Development of eco-friendly advanced energy absorbing composites

Francisco J. Galindo-Rosales*
FEUP, Faculdade de Engenharia da Universidade do Porto, 4200-465 Porto (Portugal)

The absorption of energy during impacts is ubiquitous in our society and there is an increasing need for advanced energy absorbing materials, especially for human protection applications. The development of advanced energy absorbing composites is an issue that has many engineering challenges. In the last decade Shear Thickening Fluids (STF's) have attracted the attention of the industry for the fabrication of passive dissipative devices, due to their viscosity increase with the applied shear stress over a critical value. Moreover, the increase in the viscosity can be tailored for the specific application by choosing properly the components of the STF[1]. All this has led to a considerable interest in incorporating STF's into other materials, like rubbers and foams (flexible porous media in general) in order to obtain energy absorbing composites possessing a combination of their best properties/characteristics[2]. The nature of the STF's can be colorful, but discontinuous STF's are particularly interesting for this work, since they transform into a material with solid-like properties at high shear rates[3]. Stabilized suspensions of cornstarch with a high loading fraction of particles are a typical example of a discontinuous and eco-friendly STF.
One of the major concerns when trying to create an effective energy-absorbing composite with these fluids is the interaction between the fluid and the geometry which confines it, as the rheological response of STF's is greatly affected by the deformation rates at which it is undergone. For these reasons, the early composites for energy absorption systems based on STF's have used porous media as scaffold, where the tortuosity of the micro-paths subjects the STF to a complex flow under confinement[4]. Thus, the addition of STF's to the porous media increases their energy absorption capabilities, due to the contribution of the viscous work done by expelling the fluid from inside the cells of the porous medium, which is added to the energy dissipated due to the elastic, plastic, and buckling modes that occur during compression. However, filled porous media by STF's bring some operational drawbacks: the filling process is not straightforward; the shape of the flow paths inside the porous media is unknown and, subsequently, it is impossible to predict the response of the composite a priori; the sealing of the filled porous media is an additional problem; by replacing the air inside the porous medium by the STF, the resulting composite is not going to be light weight anymore; etc.

An alternative way of developing energy absorbing composites able to maximize the energy dissipated under impact would be based on the combination of the mechanical properties of natural cork, shear thickening behavior of stabilized suspensions of cornstarch and microfluidics. The novelty consists of engraving a network of microchannels on a sheet of micro-agglomerated cork, filling them with a discontinuous STF and closing it with another sheet of micro-agglomerated cork. When subjected to an impact, the energy will be absorbed and dissipated by the combined effect of the elasticity of the cork and the enhanced viscous/normal forces of the STF flowing under confinement through the microchannels. So the question we want to address with this work is the following one: How can we relate the viscosity curve of a STF with the mechanical properties of the natural cork and the pattern of a network of microchannels in order to create customized composites able to maximize the dissipation of energy under impact for any application? As depicted in Fig.1, the answer will require combining experimental, theoretical and computational approaches.

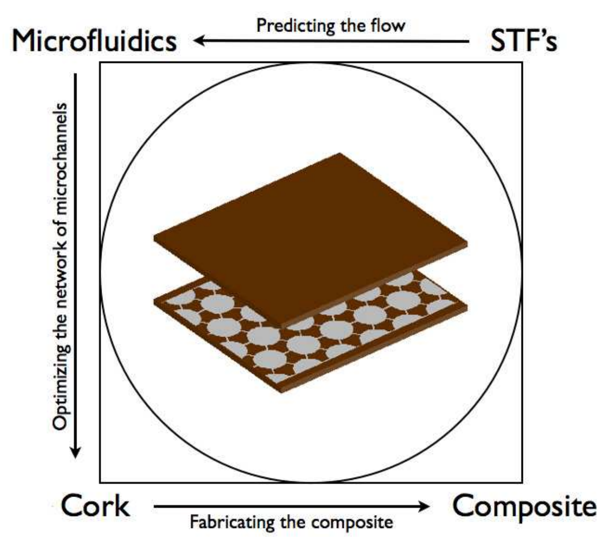

FIG. 1. Development of eco-friendly advanced energy absorbing composites: Flow chart.

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* galindo@fe.up.pt

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