Master or/and Phd Thesis proposition
Experimental or/and theoretical study of contraction cracks

Laboratory name and web site: Fluides, Automatique et Systèmes Thermiques (UMR 7608, UPMC/UPS/CNRS, http://www.fast.u-psud.fr)

PhD supervisor : GAUTHIER Georges, gauthier@fast.u-psud.fr, (33) 1 69 15 80 41.
PhD Co-supervisor: LAZARUS Véronique, lazarus@fast.u-psud.fr, (33) 1 69 15 80 39.

Collaborations:
B. Bourdin (Department of Mathematics, Louisiana State University, USA, www.math.lsu.edu)
C. Maurini (UPMC, Université Pierre et Marie Curie, Paris 6, www.dalembert.upmc.fr)

Abstract:
Giant’s Causeway, Port Arthur tessellated pavement (fig. 1), Bimini Road, Mars polygons, septarias, fracture networks in permafrost, mud or thin films (coatings, paints) are some more or less known examples of self-organized crack patterns that have intrigued people throughout history. These patterns are formed by constrained shrinkage of the medium due, for instance, to cooling or drying leading to fracture. Some aspects of their formation are still poorly understood.
Star-shaped intersections are present in those patterns. Recently, we have shown that the number of radial cracks is governed by a linear elastic fracture mechanics energy minimization principle hence by only one dimensionless parameter. Experimentally, directional drying experiments of colloidal suspensions in capillary tubes have been used for this purpose.

Figure 1 Port Arthur (top left) and Giant Causeway (top right) and drying and theoretical cracks patterns (bottom)

At present only the dependence of the crack paths on the cell shape and drying velocity has been partially studied. Further systematic experiments are necessary to understand the influence of the suspension (particle size and nature, mono/polydispersity, fluid viscosity) on
the crack dynamics of formation. In particular, the self-organization of the crack paths will be studied in relation with the loading history.

The drying experiments belong to the traditional research areas and skills of the lab FAST and are interesting since the volumetric nature of the loading allows us to obtain quasi-static crack propagation, stationary crack shapes in a frame linked to the crack tip and nice multi-cracks self-organization. But the numerous multi-physics couplings complicate the comparison between experiments and theory. To obtain such volumetric loading, without those disadvantages, we will also study cracks induced by cooling experiments [Yuse 1993, Ronsin 1995, Yang 2001]. In these experiments, directional contraction is obtained by dipping at controlled velocity a thin (<100 mm) pre-cracked hot glass plate in a colder bath. Despite nice qualitative predictions [Yang 2001, Corson 2009], precise quantitative predictions are still missing due probably to the lack of interaction between experiments and simulations. In order to fill this gap, the PhD student will extend these experiments by changing the solid geometry, the loading history and material to study the crack propagation from their initiation to self-organization in strong interaction with theoretical and numerical developments.

In brief, the aims of the thesis are double: first, extend the experiments by studying the influence of the particle size and material, the composition of the solvent, the composition of the suspension (concentration, mono/poly-disperse) and develop cooling experiments. Second, apply the minimization approach to the crack patterns obtained in the experiments.

Though this PhD thesis is mainly experimental, the student will have the opportunity to use (and even develop) modern numerical code, which will give to the student a complete formation, both experimental, numerical and theoretical, on fracture mechanics. These skills can applied to many industrial fields (building, aeronautic, coating developments...).

Publications of the laboratory in the field:


Specific requirements to apply:

Master thesis in physics and/or mechanical engineering.