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ANALYSIS AND OPTIMIZATION OF AN EXPANDING ENERGY ABSORBER WITH VARIABLE THICKNESS DISTRIBUTION TUBE UNDER AXIAL DYNAMIC LOADING

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ABSTRACT–An expanding energy absorber with variable thickness distribution tube is proposed and studied in this work. At first, a uniform thickness tube structure finite element (FE) model was developed and then verified by the results of an impact test. The parametric study found that outer obliquity angle β and inner obliquity angle γ have positive influence on initial peak force (F_p). While as axial distribution ratio l less than 0.1, the l has significant positive effect on F_p. The non-monotonicity of specific energy absorption (SEA) with design parameters of β and γ was found. Increasing the parameter l could obviously improve the SEA. To obtain the optimal design, an integrated optimization methodology was applied. The Pareto fronts show that there is a lot of room for improvement of original design. The optimal compromising solution increased the SEA by 12.60 % with F_p decreased by 14.24 kN comparing with that of original design. At last, the optimization result were verified. The study stated that the proposed variable thickness distribution tube of expanding energy absorber is conducive to improving the crashworthiness of rail vehicles.

KEY WORDS : Expanding tube, Variable thickness, Finite element (FE) model, Optimization, Crashworthiness

1. INTRODUCTION

Considering the serious casualties and economic losses caused by the rail vehicle accidents, many scholars focus their research interest on the crashworthiness of the rail vehicles in recent years (Lin *et al*., 2019; Wang *et al*., 2019a; Peng *et al*., 2017). Thin-walled tube type energy absorbing structures consume impact dynamic energy by the irreversible plastic deformation process of energy-absorbing tubes (Efremov *et al*., 2019). Thus, the tube type energy absorption structures have been widely applied in various fields, especially in rail vehicles, as the energy absorber due to its great impact performance and ultra-light weight (Yan *et al*., 2016).

In the past decades, numerous researchers had made significant contributions to study the progressive plastic collapse process of various energy absorption tubes and the interference between the tubes and filler structures (Mohammadiha and Ghariblu, 2016; Guler *et al*., 2010; Toksoy and Güden, 2005). By comparing the different section shapes of energy absorption tubes, Nia and Hamedani (2010) concluded that tapered tubes can reduce initial ultimate force generated as the tube is triggered and the impact force shows a higher uniformity. Furthermore, the square tubes and cone-shaped tubes exhibit better impact performance in energy absorption (Zhang *et al*., 2005; Tang *et al*., 2013). Numerous studies revealed that multi-cell structure behave better in crashworthiness comparing with that of single cell structures, among which multi-cell structures with hexagonal and octagonal sections obtain the most efficient energy consumption (Wierzbicki and Jones, 1989; Nia and Parsapour, 2013; Kim, 2002). Generally, the thin-walled structures exhibit an obvious initial peak force at the first stage of impact process, which may cause serious biomechanical injuries for occupants (Liao *et al*., 2008). The studies of Yang *et al*. (2016) showed that the initial imperfection design could largely stabilize the deformation process to reduce the initial impact force pulse. To further improve the impact performances of thin-walled structures, several researchers tried to combine the hollow tubes and the filler material (Taherishargh *et al*., 2016; Usta and Türkmen, 2019; Duarte *et al*., 2019). What is more, the comparative studies (Santosa and Wierzbicki, 1998; Peng *et al*., 2015) exhibited that aluminum foam filler is more efficient comparing with

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