Impact properties of NBR/HDPE based composites reinforced with polystyrene and vermiculite for aeronautics

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ABSTRACT

This study investigates the damping properties of sustainable high-density polyethylene (HDPE) and nitrile-butadiene rubber (NBR)-based composites reinforced with polystyrene (PS) or vermiculite (VRM) particles. Composite specimens were produced by hot compaction after incorporating 5, 10 and 15 wt.% of PS or VRM filler into a rubber-modified HDPE matrix. Drop-weight impact tests were carried out according to ASTM D7136-20, and the absorbed energy was determined from the force–time curve. The neat HDPE/NBR matrix absorbed 62 J, whereas the composite containing 10 wt.% of PS achieved the highest energy absorption, reaching 72.5 J. Fracture surface analysis by Scanning Electron Microscope (SEM) revealed typical polymer damage mechanisms, including ductile tearing and micro void formation in the matrix, as well as filler-driven crack interactions that influenced the overall failure mode. The results demonstrate that an intermediate PS content provides the most effective balance between ductility and reinforcement, identifying HDPE/NBR–PS composites as promising candidates for impact-resistant aeronautical structures.

Keywords: Polymer-based composites, Sustainable rubber, Damping properties, Aeronautics materials

INTRODUCTION

The growing demand for lightweight and sustainable materials in aeronautics has increased interest in polymer-based composites, which offer low density, high design flexibility and good energy-absorption capability. At the same time, the accumulation of post-industrial polymeric residues highlights the value of reusing these materials in composite systems [1-2]. Such composites are already widely employed in aircraft structures, yet they remain exposed to impacts and other service-induced damage that could compromise structural integrity and therefore the safety of the passengers [3]. For that reason, the enhancement of impact resistance is of particular importance in the aerospace field [4].

MATERIALS AND METHODS

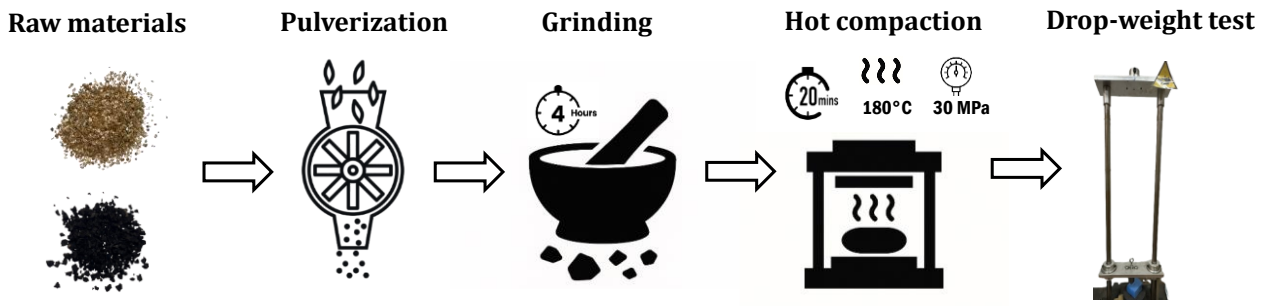

Figure 1. Workflow, including all the stages from material selection and formulation to specimen manufacturing and mechanical testing.

Composite specimens were manufactured by blending HDPE with recycled NBR and subsequently incorporating PS or VRM powders at 5, 10 and 15 wt.% before hot compaction at 180 °C and 30 MPa for 20 minutes [5]. Drop-weight tests were carried out using a 3.5 kg conical impactor according to ASTM D7136-20. The energy absorption was evaluated using the trapezoidal integration method applied to the area under the force–displacement curve following $E_a = \int F dy$.

After mechanical testing, the specimens fracture surfaces were examined by SEM to identify the failure mechanisms associated with each reinforcement type and fraction.

MAIN RESULTS

The results of the drop-weight tests revealed a remarkable enhancement in energy absorption depending on the filler type and content. The neat rubber-modified HDPE matrix has dissipated 62.07 J of impact energy while superior damping for the PS-reinforced composite with 10 wt.% filler was observed, dissipating 72.5 J without failure. These findings highlight that an intermediate filler content (10 wt.% PS) provides the best compromise between stiffness, ductility, and energy dissipation. The fracture surfaces demonstrated that rubber domains have induced cavitation and ductile tearing, whereas PS promoted crack deflection and formation of additional cracks, and VRM induced brittle fracture mechanisms when at higher content.

CONCLUSIONS

The impact behavior of HDPE/NBR composites is strongly influenced by the type and amount of the reinforcements. An intermediate content (PER PS10), provides the most favourable balance between ductility and reinforcement, leading to the highest energy absorption without catastrophic damage. These results identify HDPE/NBR–PS composites as promising candidates for lightweight, energy-absorbing applications in aeronautical structures.

REFERENCES

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