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ORIGINAL ARTICLE

Bending crashworthiness of elliptical tubes with different aspect ratio and stiffeners

Quirino Estrada[1] · Dariusz Szwedowicz[2] · TrongNhan Tran[3] · Alejandro Rodriguez-Mendez[4] · Milton Elias-Espinosa[5] · Oscar A. Gómez-Vargas[6] · Gonzalo Partida-Ochoa[7]

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Abstract
Lateral car collisions are common scenarios that represent one of the top causes of passenger's fatalities and injuries. For this purpose, the current article investigates the effect of cross-sectional aspect ratio (β) on the crashworthiness performance of elliptical profiles under lateral loads. For this purpose, structures with different aspect ratios (β) were evaluated. Special emphasis was set on modelling progressive damage by the Johnson–Cook (J-C) failure model for aluminum 6063-T5. The accuracy of our numerical results was determined by experimental validation of a first three-point bending model. From the numerical results, an improvement of energy absorption (E_a) and crushing force efficiency (CFE) is achieved as the aspect ratio (β) increases. In this sense, the best CFE performance (0.728) was obtained for a structure with $\beta = 1.50$, which means an improvement of 30.59% of E_a and 9.96% of CFE relative to a circular tube. At this point, the limits for sizing of elliptical profiles in terms of (β) were determined by practical equation. To improve even more the crashworthiness capacity of the elliptical profile with $\beta = 1.50$, the use of plates in horizontal, vertical, and combined mode was also explored. As a result, the effectiveness of vertical ribs was demonstrated. The highest CFE performance was obtained for a structure vertically reinforced with three ribs, which allowed a further increase of CFE up to 0.805. Then a final improvement in CFE of 21.60% was computed. Finally, an application of our study to a side sill system is also investigated.

Keywords Crashworthiness · Elliptical profiles · Stiffeners · Aspect ratio · Three-point bending test · FEM

1 Introduction

A vast literature exists on the axial crushing process of thin-walled tubular structures. However, car crashes can occur from different directions. Lateral impacts are among the most common, and they are responsible for a large number of passenger fatalities and injuries [1]. To improve passenger safety, the use of thin-walled structures in vehicles has been proposed as a low cost but effective solution [2]. Many characteristics are associated to them; however, the most important is their large capacity to absorb energy by plastic deformation when deformed. The energy absorption capacity depends on several mechanical and geometrical factors. In this sense, the manufacturing material of the structures is an important design variable among engineers and designers. Lately, the use of light materials such as aluminum alloys is increasing with the purpose of reducing the mass of vehicles, hence decreasing fuel consumption and CO_2 emissions to the environment [3]. In order

✉ Quirino Estrada
quirino.estrada@uacj.mx

1 Instituto de Ingeniería y Tecnología, Universidad Autónoma de Ciudad Juárez (UACJ), Ciudad Juárez, Chihuahua, México

2 Departamento de Ingeniería Mecánica, Tecnológico Nacional de México/CENIDET, Cuernavaca, Morelos, México

3 Faculty of Mechanical Engineering, Industrial University of Ho Chi Minh City, HCM City, Vietnam

4 Department of Mechanical Engineering, University of California, Berkeley, CA, USA

5 Instituto Tecnológico de Estudios Superiores de Monterrey-ITESM, Campus Santa Fé, Ciudad de México, México

6 Instituto Tecnológico de Tlalnepantla TecNM/ITTLA, Tlalnepantla de Baz, Estado de México, México

7 Tecnológico Nacional de México, Campus Ciudad Guzmán, Ciudad Guzmán, Jalisco, México