, consideration should be given to material suitability, corrosion potential, manufacturing limitations, stability, and testing to produce a pipe that meets the requirements while addressing service restrictions.

5.1 RECOMMENDATIONS

1. Groove profile: The groove profile can affect the energy absorption of the pipe. Darker grooves generally absorb more energy, while shallower grooves provide softer deformations.

2. Wall Thickness: The wall thickness of a tube also affects its energy absorption capacity. Thicker walls help increase the energy absorption ability of the pipe, but can also add weight and make it unsuitable for some applications.

3. Diameter: The diameter of a pipe also affects the suction power. Larger lines can absorb more energy, but may also be heavier and more difficult to pack.

4. Testing and Verification: It should be tested and verified to ensure it meets vacuum, suction and deflection requirements. This may include using software simulations or performing physical tests. When the

bellows is produced from 2090 aluminum alloy, it is recommended to choose a corrugated profile with a wall thickness and diameter suitable to meet the requirements of the application, which can take into account the energy absorption capacity and uniform deformation. It is also important to complete testing and verification to ensure systems meet the required standards.

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