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Soroosh Borazjani, Giovanni Belingardi

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Soroosh Borazjani* and Giovanni Belingardi

Department of Mechanical and Aerospace Engineering (DIMEAS), Politecnico di Torino, corso Duca degli Abruzzi, 24, 10129 Torino, Italy
soroosh.borazjani@polito.it- giovanni.belingardi@polito.it

Abstract

Obligatory standards are dictated to vehicle manufacturers for decreasing the high number of road dead tolls in rollover crashes; at the same time demands to produce light-weight vehicles have increased substantially to reduce the toxic gases emission. This paper presents a new design of the roof strengthening configuration in which sandwich material has been used. This type of configuration improves the energy-absorption capacity of the vehicle roof system and dissipated impact energy in a controlled manner. In reality, carrying out roof crush test is not cost effective, thus numerical analysis of vehicle roof crush test has been performed according to standard FMVSS 216 test. Sandwich structures with unidirectional carbon /epoxy composite face-sheets and Expanded Polypropylene (EPP) foam core have been used to model different configurations for vehicle roof structure. The effects of increasing the foam core density and face-sheets thickness on the energy absorption and strength-to-weight ratio (SWR) of vehicle roof structure have been investigated. Results revealed that, the optimized sandwich solution type 6 with the face-sheets of 0.8mm and foam core of 70 Kg/m^3 density reduces the vehicle roof panel by 68% while it has almost the same structural performance with the steel solution having equal value of SWR.

Keywords: Rollover, roof panel, sandwich material, energy absorption, SWR

1. Introduction

The high rate of crash accidents fatalities urged the car manufacturer companies to improve the safety of vehicles. It is reported that around 33000 people died in United States due to different type of accidents in 2010 [1]. It is quite important to mention that although rollover crashes allocate small portion of total crashes, around 2.1%, this is the most deadly type of crash. Unfortunately 35% of people involved in rollover crashes died, that is around 7600 people. Since, even if passengers are fastening their seatbelts (but in this particular case seatbelts are less effective due to their particular geometry), there is a high chance of fatalities, 31%, in rollover accidents, it is vital to design the vehicle roof component structure with an high standard of safety [2].

In spite of the existence of various roof crush tests, government institutions are pushing even higher safety margins. There are different types of static and dynamic roof crush tests such as the Federal Motor Vehicle Safety Standard (FMVSS) 216 [3], Inverted Vehicle Drop Dynamic Test (Society of Automotive Engineering, SAE, J996) [4] and Dolly Rollover Test (SAE J2114) [5] that are aimed to evaluate the vehicle roof structure performance. The initial rules of FMVSS prescribed that the vehicle roof should sustain a force equal to 1.5 times the unloaded vehicle weight (UVW). The new updated standard, FMVSS 216a, [6] increased this margin by considering the force to be applied to the vehicle roof structure equal to 3 times the UVW with the new obligation of making test on both driver and passenger sides. There is also more conservative type of vehicle roof crush test standard which is considering the applied load equal to 4 times UVW, set by Insurance Institute for Highway Safety (IIHS) [7].

Composites as energy absorber, light-weight and anti-corrosion materials are the perfect substitutions for metallic structure specifically in the case of impact. Although these materials have not the possibility for plastic deformation due to their brittle nature, they have high stiffness and strength to weight ratios. Several works have been done on investigating the energy absorption and crashworthiness of composite and sandwich structures. Mamalis et al. [8] studied the collapse modes of sandwich panels made of composite face sheets and a foam core under axial compression force. Three collapse modes were observed. The first collapse mode occurred with foam core shear failure and sandwich fragmentation. The second mode was characterized by face sheets delamination and buckling and the third one was the progressive crushing mode. It was proved that the third mode is the most important type of sandwich collapse mode due to energy absorption capacity of the structure; it depends on the foam core properties.

* Corresponding author.
E-mail address: soroosh.borazjani@polito.it (S. Borazjani).