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Design and manufacturing issues in the development of lightweight solution for a vehicle frontal bumper

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Abstract

Automobile bumper subsystem is the frontal and rear structure of the vehicle that has the purpose of energy absorption during low velocity impact. The main component of this subsystem is the transverse bumper beam, generally made by steel. Design of vehicle subsystem for lightweight and for safety seems to lead the designer toward opposite directions. Quite interesting solutions can be obtained with the use of composite materials. This paper is analysing some possible alternative solutions for the particular case of the front and rear bumper.

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1. Introduction

Automobile bumper subsystem is the frontal and rear structure of the vehicle that has the purpose of energy absorption during low velocity impact. Usually, bumper subsystem consists of bumper transverse beam, stays, impact-absorbing materials (such as foam or honeycomb) connected to the structural components (generally the bumper beam) and a cover, that has both aesthetic and protection purposes. Among those elements, the bumper beam is the main structural component; it is expected to be deformable enough to absorb the impact energy, in order to reduce the risks of injury for pedestrians and other vulnerable road users, but, at the same time, it should also have sufficient strength and stiffness to give place to small intrusion of the engine compartment and, therefore, to protect the nearby vehicle components.

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Composite materials are characterised by high specific strength, both in static and impact loading conditions, and high specific stiffness; they could be an interesting candidate material for this type of component, posing as targets the lightweight together with the maintenance of at least the same level of safety performance in comparison with the present steel solution.

When designing with composite material, it is always needed not only to chose the appropriate material but to think composite (i.e. to not simply replace the metallic material with the new one, but to redesign the part) and to select the type of production technology that will be used in manufacturing, as this choice will affect deeply both the structural performance, the cost and the production rate [1]. Therefore material, design and manufacturing technology are strictly linked each other and should be considered all together.

From the point of view of manufacturing technology we have taken into consideration two different of manufacturing processes: pultrusion and die forming.

Pultrusion is a rapidly growing, cost-effective and fully automated manufacturing process for producing constant cross-section composite profiles. FRP pultruded products are often stronger then a similar product manufactured by hand-layup, vacuum bag infusion, and other composite processing methods. This is due to the fact that, during the pultrusion process, the many fiber bundles are pulled downstream using hydraulic or caterpillar grippers'. Due to this pulling, the fiber filaments are in tension when curing in the heated die. When in tension, the fibers have higher strength values and are better aligned allowing good compaction, with more fibers fitting into a given volume.

Die forming manufacturing technology is also rapidly growing technology able to produce composite shells with the desired shape. Die forming has a capability of producing structurally integrated crash box and beam as a single component. This is an extremely interesting feature of this technology because it leads to remarkable improvements both manufacturing and assembly rate and for reduction of the number of different components that should be produced and assembled to construct the front end structure. Besides, since joining is one of the critical issue in using composite part in automotive structures (as structures often have their weak points where their parts are joined together), The die forming technology is suitable for producing an integrated bumper beam and crash box structure thus eliminating the need of joints in between.

To assess the structural performance and the energy absorbing capability for the bumper beam made from composite material with the above mentioned manufacturing technology, six different materials were considered:

- E Glass/epoxy pultruded bumper beam solution compared with a bidirectional fabric E Glass/epoxy and reference steel material. The detailed mechanical properties of the three material are documented in [2].
- die formed integrated crash box- bumper beam made by a classic glass-mat-reinforced thermoplastics (GMT) compared with GMTex, i.e. a chopped fiber glass mat reinforced PP laminate with randomly oriented glass fibers and additionally reinforced with a fabric inside, GMT-UD, i.e. a chopped fiber glass mat reinforced PP laminate with randomly oriented glass fibers and additionally reinforced with unidirectional glass fiber layers and with reference steel solution . The detailed mechanical properties of the three material are documented in [3]

The impact responses and damage mechanisms for the whole group of composite materials are more complex than conventional metallic materials and depend on a number of different parameters including fibre and matrix type, section shape and dimensions, impact velocity, impact angle, shape of striker, target geometry and target material. A composite tube is capable of absorbing significant impact energy by material fragmentation and large changes in the tubes cross-sectional geometry when the tube undergoes large flexural deformation [4, 5, 6, 7, 8, 9, 10, 11].

2. Bumper beam design

As indicated in the introductive paragraph, two different types of manufacturing technology, namely pultrusion and die forming, have been considered to manufacture the beam with the desired shape.