Gérard A. Maugin
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Gérard A. Maugin born at Angers (France) on December 2, 1944, married to Eleni Zachariadou in 1978, passed away in Villejuif (FR) on September 22, 2016, 7 p.m. He had retired from the University of Paris VI since 2010.

His longstanding scientific activity in continuum mechanics and continuum physics is well known in the community of mechanics. In these fields he enjoys a well-established reputation. His interests covered almost all disciplines of continuum mechanics and his studies have addressed fundamental problems of mechanics and electromagnetism and applications as well.

One of his first papers (1965) is concerned with The *Race tidal power plant*, a topical subject in the current engineering applications. A few years later he published a series of papers in the Comptes Rendus de l'Académie des Sciences, Paris (1970-71), on the macroscopic description of magnetic media in the relativistic framework. His striking versatility in scientific research, which emerged since the very beginning of his career, cannot be unnoticed. In April 1971 he defended his PhD thesis on micromagnetism under the supervision of Cemal A. Eringen from Princeton University. The Princeton University Press has published the thesis with the title *Micromagnetism and polar media*, 1-294, (1971). Four years later, in May 1975, Gérard Maugin achieved his "habilitation" (doctorat d'État és sciences mathématiques) in Paris. The mentor was Paul Germain of the Académie française.

By 1975, Gérard Maugin already had a ripe scientific *curriculum studiorum* in mechanics and physics: 45 papers published in the most well known scientific journals of mechanics and mathematics (Ann. Inst. Henry Poincaré, J. of Physics, J. of Mathematical Physics, General Relativity and Gravitation, J. de Mécanique and others).

His favourite topics in this period are the behaviour of electromagnetic materials in the relativistic framework and in the Galilean approximation as well. Specifically, the behaviour of deformable dielectrics, ferro-magnetic and ferri-magnetic bodies are examined and explored in such frameworks. Naturally, because of his training in relativity and in electromagnetism he developed a specific sensitivity toward the mathematical description of continua with coupled-fields, continua with structures and/or microstructures.

In 1980 Gérard Maugin published the paper *The method of virtual power in continuum mechanics: Application to coupled fields*, Acta Mechanica, **35**, 1-70, (1980). The energetic approach therein proposed represents one of the most powerful methods for describing complex materials from the viewpoint of continua. The method also provides the proper tools, with which to attack problems of structured continua, both from the theoretical viewpoint and from the standpoint of applications. The method of virtual power, such as expounded in the aforementioned paper, is formulated in its most general form and is applied to electromagnetic materials in their various aspects (thermo-elastic dielectrics with polarisation gradients, dielectrics with quadrupoles, ferromagnets, liquid crystals in external electromagnetic fields, et cetera). This contribution of Maugin stands as a referential point to many researchers in continuum mechanics.

Wave propagation was also one of his favourite topics of interest. To this topic he devoted his attention and his studies since the very beginning of his studies. Due to the interesting results achieved in applied problems of wave propagation, he was awarded the scientific *prize of Mechanics Doisteau-Blutet* of the French Academy of Sciences in 1982. His interest in wave propagation never ceased nor decreased in the subsequent years, even when his main efforts were focused on other fields. As a result of the expertise that he had acquired in this field, Gérard Maugin was invited to deliver a course on *Physical and mathematical models of nonlinear waves in solids* in Udine at the International Centre for Mechanical Sciences (CISM) in 1993. Springer-Verlag published the lecture notes of this course (G. A. Maugin: Physical and mathematical models of nonlinear waves in solids, eds. A. Jeffrey, J. Engelbrecht, CISM courses and lectures, volume 341 (1994), 109–233). Afterwards, he also published the book *Nonlinear waves in elastic crystals*, Oxford University Press (1999).

This specific attention to the dynamical problems in continua is often transferred to his graduate students. Some of them investigated the possibility of "soliton-propagation" in structured materials under his advice. Interesting and unexpected results are made evident by their studies with the help of numerical techniques.

Gérard Maugin not only provided his students with an excellent professional training in continuum mechanics and physics, he also transferred to his students and co-workers enthusiasm in research along with motivation and scientific curiosity. These qualities represent the primary source of his prolific scientific activity.

An impressive number of papers and many books and monographs (published by Springer-Verlag, MacGraw-Hill, Elsevier, Oxford University Press, Cambridge University Press) emerge from his curriculum and numerous awards and honours. A detailed list can be found on his website[1]. I will not elaborate upon the membership of Gérard Maugin in the editorial board of many scientific journals, or his membership in scientific societies (in most of the cases as member of the executive committee or of the advisory board), or his appointments as consulting editor

[1] http://www.dalembert.upmc.fr/home/maugin/

(for Spinger, J.Wiley, Kluwer, Oxford University Press) or as expert for research contracts and grants (in USA, Canada, UK, Belgium, France and other countries).

I would like rather to emphasise his natural attitude as researcher and as teacher. This attitude combined with his skill in finding the proper (and often the simplest) mathematical tools, through which to expound and to clarify the physical nature of the phenomenon under consideration.

The so-called configurational mechanics or material mechanics is the "novel" field, to which Gérard Maugin devoted his main interest during the last decades. He initiated the search and the studies of configurational forces in elasticity, being concerned with the elastic energy-momentum tensor, a notion introduced by Eshelby in a few seminal papers in the fifties. It is not difficult to show that the Eshelby tensor naturally applies to defective materials and in fracture mechanics. For instance, based on this tensor, one is able to recover all known invariant integrals around a defect, including the celebrated J-integral around the tip of a crack. In addition, fracture criteria can be (and indeed, are) properly extended to elastic dielectrics and to elastic magnetised materials.

The early studies of Gérard Maugin and others in this field are also concerned with inhomogeneous materials. Specifically, Maugin and others re-proposed the Eshelby tensor in finite elasticity, building on Noll's notion of homogeneity and uniformity. Such an extension of the Eshelby tensor shows in evidence important physical properties and relevant geometrical features, which are hidden in the linear framework. All these features eventually address the notion of configurational force. Gérard Maugin and others suddenly realised that the notion of configurational force confers to the Eshelby stress tensor a deeper physical meaning. They also realised that the notion of configurational (or material) force could not be confined to the inhomogeneities in the elasto-static framework. Hence, the important role of this force was enquired in dynamics. One of the relevant results is the natural relationship of the material force with the so-called *material-momentum*, or *pseudo-momentum*. Such a result also represents a turning point for the introduction of the so-called configurational mechanics, which now stands on firm basis. In addition, configurational mechanics is also shown to be the natural framework for thermodynamical transformations, such as solid-phase-transitions.

The notion of configurational force becomes even more powerful in complex materials and materials with structures. Based on this notion, Gérard Maugin (with a second author) contributed to disentangling the following quarrel in liquid crystals [Int. J. Engng. Sci., **33**, 1663-1678, (1995)]: as whether the Ericksen stress tensor should be regarded as related to a configurational force or to the classical traction. The point is that the Ericksen tensor for liquid crystals has the form of an energy-stress tensor, just like the Eshelby stress. Hence, one could be tempted to incorrectly identify the one with the other. It is worth noticing that the quarrel involved Ericksen and Eshelby themselves, along with Kröner and other prominent people.

Eventually, the interest arises in discriminating configurational forces from traction in the more general context of structured continua. This discrimination be-

comes a crucial need in the case of electromagnetic materials. In this regard, it is worth recalling that Eshelby was initially inspired by the Maxwell stress tensor of electromagnetism. The latter however, though possessing the form of an energy-stress, is undoubtedly related to the classical traction. In order to avoid misunderstandings, one envisages the existence of two meaningful energy-stress-tensors in continua and, more specifically, in electromagnetic materials. The introduction of the material energy-stress (namely, the Eshelby tensor) provides a novel standpoint, which allows one to enlighten unclear issues or rather obscure aspects of electromagnetic materials. One of these is the proper form of the electromagnetic momentum. Based on a criterion established by Gérard Maugin and others, one is able to distinguish between momentum and *pseudo-momentum* or *crystal-momentum*, in the language of Solid State Physics. These themes are still nowadays open to further developments. New applications of these ideas are proposed from time to time in the community of continuum mechanics, in which a steadily increasing interest is recorded on this subject.

Gérard Maugin was also greatly attracted by searches in epistemology and the history of science. The naissance of fundamental concepts of mechanics and physics and their evolution through the centuries were fascinating topics for him. Toward these topics he had developed a unique sensitivity since he was a young researcher. To them he devoted his efforts in the last years until the end of his life by writing a history of continuum mechanics in the following three volumes published by Springer in the *solid mechanics and applications* series:

- *Continuum mechanics through the twentieth century: A concise historical perspective* (2013).
- *Continuum mechanics through the eighteenth and nineteenth centuries: Historical perspectives from John Bernoulli (1727) to Ernst Hellinger (1914)* (2014).
- *Continuum mechanics through the ages: From the renaissance to the twentieth century* (2016).

His memory will endure among his many friends and in the scientific community of mechanics

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