TITLE:

TOWARDS COMPUTATIONAL MULTISCALE SHOCK-ABSORBING METAMATERIAL DESIGN: FROM THE UPPER-SCALE TO THE LOW-SCALE

SHORT SUMARY:

Metamaterials, designed and artificially manufactured materials that exhibit apparent exotic (or unnatural) properties at the macroscopic scale, are presently a relevant topic in material science. This is due to the fact that these unnatural properties are achieved by endowing the material with a devised, normally highly complex, artificial morphology (and/or topology), at the low scales of the material (meso/micro.../atomic scale), which, some times, is far from being captured by means of physical intuition. However, the positive counterpart of this fact is that those complex typologies can be nowadays manufactured, at least at the meso/micro scale, by resorting to cutting-edge manufacturing technologies: typically additive manufacturing. To face the computational multiscale design of a metamaterial (endowed with macro/meso scales, for instance), two alternative approaches can be used:

I) First, focus on the low scale, and detect some typical behavior, associated to the material at this scale, which is “intuitively" connected to the exotic behavior aimed at being obtained at the upper scale. This is the method traditionally used in some specific areas, like acoustic metamaterials for sound attenuation. Then, in-lab experimentation or appropriated multiscale computational modeling can confirm, in a second stage, if that intuition is (or it is not) correct.

II) Focus first on the macroscale, and identify what is the unnatural material behavior aimed for the metamaterial, and the apparent homogenized material properties conferring to it the desired exotic behavior. Then, in a second stage, focus on the low scale and use intuition, or alternatively, computational optimization tools, to determine the optimal microscopic morphology or topology, at said scale, to achieve the intended exotic macroscopic behavior.

The second methodology may provide some intrinsic advantages, essentially concerning its generality (”***set first the goal and, then, manage to achieve it”***) and the fact that, it minimizes the room left to intuition in the metamaterial design process.

The lecture focus on approach II) applied to the computational design of shock-absorbing hyperelastic metamaterials. In a first stage, non-convexity of the effective (macroscopic) free energy in hyperelastic metamaterials is identified as: 1) the source of the extrinsic dissipation (this qualifying the metamaterial as kinetic-energy absorbing), and 2) the (fast) recovery of shape after impact exhibited by absorbing devices made of this metamaterial. In a second stage, consistent multiscale homogenization of bucking frames, constituted by 2D periodic RVE’s made of beams endowed with a 1D large-strain convex-elastic constitutive law, shows that the macro/meso multiscale coupling confers the intended exotic 2D non-convex behavior to the metamaterial's macro-scale.