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ENERGY ABSORPTION IN AXIAL CRUSHING OF FOAM FILLED THIN WALLED CONICAL FRUSTA

S. A. Meguid

Mechanics and Aerospace Design Laboratory
University of Toronto, 5 King's College Road
Toronto, Ontario M5S 3G8
CANADA
meguid@mie.utoronto.ca
www.mie.utoronto.ca/labs/madl

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The US National Highway Traffic Safety Administration reported 30,000 fatalities and over 1.5 million injuries resulting from motor vehicle crashes in 2010. Recent legislative pressure led automobile manufacturers to design lightweight vehicles to reduce cost, fuel consumption and gas emissions. There exist various energy absorbers that can be used to improve the crashworthiness of these vehicles, without drastically increasing their weight and cost. In particular, thin walled structures that experience progressive folding, as opposed to global buckling, are ideal shock absorbers, because they can undergo large displacements at near constant load. Furthermore, they are highly economical and easy to manufacture. It has also been proven that by filling thin-walled sections with foam, the energy absorption capacity can be improved significantly. The improvement is attributed to interaction effects between the foam and the tube walls.

Comprehensive analytical, numerical (FEM) and experimental investigations are conducted to study the crush behaviour of foam-filled thin-walled circular tubes and frusta. Accordingly, three aspects of the work are considered. The first is concerned with the analytical modelling of the quasistatic crush behaviour of empty and foam-filled frusta. The analytical crush model is idealised into an axisymmetric multiple-fold mechanisms with the energy being dissipated in the formation of plastic hinges, the circumferential deformation of frusta walls and the interaction effects between the inside wall and the filler. The second deals with the nonlinear finite element modelling of the crush behaviour of foam-filled frusta accounting for the different contact surfaces and the nonlinear constitutive behaviour of the considered materials. The third deals with the experimental validation of the developed models via quasistatic crush tests of foam-filled and unfilled frusta.

The analytical and numerical predictions are compared with the findings of the crush test results with a specific interest in the normalised load-deformation behaviour, the specific energy absorption and the mode of collapse. The influence of the wall thickness, the semiapical angle and the density of foam filler are also investigated and the results highlight the advantages of using foam-filled frusta as energy absorbers. Overall, this research shows clearly that foam-filled frusta are superior to empty ones because of the greater specific energy absorption, the improved load ratio, the interaction effects, and the stability of the crush response. To take advantage of the interaction effects and the stability of the crush response, multi-frusta configurations are further developed and examined in this presentation.

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