

In search of lighter footwear

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The Portuguese footwear industry today is a modern and highly competitive economic driver that has attained the position of being one of the most important European and worldwide exporters in the leather shoe sector. Recognised for its high quality products, it puts special focus on design and innovation, and exports more than 95% of its production to over 150 countries across five continents.

In addition to footwear manufacturers, the Portuguese footwear industry cluster includes dynamic materials, components, equipment, software and leather goods producers. It is also especially outward looking and has increased exports by more than 50% since 2010. The sustainability of the cluster is not merely limited to growth in exports but has also had a positive impact on employment with more than 10,000 new jobs being created in less than 10 years.

This progress is strongly related to the investment in research, innovation and technological development made during this time, coupled with a proactive surveillance of the latest market trends, which has allowed emerging consumer and business opportunities to be identified. Two examples of these trends are a consumer demand for comfortable lightweight footwear and the evolution of environmental awareness linked to a demand for greener products, both of which can be considered actual challenges for the footwear sector.

In this frame, technological and innovation centre CTCP, research institute CIMO/LSRE-LCM/IPB, safety shoes manufacturer AMF and cork insole manufacturer 3DC, all located in Portugal, are jointly developing the Extra Light Safe Shoe project. The aim is to develop new materials, processes and footwear, including ultralight microcellular polyurethanes with suitable properties for the production of midsoles and higher performance cork composites for the production of insoles for fashion, technical and casual footwear.

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TABLE 1: IMPACT ABSORPTION VALUES OF PU WITH ADDITIVES

Sample	Density (g.cm ⁻³)	Max. deceleration (m.s ⁻²)	Return energy (%)
PU+1%	0.31	210.29	36.34
PU+2%	0.31	225.22	40.73
PU+3%	0.30	232.93	35.94

ULTRALIGHT MICROCELLULAR PU

Reducing the density of polyurethane leads to a decrease in raw materials consumption and promotes energy savings, together with weight reduction which can result in an increase in footwear comfort. One possible strategy for microcellular PU density reduction involves the modification of the cellular structure by increasing the number of cells and improving the homogeneity of their distribution within the material itself.

This can be achieved through the incorporation of hollow and/or expandable microparticles into the PU formulation. These additives will preferably be located at the cell wall. However, they must also maintain or improve physico-mechanical properties of the resultant PU, something that requires a systematic study involving an evaluation of the amounts used and how they affect the material's final properties.

A base chemical formulation used for midsole production at an industrial level was modified by the incorporation of 1, 2 and 3% of additive. The results obtained clearly demonstrated the success of the adopted strategy at lab scale. Preliminary industrial pilot tests with the addition of the additives at 3% of content results in PUs with densities comprising between 0.35 and 0.30 g/cm³, corresponding to a reduction of 30-40% compared to the base formulation.

The assessment of the cellular structure by optical microscope (OM) allowed the differences between the base PU and the modified ones to be closely observed and a reduction of cell size was noted as the additive content increased. Furthermore, the presence of the additive on the cell wall was identified, allowing a reduction of cell wall density and, consequently, the final PU density.

The performance characteristics indicated the resulting PUs would have adequate technical properties with a special emphasis on impact absorption, which is closely related to overall comfort. The dynamic analysis of a material's ability to absorb impact on the heel when subjected to a standard impact weight is correlated with the degree of impact absorption of the material itself. Maximum deceleration and the percentage of energy are the most important properties since they represent respectively damping and resilience.

With regard to maximum deceleration, lower values represent a better capacity to absorb impact. On the other hand, higher values of energy return show an improved resilience. Some of the results obtained are presented in *Table 1*. It can be seen that the density reduction results in PUs with higher maximum deceleration values, by and large, increase with the rise in additive content from 1% to 3% (PU+1%, PU+2% and PU+3%).

However, the energy return of the materials does not present a similar behaviour. A general analysis shows that PUs with the additives show values of maximum deceleration and energy return that fulfil the defined specifications values: maximum deceleration ≤ 280 m.s⁻² and energy return between 30% and 50%. Based on these results, it can therefore be concluded that low-density PUs could offer adequate impact absorption properties and be suitable for the production of midsoles for extra light weight safety shoes.

CORK COMPOSITES

The cork composites used for insoles usually offer relatively low rates of water absorption and flexibility, coupled with some rigidity, all of which are related to the specific properties of cork itself and the binders used for its agglomeration. These may result namely in low sweat and impact absorption properties. Additionally, some of the binders could well be replaced by emerging alternatives that are more environmentally friendly.

Based on these facts, the adopted strategy included the use of greener water-based binders, the improvement of water absorption properties through the incorporation of residual biomass comprising almond shell (AS) and olive stone (OS) at up to 25% of total content and an increase in flexibility through the addition of recycled microcellular polyurethanes.

Two types of binders were tested, DIS, a water-based polyurethane adhesive, and ACR, an acrylic-based water dispersion. Regarding the base composites, the ones produced using DIS binder showed a similar flexibility. The ACR-based composites, however, showed the lowest flexibility for both tested contents (20% and 30%) and ACR was therefore rejected. With regard to the water absorption results, the composites produced with DIS binder and the selected biomass addition compared with the usual binder and no biomass, showed a water absorption increase of over eight times reaching up to 70 mg/cm² coupled with satisfactory water desorption and dimensional stability.

Regarding the increase in flexibility, the addition of the selected biomass showed a positive effect. With the incorporation of recycled microcellular polyurethanes the overall results suggested that while impact absorption properties could improve, the flex resistance remained similar to the base formulations (without PU residues). However, this strategy might nevertheless contribute towards reducing the material resources needed, maintain the materials in the life cycle and reduce waste management costs. 🌀