The influence of void cells on the microstructure of thermoplastic polymers TPE-S and TPE-V

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Abstract

Sustainable development in the transport sector is based on several strategies to reduce the environmental impact of vehicles. One of the most important strategies is to use recyclable materials to limit carbon emissions and promote a circular economy [1,2]. In addition, lightweight structures reduce energy consumption by cutting vehicle mass, improving efficiency, and reducing greenhouse gas emissions [3,4,5,6].

One innovative approach to achieving this objective is the development of new ranges of materials, particularly porous materials. These can be designed by inserting void cells within a polymer matrix. The microstructure of porous materials refers to the arrangement of their pores, which significantly influences their mechanical and thermal properties. These pores vary in size, shape, and connectivity. These features have to be characterized to go further in the comprehension of deformation mechanisms as well as to enrich mechanical models.

This work focuses on two thermoplastic materials, TPE-S and TPE-V, reinforced by void cells. Characterization of their microstructure and physicochemical properties has been carried out with different techniques.

X-ray microtomography studies have revealed that the distribution of empty cells is influenced by both the nature of the polymer matrix and the proportion of empty cells incorporated within it. This technology makes it possible to examine the interior of a material to identify differences in composition or X-ray properties. It can also be used to accurately detect internal defects such as inclusions, voids, and discontinuities, or to verify the integrity and positioning of complex mechanical assemblies. In addition, this technique has enabled us to determine the shape and size of empty cells within the matrix TPE-S and TPE-V.

Additional analyses carried out with a scanning electron microscope (SEM) highlight a main difference between the two materials: the cell walls in the TPE-V matrix have a rough surface, whereas they are smooth in the TPE-S matrix. It is observed that cells contain weak connections with the TPE-V matrix.
Figure 1 shows SEM analysis carried out on both types of material.

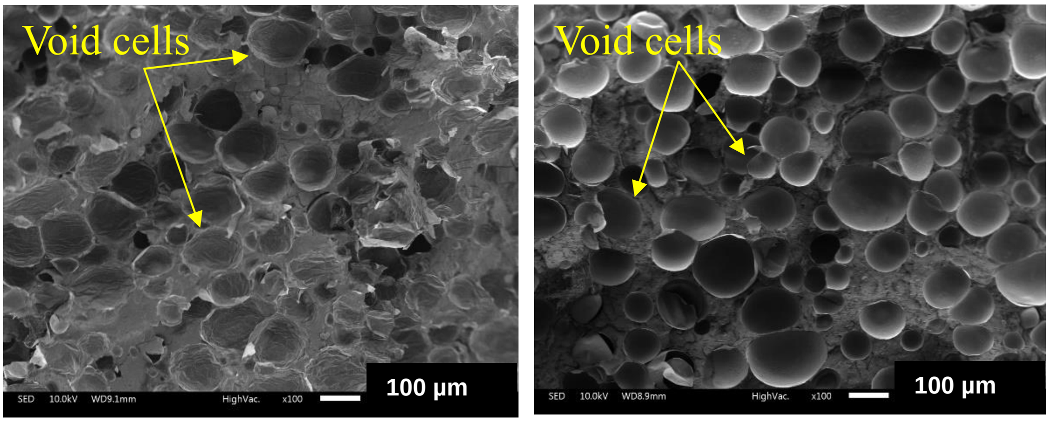

Figure 1: SEM analysis for TPE-S and TPE-V reinforced by void cells.

This finding was confirmed by Fourier Transform Infrared Spectroscopy (FTIR) analysis, which revealed that the void cell material and TPE-S have a similar chemical composition, indicating the presence of comparable functional groups and confirming the chemical affinity between the two materials.
Such analysis, carried out at the microscopic scale, is important to better account for the microstructure effect in modeling the mechanical behavior of porous polymers.

Following the physico-chemical analyses, mechanical tests were carried out on the different materials, varying the percentages of reinforcement incorporated. The mechanical results showed a significant improvement in properties (such as tensile strength and modulus of elasticity) for the TPE-S and void cell composites. However, for the other polymer matrix TPE-V, a decrease in mechanical performance was observed with the addition of void cells. This difference in behavior can be attributed to the interfacial adhesion between matrix and reinforcement: good compatibility in the case of TPE-S favors efficient stress transfer, while poor adhesion in TPE-V limits the reinforcing effect and may even give rise to structural defects.

References

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