Head Protection in Micromobility: Materials and Design

Gabriel F. Serra, Ricardo Alves de Sousa, Eduardo Noronha and Fabio. O. Fernandes

I. INTRODUCTION

E-micromobility (EMM) has recently appeared as a practical solution for short-distance commuters, and it is growing at upsetting rates thanks to the introduction of sharing services. The downside of portable e-transportation is the rapid increase in injuries and fatalities. Regarding standing e-scooters, head injuries are becoming one of the most common, as shown by research conducted in different urban emergency departments, alongside bone fractures, skin abrasions, and lacerations [1]. The evolution of safety measures and regulations did not keep pace with such a drastic change in mobility trends.

Literature [2] has proven that cork, a natural cellular material in its agglomerated form, has excellent potential to replace synthetic foams for impact protection applications. Therefore, experimental campaigns involving dynamic impact tests have been conducted on cork and other new promising materials with energy absorption capabilities, such as shear thickening fluids (STF) [3], to evaluate the best combinations for replacing the standard materials used by the helmet industry.

The final result is an innovative helmet that can be flattened to about the size of a laptop when not in use and be easily stored in a backpack. It represents a significant innovation for the helmet industry in aesthetical and functional aspects and sustainability, having the concept met three of the seventeen goals established by the UN 2030 agenda for sustainable development.

II. METHODS

Experimental Testing

Hybrid composites comprising layers of agglomerated cork (AC) material combined with STF in the liquid state, impregnated textile and foamed PVC/PU were tested for crashworthiness properties. The setup consisted of a drop-tower testing apparatus to measure the force (acceleration) and displacements. Raising the impactor to the desired height imposed a moderate energy level (20 J). Parameters such as peak acceleration and peak forces were recorded and compared. Figure 1 depicts the samples' compositions, and Figure 2 presents results in terms of mechanical response.

Figure 1: Samples tested.

Table 1: Samples' mass geometry and impact response.

Combination code	Total mass	Thickness	Impact Area	Peak 1 duration	Peak 2 duration	Peak 2/ Peak 1	σ_{max}	ε_{max}
unit	[g]	[mm]	[mm2]	[ms]	[ms]		[MPa]	%
C10+TI	5,8	14,15	2495	23	30	0,292	1,52	50,13
C10+PVC	13,76	12,95	2657	20	41	0,265	1,51	48,36
C10+BP3,3	12,94	12,95	2076	23	32	0,278	1,69	49,25

Gabriel Serra is a PhD student, while Ricardo Sousa (rsousa@ua.pt, +351234378150) and Fabio Fernandes are Assistant Professors and Researchers at the Center for Mechanical Technology and Automation, Department of Mechanical Engineering. Eduardo Noronha is a researcher at ID+, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal.

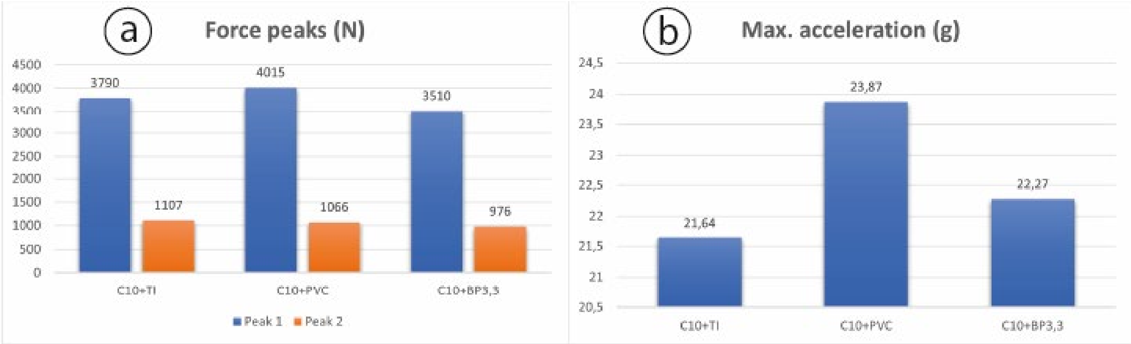


Figure 2: Comparison of the mechanical response of a C10+TI, C10+PVC and C10+BP

Combining agglomerated cork with STF impregnated textile material gave the best ratio of crashworthiness properties to sample weight under the studied conditions. Therefore, this combination proved to be the most suitable one for developing the helmet's concept.

III. INITIAL FINDINGS

A complex product design was carried out and not described in this short communication. The resulting initial design is rendered in Figure 3: a compact helmet that can lie on a flat surface and measure roughly the size of a 15' laptop.

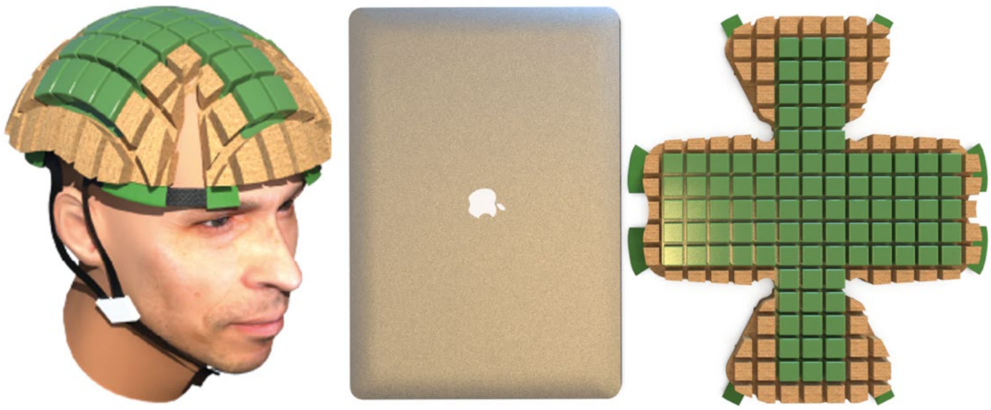
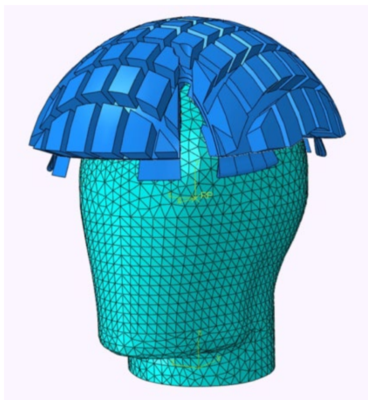


Figure 3 – Final design of the helmet incorporating the best performing materials

IV. DISCUSSION



The several hybrid STF-cork material combinations discussed in section 2 were already modelled and validated under a finite element environment. The current steps in this study are to perform impact tests for different scenarios. To this end, and although there are not currently standards expressly set for e-scooters safety apparel, the European EN1078 for bikes appears to be the logical one to follow. Boundaries conditions will be selected, and tests will be performed with a rigid headform. Afterwards, kinematic data will be extracted and introduced in a Finite Element Head Model, specifically the YEAHM, to measure biomechanical data and correlate it with the likeliness of sustaining severe injuries after a given accident scenario.

V. REFERENCES

[1] Badeau A. et al., *American J. Emergency Med., 2019,* https://doi.org/10.1016/j.ajem.2019.05.003
[2] Ptak M et al., Int. J. Impact Eng. 2017, https://doi.org/10.1016/J.IJIMPENG.2017.04.014
[3] Gurgen S et al., Progress Polymer Sci. 2017, https://doi.org/10.1016/J.PROGPOLYMSCI.2017.07.003
[4] Fernandes F. et al, Eng. Comp. 2018, https://doi.org/10.1108/EC-09-2016-0321