

Full length article

Investigating the energy absorption, SEA and crushing performance of holed and grooved thin-walled tubes under axial loading with different materials

Saharnaz Montazeri^a, Majid Elyasi^{b,*}, Amin Moradpour^c^a Department of Mechanical Engineering, McMaster University, Hamilton, Canada L8S 1X7^b Faculty of Mechanical Engineering, Babol Noshirvani University of Technology, Babol, Iran^c Department of Management, Mazandaran University of Science and Technology, Babol, Iran

ARTICLE INFO

Keywords:

Thin walled tube

Crushing

Specific energy absorbent

Holed and grooved thin-walled tubes

Axial loading

ABSTRACT

In the present study, the crushing mechanism of two types of thin walled structure, holed tube and grooved tube, were analyzed by analytical, numerical and experiments. Plastic deformation was occurring on thin walled tubes by introducing grooves and holes predetermined intervals along the tube. For this purpose, crushing performance of grooved model and holed model were analyzed through finite element simulation and then verified with experiment. Firstly, the comparison of crushing performance, load-displacement curve, energy absorption, mean crushing load and Mass specific energy (SEA) was performed for grooved and holed thin walled tube of mild steel analytically, numerically and experimentally. Secondly, crushing mechanics of holed tube with grooved tube were investigated. At last, the load-displacement curve of holed steel tube and grooved steel were investigated and then the load displacement curve of holed thin walled tube which were made by mild steel and aluminum were investigated. The results indicate that the holed thin walled tube which was made from aluminum has the maximum crushing performance, SEE and energy absorption.

1. Introduction

Energy absorption systems are widely used in aircraft, ships, lifts and machinery. The purpose of using of energy absorption is to absorb the amount of energy in accident or impact force to reduce damages. So, the sample which is able to absorb high amount of energy is important. Aluminum and steel are the most commonly used metals in these systems. Aluminum has the advantages of being light-weighted and having high formability, and the advantage of steel is its high strength. Many works have been done in this area so far.

Warior et al. [1] studied the axial loading in composite tubes filled with polymers, and showed that the maximum energy absorption occurred in R/t ratios of < 1. Tao et al. [2] studied the crushing behavior of steel tubes stiffened by welding plates along the tube length, and obtained acceptable results. Wang et al. [3] investigated the mushroom phenomenon in thin-walled tubes with different wall thicknesses, and found that this phenomenon would occur in high impact speeds. Tai et al. [4] investigated the energy absorption systems and the behavior of thin-walled tubes under impact load and they obtained the relationship between displacement and load, average load and energy absorption properties. Rossi et al. [5] investigated energy absorption and axial collapse of thin-walled tubes with polygonal cross-sections.

Crushing results showed that the addition of flanges had a direct impact on the axial force. Song et al. [6] studied the structure of light-weighted thin-walled tubes under axial pressure. Their proposed model was square section tubes with openings on the surface, and after examining the behavior of tubes with different size of openings, it was found out that by proper change in the size of the openings, the energy absorption capability could be increased. Tarigopula et al. [7] improved the performance of thin-walled steel tubes by changing the parameters of plate thickness and flange width. Alavinia et al. [8] studied the effect of circular and square cross-section on the energy absorbing capacity of thin-walled tubes and found that energy absorbing capacity in circular cross-section tubes are higher than that of square tubes. Yousefsani et al. [9] investigated the crushing behavior of steel and aluminum thin-walled tubes with different cross-sections, and showed that although Young's modulus has an impact on the energy absorbing capacity, specific energy absorption (SEA) also has a significant impact on the absorbed energy. Adachi et al. [10] studied denticulate cylinders under axial loading, and investigated denticle spacing arranged symmetrically and asymmetrically. They concluded that obtaining an appropriate denticle spacing leads to either symmetric or asymmetric crushing of cylinders. Salehghaffari et al. [11] studied the crushing behavior of steel tubes externally stiffened by multiple identical rings under axial

* Corresponding author.

E-mail addresses: elyasi@nit.ac.ir, elyasima@yahoo.com (M. Elyasi).

Nomenclature

D	mean diameter of tube
d	hole diameter
λ	the distance between center to center of each hole
w	weight of hole
E_t	total energy
L	tube length

N	number of rows
t	tube wall thickness
W	weight of tube
l	the distance between edge to edge of each hole that calculate
S	number of holes in each row
σ_0	flow stress

loading. The results showed that these rings help to improve formability and energy absorption capacity in the steel tubes. Younes [12] studied the crushing behavior of steel thin-walled tubes with various cross-sections using simulation and experimental tests. The maximum and minimum crushing occurred in the circular and triangular specimens, respectively. Additionally, circular specimen has the highest amount of absorbed energy. Hosseinipour et al. [13–15] created alternate circumferential grooves inside and outside of tubes with circular cross-sections and investigated energy absorption capacity. The authors of the current research introduced holed thin-walled tubes for the first time [16,17]. In that study, various geometries for both aluminum and steel was examined regarding appropriate crushing performance. The results showed that a structure with number of 5 rows including 12 holes in each row with diameter of 6 mm guarantees desirable crushing performance.

Although a rich body of knowledge in this area can be found in above literature, but it is found that the geometry of their developed structure are so complex and needs to specific production methods. Therefore, the cost of fabrication is too high and it takes long time. In this study, a new model for thin-walled tubes with holes drilled on their circumference is designed with the aim of improving the overall energy absorption under axial load. The new holed tube structure is proposed in current work with simple geometry and lower cost of fabrication. Authors have previously proved that the model is considerably effective in improving energy absorption and initial impact force (Refs. [16,17]). Author, in the present study, an attempt is made to compare the crushing performance of new developed thin walled tube with the former structure namely grooved tube that had been developed in Refs. [12,14] to demonstrate the excellent performance of the new developed model. Here finite element simulation using ABAQUS/EXPLICIT software is used to analyze the results. The comparison firstly is performed on specimens made of mild steel. Then the crushing performance (i.e. deformation during crushing, crushing load and specific energy absorbent) of new structure made of aluminum is compared with that of grooved structure made of mild steel. In each stage of the work, the developed FE simulation is verified with experiments to show the accuracy of developed FE model.

2. Experimental

As shown in Fig. 1 the grooved thin walled structure according to Ref. [14] and holed thin walled structure according to the previous research [16,17] with same geometry and parameters made from mild steel and aluminum 6061 were investigated. In Fig. 1 the parameters L (length of tube), D (diameter of tube), λ (the distance between center of tube and center of holes or grooved), W (Width of grooves), d (diameter of the holes) and t (thickness of tube) were considered as 96 mm, 54 mm, 16 mm, 3 mm, 3 mm and 2 mm, respectively. For doing the experimental test, first the raw tube with mentioned length and thickness was produced, and then for the holed specimen, circular holes with the same diameter were drilled in the specific rows on the tube. Also, for the grooved specimen, after providing the raw tube with the same dimension, the groove with 3 mm wide and 1 mm deep fabricated inside and outside alternatively on the tube wall. The specimens have crushed, between parallel steel plates of the 600 kN DMG (Denison and

Mayes Group) Universal Testing Machine with the constant speed of 50 mm/min without any additional fixing. Load displacement curves were obtaining from the output a computer which was connected to the test machine during the experiments. Energy absorption and mean crushing loads have calculated by measuring the area under the load-displacement curves according to following Eq. (1). In the Eq. (1), E is the absorbed energy, p is the force and L is the crushing length.

$$E = \int_0^L p(x)dx \quad (1)$$

3. Finite element simulation

3.1. Development of FE model

In this study, the finite element software ABAQUS/Explicit version 6.10 was used to compare the deformation process of hole-drilled and grooved cylindrical tubes as well as their energy absorption. As shown in Fig. 1 the grooved thin walled structure and holed thin walled structure with same geometry and parameters made from mild steel and aluminum 6061 were simulated in FEA software.

In this study, Because of the symmetry of the structure, the thin walled structure is modeled according to the only quarter of the geometry in software. In the simulations, the tube was modeled as three-dimensional solid and deformable geometry, and the upper and down plan were modeled as rigid shells. To develop a finite element model, the mechanical properties of the materials along with this constitutive equation should be considered in FE model. For this purpose, uniaxial tension test for aluminum and mild steel were performed and the obtained results were given to ABAQUS software. Fig. 2 shows the engineering stress-strain curves for aluminum 6061 and mild steel. Also, the mechanical properties were applied in the tube as shown Table 1. To simulate the crushing process, the effect of material anisotropy was ignored. In order to simulate the tube, formable 3-dimensional elements C3D8R were used for meshing the thin walled tubes with the element size of 0.002. In addition, three elements were considered along the tube thickness. In the simulation, the loading plate velocity was kept

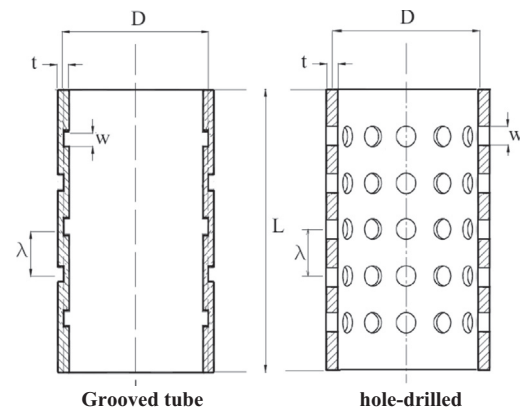


Fig. 1. Introducing geometric parameters of both hole-drilled and grooved thin-walled tubes.

Download English Version:

<https://daneshyari.com/en/article/11001321>

Download Persian Version:

<https://daneshyari.com/article/11001321>

[Daneshyari.com](https://daneshyari.com)