Review of Renormalizations in Solid and Fracture Mechanics by H.D. Bui

Anonimous reviewer.

Reading this MS is very close to what wikipedia defines "Pleasure": *a positive experience, happiness, entertainment, enjoyment, ecstasy, and euphoria.*

The paper is one of those inspired by analogies, closing gaps, and *hence* opening new avenues. It should win a prize, and get the front page of the journal, if possible, since, again using wikipedia (this time in french)[1], it is touched by "Créativité" and as such can generate "gamechanging" vision, particularly connecting powerful results in physics and mathematics, with more traditional engineering. See also that website for connection to "brainstorming" , Louis Armand , Académiciens de France, and « synonyme d'inventivité ».

This MS also reminds me immediately that Engineering, physics and maths were at first united in geniuses such as Leonardo. While we need technical skills in solving solid mechanics problems, the literature is too replate with that sort of approach, and lacks this kind of innovations. Too incremental work obscures our mind, and Bui is one of the few inspired people of our days. He tends to be forgotten, probably he has published too much in French journals, and suffers what Nicolas Sarkozy now calls the problem of *Francophony*! In some cases, I think Bui has also suffered from plagiarism from other French authors, but that I will omit not to confuse his name with gossip and human weaknesses.

I will therefore mention a few names which are appropriate to compare to Bui: while this may perhaps sound a little out of theme for the present review, I think I will attempt in turn to make an inspiring review, what else can I do in reviewing Bui's paper which cannot be improved?

- *Loenardo da Vinci*: Bui doesn't make the connection, but by restricting attention to Solid Mechanics, Leonardo had already imagined that renormalization of strength meant some sort of size effect (Bazant, 2003). Leonardo discussing questions of size effect and scaling in his notebooks did not solve any solid mechanics problem, yet predicted a lot of what we know now, including perhaps nanomechanics! Not many know that Leonardo had solved even beam theory[2], well before Cauchy notion of stress, and not even that of elasticity, normally attributed to Hookes in Oxford!! I will not mention that Galileo made an error much later in his beam theory. But Leonardo had no interest to publish: this also sounds a little Bui's style, as I know a lot of reports which are still unpublished and should be published before they are forgotten as Leonardo's code,

[1] http://fr.wikipedia.org/wiki/Cr%C3%A9ativit%C3%A9

[2] Codex Madrid I, one of two remarkable notebooks that were discovered in 1967 in the National Library of Spain (Madrid),http://www.memagazine.org/contents/current/webonly/webex418.html

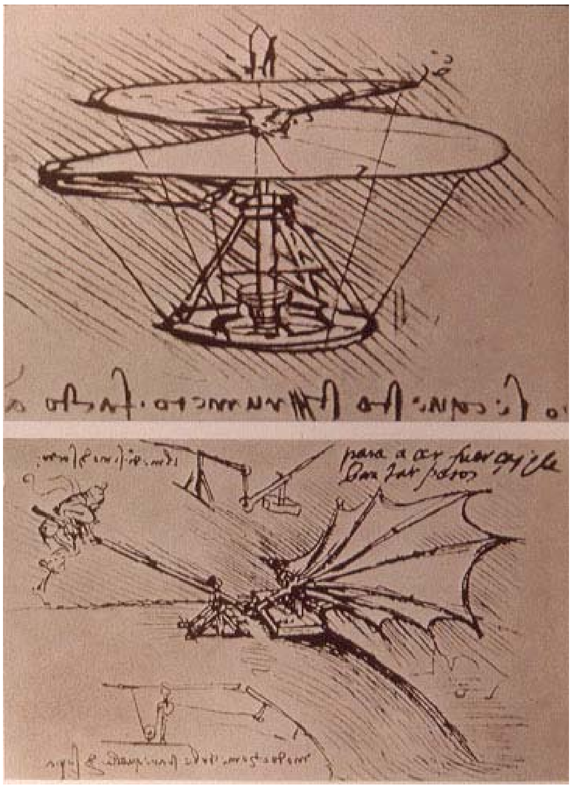

Figure 1: Leonardo da Vinci helicopter and lifting wing.

for 400 years. In a recent special issue of Comptes rendus - Mecanique (336-1-2 Jan - Feb 2008) dedicated to HD Bui, we can find a list of papers and in "PART II: Internal reports (in French)", I think there are many treasures. We need these days inspiration because while computational power is increasing, people continue to attack problems with brute force, and existing techniques. Bui introduced fracture mechanics and inverse problems in France, to say only a coincise statement.

- *Coulomb* who in 1776 wrote a milestone paper on friction, mainly based on equilibrium and before the concept of stress had been devised[3]. Coulomb indeed defined cohesion and friction ("cohésion" and "frottement" in the original) as "coercitive forces" to distinguish them from "active forces" such as gravity. In other words, these forces can only be estimated by their resistance (*"l'on estime ces deux forces par le limites de leur résistance"*). Coulomb's paper is the milestone, together with Galileo's Discorsi, of the "Yield Design" (Salencon, 2002, par.6.2), and in particular has generated a large literature in geotechnical engineering with methods which are however remarkably close to the original Coulomb's method. What is remarkable about Coulomb's method, is that today with many developments of plasticity theory, the concept of stress, people still cannot do any better than Coulomb, because friction is non-associative and unstable, in the Drucker sense. Hence, some people try to apply plasticity theorems simply because they think they would be more rigorous, or because they are used to use them, but they are generally only necessary and non-sufficient conditions, and hence in friction, Coulomb's thinking is still better — one should read the original, rather than the many less good modern developments perhaps using Finite Elements and complex variational strategies and convex optimization methods. This reminds me of a great italian writer and poet, Ugo Foscolo, who did not like the Homerus "Iliade" translated by Vincenzo Monti from Latin and not from the original (simply because Monti didn't know greek). Foscolo, said Monti was a "Great translator of the translators of Omero"!

- *Griffith*, the father of Fracture Mechanics at the age 26[4], but not many know that he is the father of the jet engine and worked many years for Rolls-Royce and could not publish his results (http://en.wikipedia.org/wiki/Alan_Arnold_Griffith). However he may also be well be the founder of nanomechanics, well before Feynman's 1959 speach "there is room at the bottom", since he suggested that materials fail at 1000 times less than this predicted theoretical value only because there are many microscopic cracks in every material. Today, we are able to devise Carbon nanotubes, and we have found retrospectively that Nature has used this for millions of years for some attachment systems like that of the Gecko Gecko. We are now making a large effort

[3] For an interesting and quick reference on the history of friction, see e.g. http://en.wikipedia.org/wiki/Guillaume_Amontons

[4] http://www.sv.vt.edu/classes/MSE2094_NoteBook/97ClassProj/anal/grealis/history.html

to be able to return to that, and Nicola Pugno, a professor of structural engineering at the Polytechnic University in Turin, Italy, says that even Spiderman's suit is not fantascience, using scaling laws and renormalization methods to predict various effects and accordingly devise systems. [5]

- *Mandelbrot*, incidentally a Polytechnicien, who is responsible to have made a large debate in the Scientific Literature about "fractals", and power laws (see for example only B. Mandelbrot et al (1998)). Some relatively obvious aspects of fractals in fracture and Solid Mechanics have been discussed already (Carpinteri & Pugno, 2005), but a lot more should be said. Mandelbrot and Taleb (2008) distinguishes broadly two classes of distributions 1) mild or "innocous" distributions, like Gaussian, where the process is sometimes even crudely approximated by dealing with the mean value only (but not always this is an accurate representation). This is one type of distribution which has clearly large applications, and has found main strenght in the Central Limit Theorem of statistics; 2) *wild* distibutions, like Pareto-Levy and power-laws, where fractals are ideally suited. In Solid Mechanics, for example in case of friction problems, despite spanning extreme ranges of space and time (from seismic faults stretching many kilometers to crystal lattice spacing in Atomic Force Microscope; from the years that separate earthquakes to the kilohertz frequencies of squealing brakes and railway wheels"), we need some more powerful methods, since with computational power, perhas atomistic models, we will never be able to model such wide range of space and time scales.

- *Feynman*, but Bui already made the connection.

- *Barenblatt*, and Bui made already some of the connection, at least to his early work on cohesive laws, which today is again popular at nanoscales, and to scaling. However, there is more there in his books, including the concept of renormalization in use with Fluid Mechanics

It is difficult to give suggestions on how to improve the paper. Clearly, more singularities can be considered: even fractal singularities. In fact, while power-laws in solid mechanics are know to change exponent in the transition from one mechanism of rupture to the other: for example, from the -1/2 singularity scaling of LEFM, which gives rise to the K_{Ic} dimension of $stress\sqrt{m}$, to the 0 power of classical strenght-based plasticity theory *stress*, it is obvious that we see all intermediate powers. Some people say that we can see this as a change of mechanism from surface to volume rupture, and while indeed this works sometimes in strong emotionally-based disputes (Bažant and Yavari, 2007), it is true that while the debate over what is fractal and what is really power law (Mandelbrot et al 1998, and references therein), it clearly opens the way for fascinating extensions of all the classical Solid Mechanics, Virtual Work

[5] http://www.news.com/Scientist-proposes-adhesive-Spider-Man-suit/2100-1008_3-6179990.html

theorems, etc. (Wnuk and A Yavari, 2005, 2008), which is to date perhaps not of immediate use, the renormalization method is certainly a general method to deal with interaction in many-body physics. Hence, it is no joke. Also, it is a powerful method to esthablishing scale invariance under a set of transformations (McComb 2004) and is at the core of many power-laws in material science as fatigue (Hall-Petch, Coffin-Manson, Basquin), fracture (Paris crack propagation), geophysics but also engineering, biology, medicine, economics, etc. (Sornette, 2004, Mandelbrot, 1997). So, perhaps in the future these unifying technique will pave the way for a new manner to do research, perhaps research papers will not be published in Nature, but will be written collectively by people as we do today in wikipedia. This way, we will close the circle from Leonardo who did not publish papers, with papers which will be written by everybody i.e. no authors. It reminds of Pirandello's "one, no-one, and one hundred thoushand". When one read Nobel prize material, it looks all connected!

Rosinger (2004) suggests that dimensional analysis is still unexplored fully, and the differences between solids and fluids are not that clear. So what we call Solid Mechanics perhaps is not that well defined and separate from Fluid Mechanics. One should keep an open view on these things.

Perhaps the merit is that Bui, like Mandelbrot, and other geniuses, didn't have proper education until much later than normally. Therefore, he doesn't follow conventional paths. We need more Bui's in the world, and less conventional people with standard education, even at Top Schools.

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