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Off-Axis Crushes Simulation of Thin-Walled Tapered Tubes Inserted with Foam-Filled Structures

A. Othman[a,]* and Azrol Jailani[b]

[a]*Mechanical Engineering Department, Port Dickson Polytechnic, KM. 14 Jalan Pantai, 71050 Si Rusa, Port Dickson, Negeri Sembilan.*
[b]*The Association of Ledang Community Youth, 152 Jalan Puteri 1/6, Bandar Baru Tangkak, 84900 Tangkak, Johor.*

Abstract

In this study deal with numerical analysis of the impact dynamic effects of crush performance of the tapered cross-section tubes, containing straight, single taper, double taper, taper triple and fourth tapered lightweight polyurethane foam filled alloy steel thin-walled tube. Foam-filled thin-walled tubes have been examined numerically. Off-axis angle load dynamic effects in front of crash were examined at an angle of 0, 5, 10, 15 and 20 degrees. Numerical analysis has been verified by experimental studies in place to validate the data. The results show that the energy absorption capacity has been significantly affected tube with various oblique angle, impact velocity and wall thickness. It was found that the foam filling in a thin-walled tubes increase the amount of energy absorbed compared with empty tubes.

Keywords: Energy Absorption, Thin-Walled Structure, Finite Element Analysis, Foam-Filled, Off-Axis Crushing.

1. Introduction

The crushing behavior of thin-walled sheet metal tubes under axial compression has received considerable attention over the past 25 years. Early investigations were conducted in order to understand the capabilities of rail coach body shells to withstand impact conditions [1]. Tests have also been conducted on scale models of both rail coaches and motor coaches in which the details of openings etc. were included. Later investigations were carried out to assess the load-compression characteristics of metal tubes of various cross-sections under impact loads in order to obtain their energy absorbing capacities for use in a variety of applications including

* Corresponding author. Tel.: +6-017-709-1560; fax: +6-06-662-2000
E-mail address:akbar.othman@gmail.com

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the arrest of dropped fuel elements in nuclear reactors and improving the crashworthiness of vehicles [2]. In the latter context attempts have also been made to improve the energy absorbing capacity of metal tubes fabricated from sheet metal by using filler materials such as polymeric foams [3]. A brief review of the literature on the various aspects of the axial crushing of empty metal tubes referred to above and foam-filled sheet metal tubes has been given in a companion [4]. That paper show experimental data have been provided on the behavior of empty and foam-filled spot-welded sheet metal tubes of uniform square and rectangular cross-sections. It was noted that relatively thin-walled tubes show non-compact plastic crushing behavior, i.e. during the first phase of deformation a series of plastic folds are formed which are separated by relatively undeformed panel sections [5].

1.1. Finite Element Model

A finite element model was developed to analyze the axial and oblique dynamic crushing responses of polyurethane foam-filled tapered tubes [6]. A specific mass was assigned to the moving rigid body to simulate the mass of impacting device. The geometries of thin-wall tube and foam material were meshed by four-node axisymmetric continuum elements, which are suitable for large plastic deformation. To find the adequate element size, a sensitivity analysis was carried out to obtain accurate results within a reasonable computational time [7].

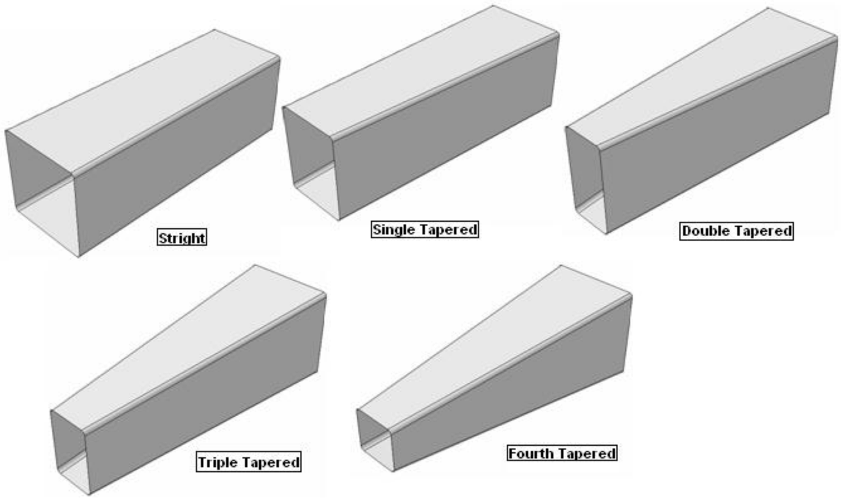

Fig. 1. Finite element model of tapered tube

The total work done (W) during the axial crushing of the cones are equal to the area under the load/displacement curve and is evaluated as:

$$W = \int Pds \qquad (kJ) \qquad (1)$$

where, P is the force acting on the column. Therefore the specific energy absorption per unit mass, E is recognized as:

$$E = \frac{W}{m} \qquad \left({}^{kJ}\!/_{kg} \right) \qquad (2)$$