Design and modelling of impact resistant bio-inspired structures

EAS Marques | LPF Garrido | S Jalali | RJC Carbas | M Kasaei | LFM da Silva

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.

MATERIALS AND 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.

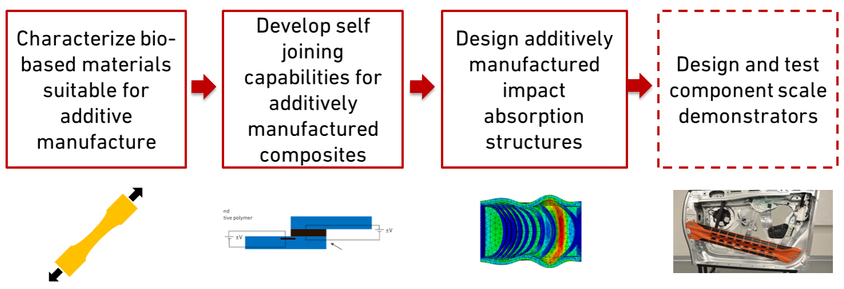

Figure 1 – Key steps towards the development of sustainable impact absorbing structures

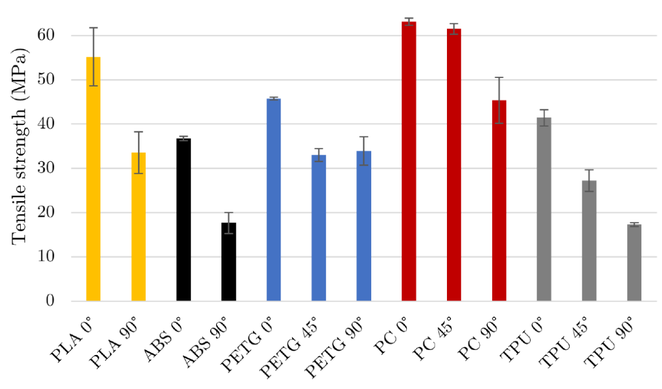

Figure 2 – Tensile strength in different printing orientation for multiple thermoplastic polymeric materials

Multiple polymeric materials, such as PLA, PETG, ABS, PC and TPU, suitable for additive manufacturing, were characterized in multiple printing orientations (Figure 2).

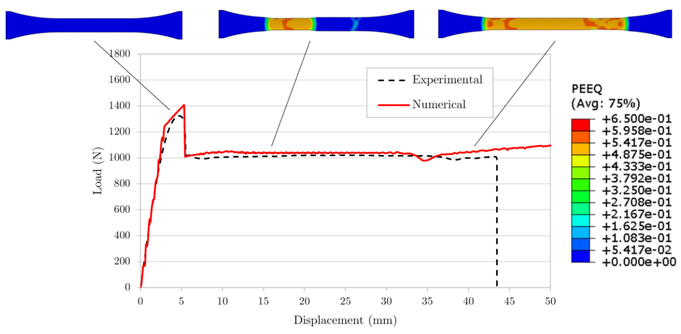

Figure 3 – Tensile strength in different printing orientation for multiple thermoplastic polymeric materials

Furthermore, material models were used to support the use of a Hill's stress criterion, allowing to simulate plasticity and damage under compression (Figure 3).

IMPACT ABSORPTION 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 4).

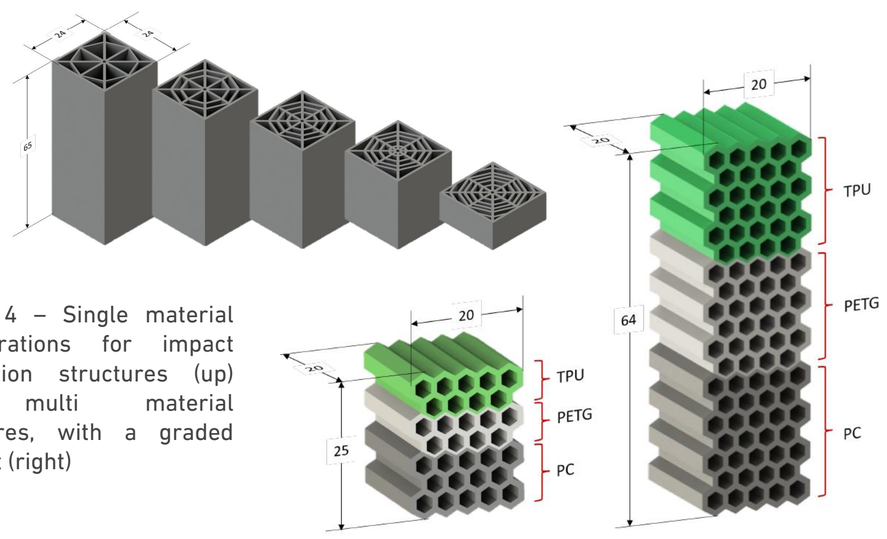

Figure 4 – Single material configurations for impact absorption structures (up) and multi material structures, with a graded concept (right)

RESULTS

Using a numerical model based on the Hill's stress criterion, it was possible to precisely model both the mechanical performance and the collapse mode of the shapes under analysis.

The model allowed to determine that multi-material structures require precise tuning of the crushing rates,

This avoid unbalanced deceleration under impact conditions, maximizing performance.

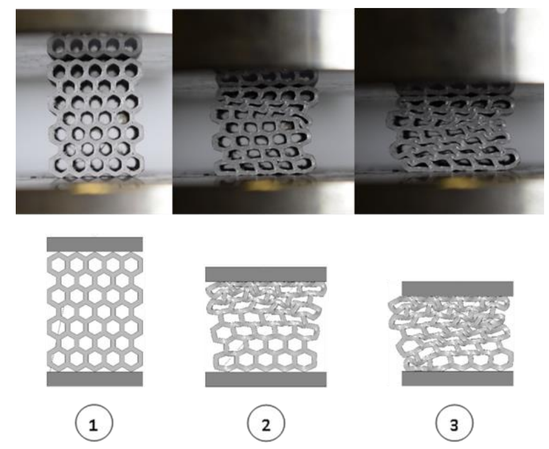

Figure 5 - Experimental (top) and numerical (bottom) failure process of a PC sample

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).

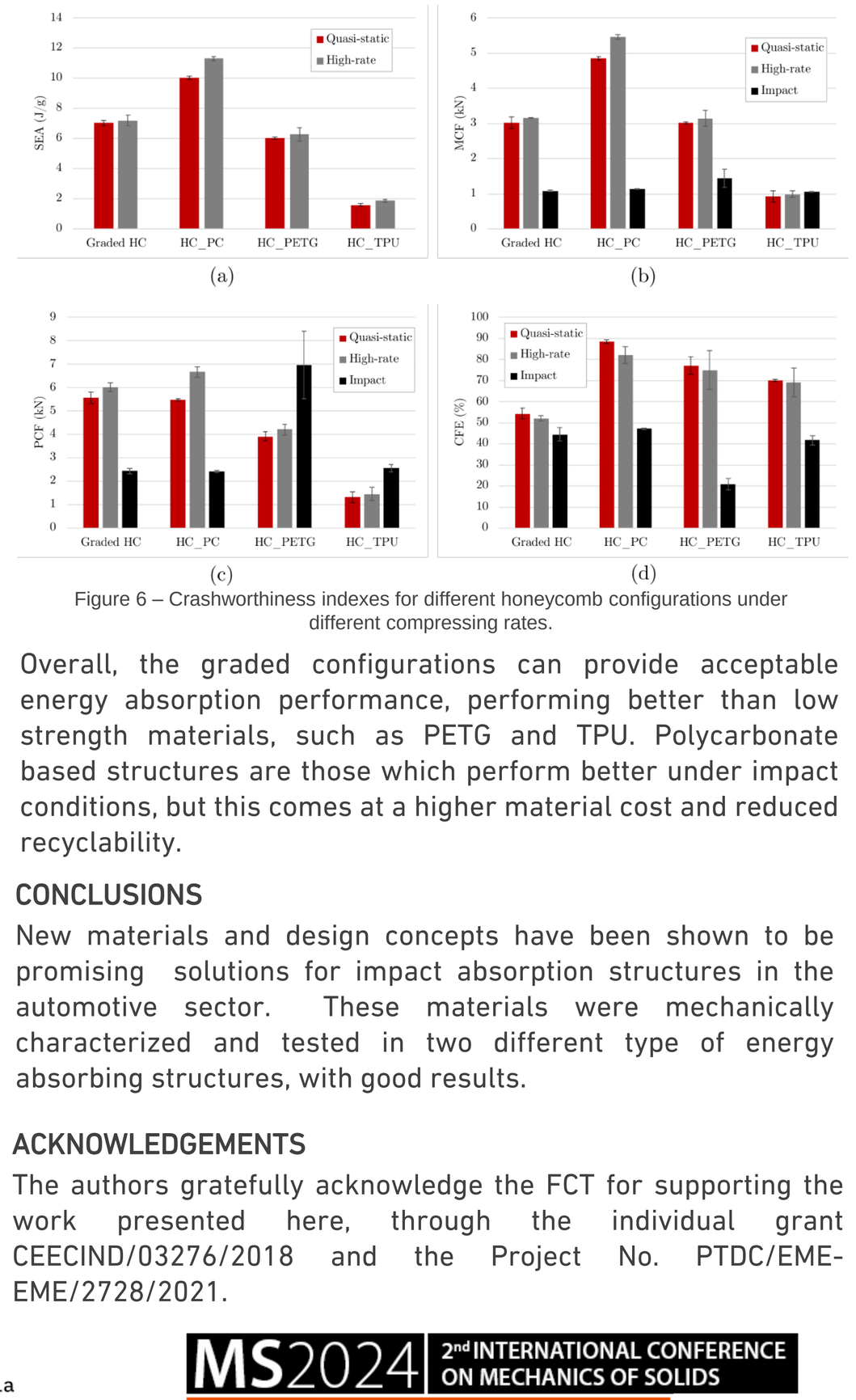

Figure 6 – Crashworthiness indexes for different honeycomb configurations under different compressing rates.

Overall, the graded configurations can 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

The authors gratefully acknowledge the FCT for supporting the work presented here, through the individual grant CEECIND/03276/2018 and the Project No. PTDC/EME-EME/2728/2021.

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
Fundação para a Ciência e a Tecnologia
MS2024 2nd INTERNATIONAL CONFERENCE ON MECHANICS OF SOLIDS
30-31 October 2024 · FEUP, Porto - Portugal