International Research Center on
MATHEMATICS AND MECHANICS OF COMPLEX SYSTEMS

and

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Professor Jean-Jacques Marigo started his professional career as a scientist (Ingénieur Chercheur à la Direction des Etudes et Recherches) in the department of Mechanics and Numerical methods of EDF, Electricité de France, after having received his PhD at the Laboratoire Central des Ponts et Chaussées. The title of his thesis was “Propagation des ondes ultrasonores et microfissuration du beton”.

He remained at EDF exactly 10 years (1980-1990) during which period he started his investigations on damage and fatigue in the framework of continuum mechanics. In the papers of that period he suggests important ideas, which he will be develop later: i) fracture and damage phenomena, although irreversible, can be put into a variational framework ii) multiple scale analysis is essential in the formulation of continuum models for composite or inhomogeneous materials iii) the rigorous formulation of nonlinear continuum thermo-mechanics is a necessary prerequisite for a precise and effective formulation of fracture and damage theories.

Those ten years gave Jean-Jacques Marigo a great opportunity to work in en environment where theoretical studies needed to be directed to relevant applications – particularly those of the nuclear industry – and provided the motivation for his budding interest in fracture and microfracture. However, the “practical” purpose of his research never induced him to compromise on mathematical rigor and rational analysis. In this respect, Jean-Jacques Marigo embodies the best French tradition, that which prizes mathematical clarity and precision as the single available tool for obtaining a clear and precise description of physical phenomena.

At the end of his EDF period, Jean-Jacques Marigo obtained his Habilitation à Diriger des Recherches in which he presents his papers “Thermodynamique et lois de comportement , Modélisation de l'endommagement ,Théorie asymptotique des poutres élastiques”. At that time, he starts his collaboration with Gilles Francfort. This collaboration will produce a major progress in the theory of fracture.

The revisitation of Griffith's theory which results from the rigorous mathematical analysis developed in the series of papers starting from Francfort, G. A.; Marigo, J.-J. Stable damage evolution in a brittle continuous medium. European J. Mech. A Solids 12 (1993), no. 2, 149–189 establishes a recognized benchmark in the field.

Using sophisticated tools from functional analysis the papers which follow and which culminate in the elegant paper Bourdin, Blaise; Francfort, Gilles A.; Marigo, Jean-Jacques The variational approach to fracture. J. Elasticity 91 (2008), no. 1-3, 5–148) lead to the formulation of very elegant and novel mathematical problems. The solution of these problems allow for the theoretical “calculation” of crack paths, impressively generalizing the classical treatment, in which these paths are assumed to be known a priori. In other words, where as the previously existing literature could only fathom the growth of a crack along a “pre-determined” path, the cited contribution now makes it possible to predict the “form” of the growing crack.

The numerical simulations performed in some of those papers are impressive: the physical behavior of complex and realistic mechanical systems is carefully dissected.
Many peculiar shapes of cracks, many typical pattern of crack growth are predicted with numerical codes – developed by Blaise Bourdin – based on the theoretical variational model. The mathematical tools needed to attain those results have been viewed as “esoteric” by many “applied” scientists. However, everybody must agree that without a functional space (as for instance BV, SBV or many Sobolev’s) “rich enough” to include discontinuous displacement fields there is absolutely no hope of capturing crack opening.

Of note is also the paper by Jaubert, A.; Marigo, J.-J. Entitled: “Justification of Paris-type fatigue laws from cohesive forces model via a variational approach”, Contin. Mech. Thermodyn. 18 (2006), no. 1-2, 23–45.

Indeed, in the authors’ words, the theoretical models proposed for fatigue phenomena are based on fatigue laws which are postulated primarily on a “phenomenological” basis. The structure of these laws can change from one problem to another and very often no clear dependence on the material properties, the geometry or the loading is recognized or imposed. In this beautiful paper the authors propose to deduce fatigue laws from more general laws of rupture. The concept is really novel and seems the basis of fruitful further analysis: its connection with the studies performed by Jean-Jacques Marigo during his tenure at EDF is striking.

The deduction process is based on the following ingredients:

1. A principle of minimal energy in the spirit of previous works by Marigo and Francfort;
2. A surface energy of the Dugdale-Barenblatttype ;
3. A condition of irreversibility.

Each of these ingredients plays an essential role: indeed i) without a condition of irreversibility it is impossible to obtain fatigue effects; ii) the convergence of the law of propagation resulting from the model of Dugdale towards Griffith's or Paris' laws rests primarily on convergence "in energy". This deduction is conceived and performed for the first time by Jaubert and Marigo. Indeed, even if the variational approach had already been used within the framework of the Griffith or Barenblatt Models, the adequate irreversibility concept from the standpoint of fatigue had never been formulated within the Barenblatt setting.

This last contribution exemplifies the role of a well-articulated rational analysis of physical problems: abstract concepts are there to clarify and improve our understanding of the phenomena, not to shroud them in the clouds of a formalism which is just the putty of our ignorance.

The controversy opposing scientists that base their investigations and their teaching on mathematical rigor and those that prize practicality is an old one: the director of the Ecole Polytechnique was, at the time, critical of Cauchy's "obsession" with abstract mathematics: *'It is the opinion of many persons that instruction in pure mathematics is being carried too far at the Ecole and that such an uncalled for extravagance is prejudicial to the other branches.*'

Jean-Jacques Marigo is proudly continuing a long lasting tradition of "extravagance" at Ecole Polytechnique: to educate new generations of engineers to the abstract formalism which is essential to describe (carefully!) all physical phenomena. This he does with modesty and poise, as should be obvious to all of us.

The committee, entrusted by the
"Fondazione Levi-Civita"

and the Scientific Committee of the
International Research Center MEMOCS

with the responsibility of awarding the
International Levi-Civita Prize

unanimously propose Professor Jean-Jacques Marigo as winner of the
2011 edition.