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Concept selection of car bumper beam with developed hybrid bio-composite material

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ABSTRACT

Application of natural fibre composites is going to increase in different areas caused by environmental, technical and economic advantages. However, their low mechanical properties have limited their particular application in automotive structural components. Hybridizations with other reinforcements or matrices can improve mechanical properties of natural fibre composite. Moreover, geometric optimizations have a significant role in structural strength improvement. This study focused on selecting the best geometrical bumper beam concept to fulfill the safety parameters of the defined product design specification (PDS). The mechanical properties of developed hybrid composite material were considered in different bumper beam concepts with the same frontal curvature, thickness, and overall dimensions. The low-speed impact test was simulated under the same conditions in Abaqus V16R9 software. Six weighted criteria, which were deflection, strain energy, mass, cost, easy manufacturing, and the rib possibility were analyzed to form an evaluation matrix. Topsis method was employed to select the best concept. It is concluded that double hat profile (DHP) with defined material model can be used for bumper beam of a small car. In addition, selected concept can be strengthened by adding reinforced ribs or increasing the thickness of the bumper beam to comply with the defined PDS.

1. Introduction

Concept optimizations of the car bumper beam can improve structural energy absorption to meet the PDS requirements. Bumper system is composed of three main elements fascia, energy absorber and bumper beam [1] (see Fig. 1). Bumper beam is the major damping structure component in passenger cars. Besides, two energy absorbers damp both the low and high impact energy by elastic deflection between two traverse-fixing points and crushing process respectively [2,3]. Due to safety requirements, in developing the bumper beam, the careful design, optimized structure, high quality and consistent manufacturing must be considered [4]. In addition, bumper beam selection can improve structural energy absorption, material consumption and cost [5]. The previous studies did not completely fulfil the impact strength requirement of the bumper PDS even in case where polybutylene terephthalate (PBT) was supplemented to the hybrid bio-composite material [6,7]. Therefore, in this recent study the optimized concept selection is employed to improve the impact stability of structure [8].

Conceptual design is the first stage of product development to satisfy customer requirements. Sapuan et al. [1] studied on conceptual design of the automotive bumper system and used the weighted objective method to find the best concept. Hosseinzadeh et al. [9] conducted a research to substitute the high strength SMC with common bumper beam material GMT to improve energy absorption. Furthermore, Davoodi et al. [10] studied about composite elliptical energy absorber for pedestrian impact test with systematic exploitation of proven ideas. Marzbanrad et al. [11] studied about the material, thickness, shape and impact condition of the bumper beam to improve the crashworthiness and low-velocity impact. He offered to substitute SMC with GMT material to absorb more structural impact. Also, European car manufacturers have done many investigations to expand the application possibilities of natural fibres in automotive industry such as front door linens, rear door linens, boot linens, parcel shelves, seat backs, sunroof sliders, headliners, door-trim panel and trunk liner [12–14]. In fact, the majority of their products are used in aesthetic and semi structural components. Mussig [15] utilized hemp and PTP® fibres in a body of bus as reinforcements, a vegetable-based thermoset resin as matrix, and sheet molding compound (SMC) as fabricating method for structural components. Although, the earlier researchers studied on energy absorption of wood for automotive structural

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