Bio-inspired structures and biomaterials: a path for the design of more sustainable bonded joints

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Introduction

Modern vehicle structures are based on high performance metallic and composite materials, allowing these structures to have excellent energy absorption capabilities. However, such structures are not easily recycled and are not biodegradable. This work seeks to provide alternative solutions for this purpose, based on bio-materials and bio-inspired bonded shapes, produced with the support of additive manufacturing.

Experimental methodology

The project encompasses four main steps, which are shown below in Figure 1. Bio-materials (such as high-performance woods and bio-polymers) are first characterized. Processes to manufacture these structures are then developed, allowing to create the desired impact absorption structures, which later will be tested at the component scale.

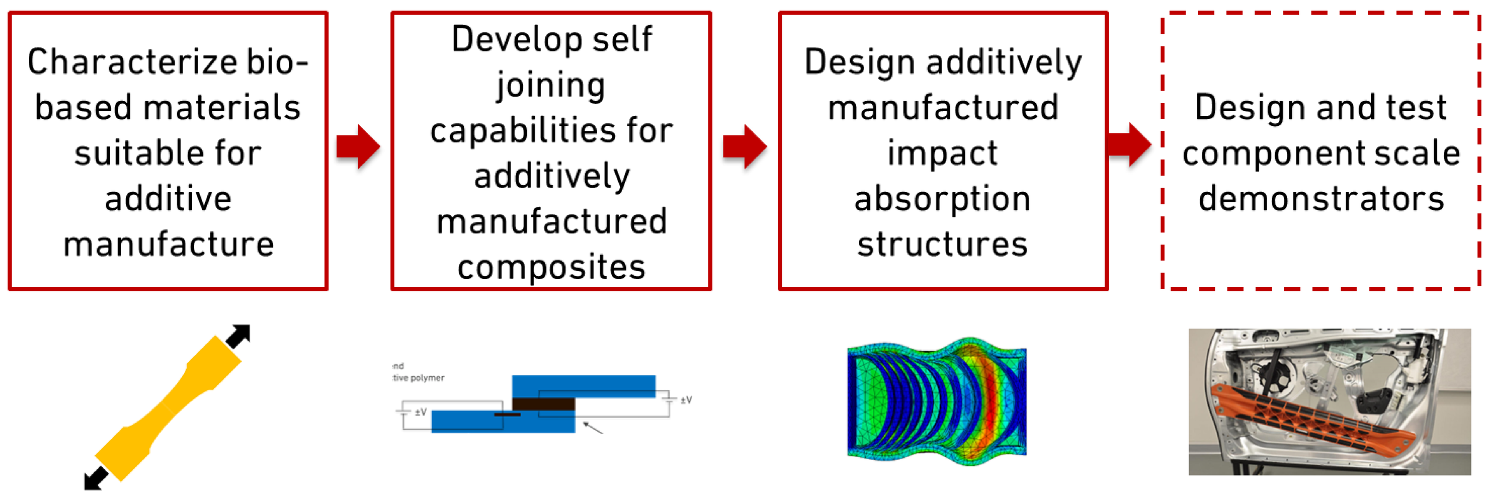


Figure 1 – Key steps towards the development of sustainable impact absorbing structures

Wood based materials under study include densified wood, whereupon natural woods are subjected to a chemical treatment and then pressed at high temperature to create a highly densified material, with significantly higher tensile strength. This process is shown in Figure 2.

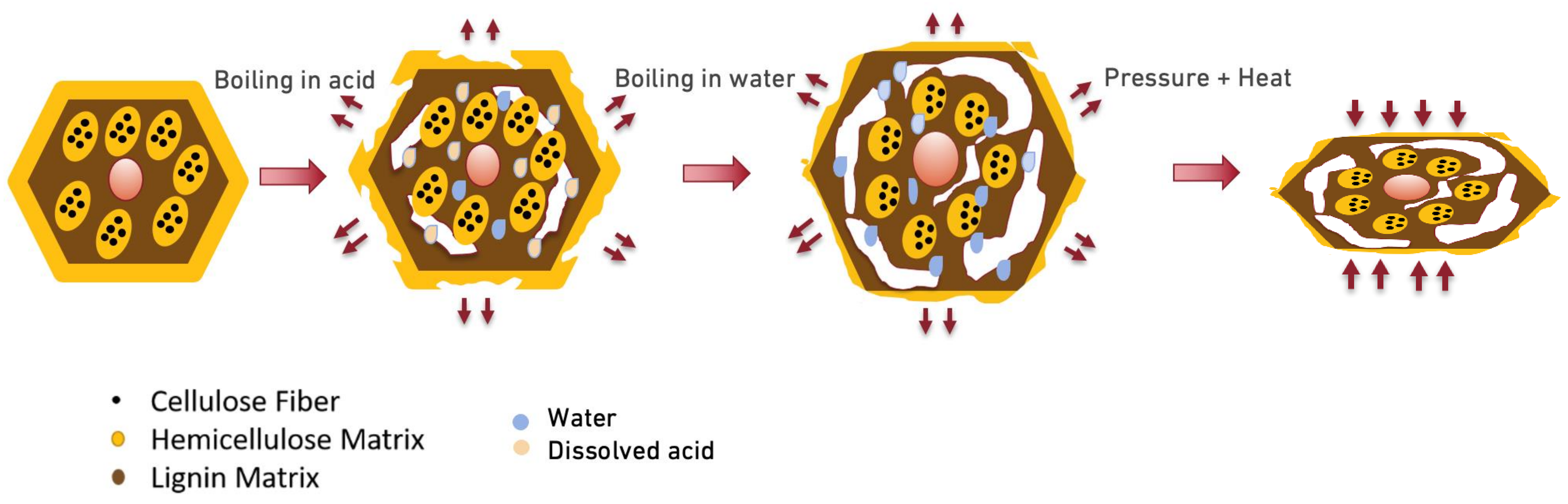


Figure 2 – Wood densification process, showing the removal of the lignin matrix and the densification process.

Material characterization and testing

The characterization results of the densified wood are shown in Figure 3, demonstrating the superior strength and stiffness attained with the densified pine wood.

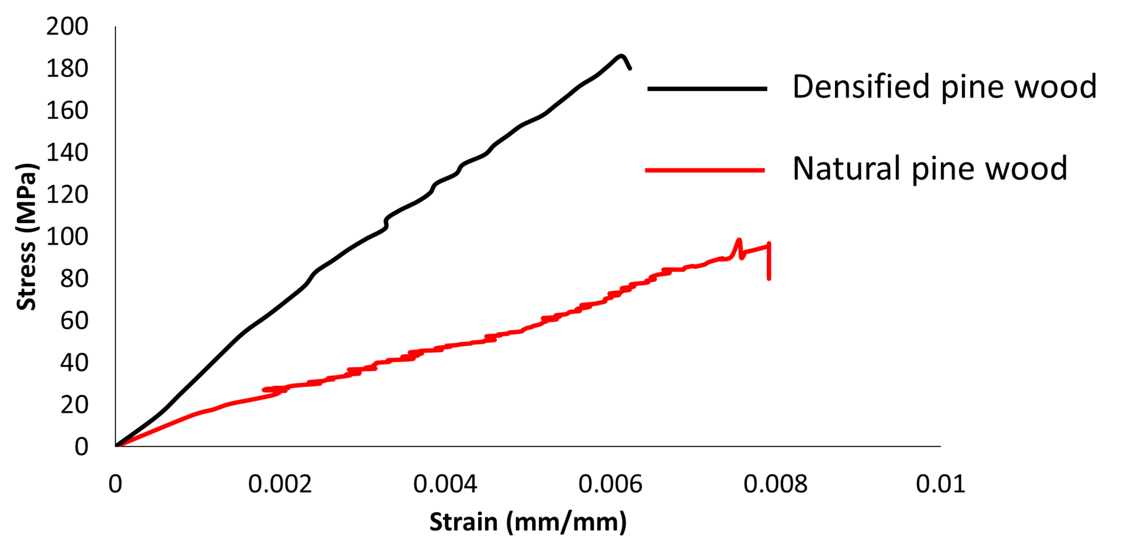


Figure 3 – Stress-strain curves of results of natural and densified wood

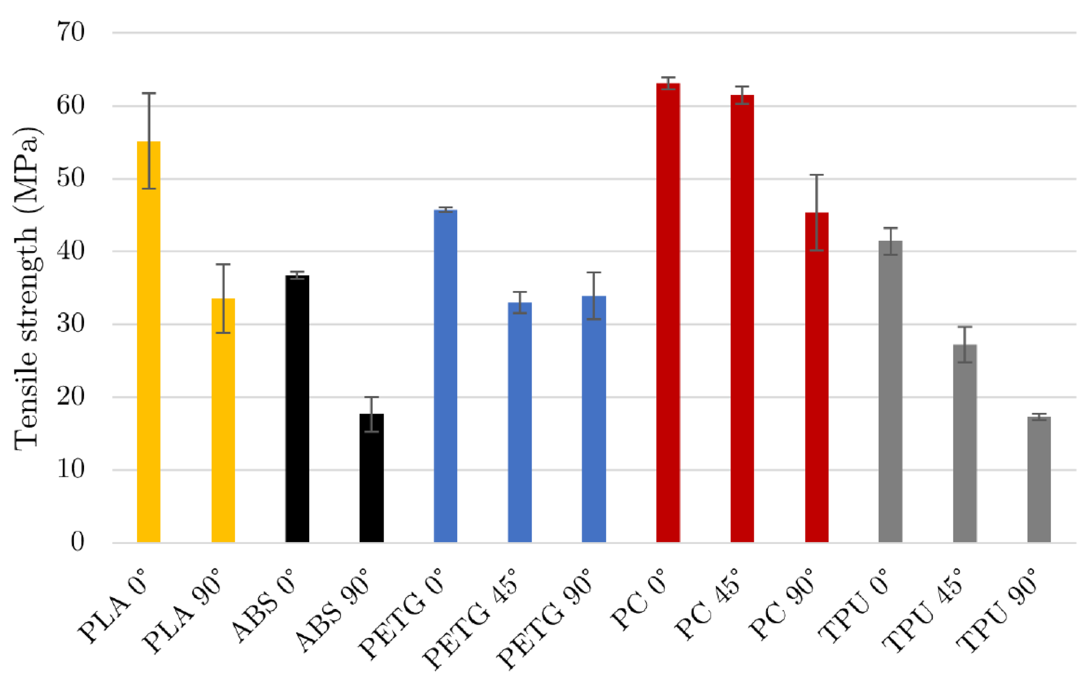
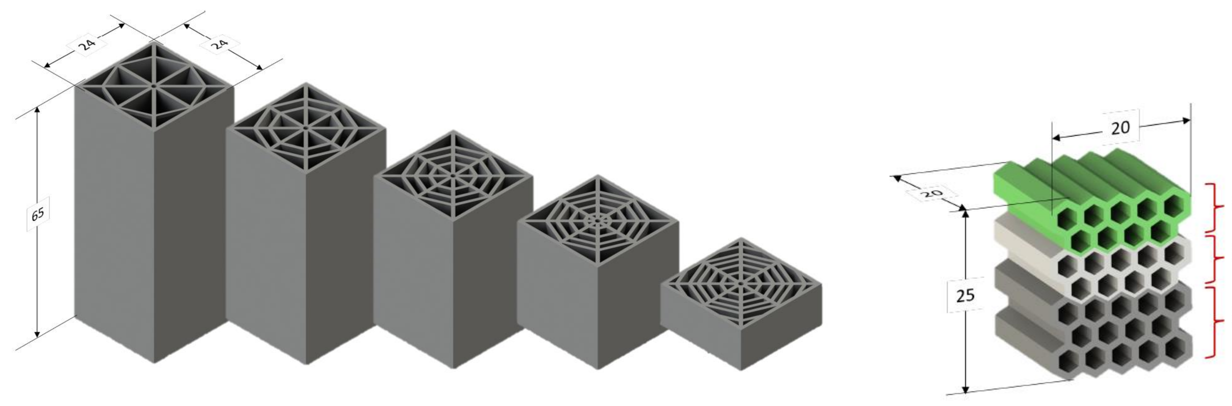


Figure 4 – Tensile strength in different printing orientation for multiple thermoplastic polymeric materials

Multiple polymeric materials, compatible with additive manufacturing were also characterized in different printing orientations, allowing to determine strength and energy absorption characteristics (Figure 4).

Novel impact absorption structure designs

Two different impact absorption structures were created using additive manufacturing and bonded design. One concept relies in a single material, using a graded spider web internal design. The second concept uses a combination of three materials, using different levels of stiffness (shown in Figure 5).



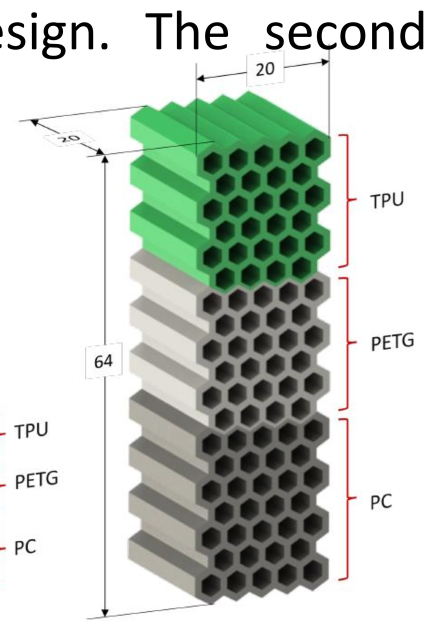


Figure 5 – Singe material configurations for impact absorption structures (left) and multi material structures, with a graded concept (right)

Results and discussion

Results of impact testing are shown in Figure 6, displaying the specific energy absorption, the mean and peak compressive force and an energy efficiency parameter (CFE).

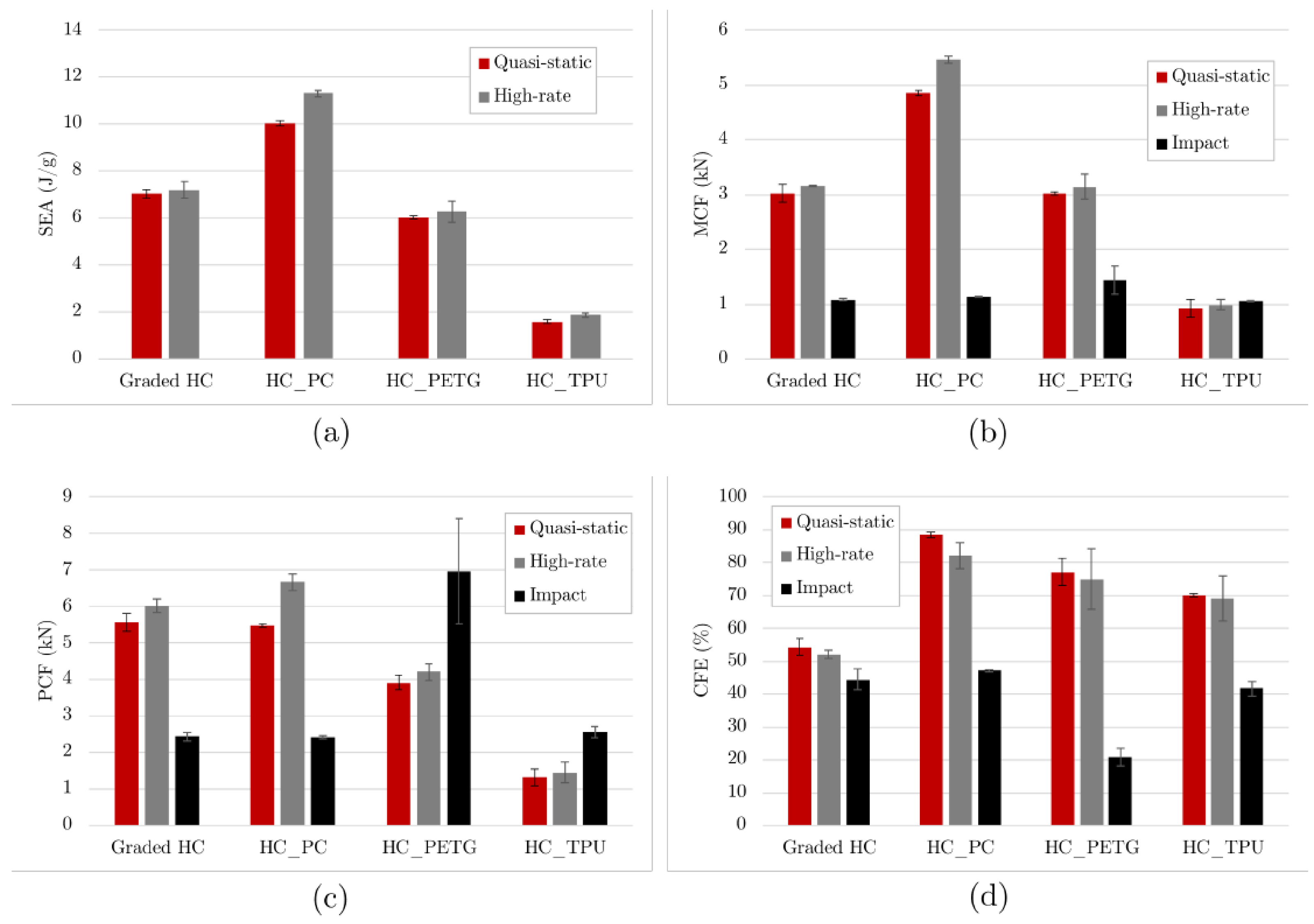


Figure 6 – Crashworthiness indexes for different honeycomb configurations under different compressing rates.

Overall, the graded configurations are able to provide acceptable energy absorption performance, performing better than low strength materials, such as PETG and TPU. Polycarbonate based structures are those which perform better under impact conditions, but this comes at a higher material cost and reduced recyclability.

Conclusions

New materials and design concepts have been shown to be promising solutions for impact absorption structures in the automotive sector. These materials were mechanically characterized and tested in two different type of energy absorbing structures, with good results.

Acknowledgements

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