Energy absorption of thin-walled tubes with origami patterns

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Abstract

Thin-walled tubes are often used as energy absorption components in automobiles. They are designed to absorb energy during a collision through plastic deformations. here we examine the energy absorption ability of a family of thin-walled tubes with origami patterns under axial compression. The patterns that are considered are developable so that the tubes can be formed by rigidly folding metal sheets.

It has been found that at the initial stage of axial crushing the tubes with origami patterns resembles the straight thin-walled tubes with polygonal section. However, the introduction of origami patterns determines the post-buckling deformation modes. A good choice of patterns can greatly improve the energy absorption efficiency.

In this study, the geometry of tubes with origami patterns can be described by five independent parameters, which are the surface area of the tube, the width and the interior angle of each panel in the pattern, and the side number and the perimeter of the polygonal cross section of the tube. By varying those five parameters, a family of folded tubes can be constructed. We then use the finite element analysis to simulate the crash behaviour of those folded tubes subjected to axial compression. The numerical results are compared with those from the straight polygonal section tubes made of the same material and have the identical surface area. It shows that some of the tubes with origami patterns have better performance than the straight polygonal tubes in terms of energy absorption capability. The initial peak load prior to buckling can be greatly reduced, whereas the mean crushing load, proportional to the total amount of the plastic energy dissipated, can be increased. Moreover, a more stable load-deflection response appears during crushing in some designs. The behaviour of one of the tubes with origami patterns is given in Figure 1.

Based on the analysis, we have identified key parameters that influence the overall energy-absorbing ability. Using the results, the geometry of the tubes can be optimized to achieve the best crushing performance.

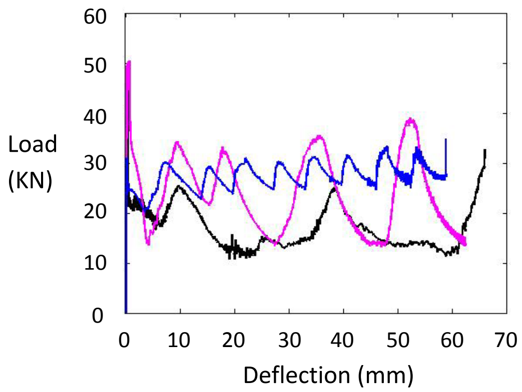

Figure 1: The load-deflection curves for tubes subjected to the quasi-static axial crushing. Black line is for a straight square thin-walled, red line for a straight octagonal tube and blue line for the octagonal tube with an origami pattern. It shows that the latter has better energy absorption capability and is much more stable.

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