Research Topic for the ParisTech/CSC PhD Program

Subfield: Mechanical Engineering, Materials Science, Applied Physics and Biology.

ParisTech School: ENSTA ParisTech

Title: **Complex dynamics of active systems**

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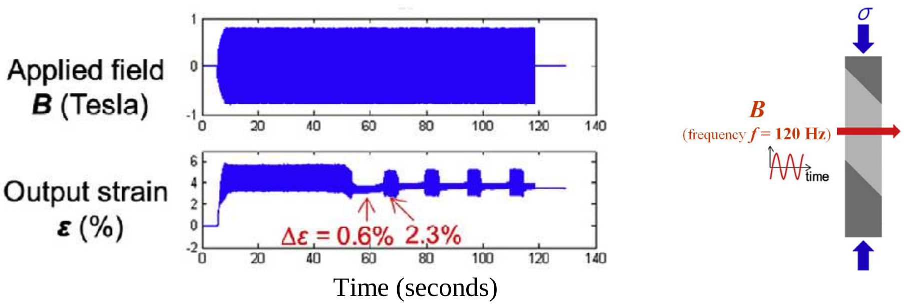
Short description of possible research topics for a PhD:

Classical active systems, also named as smart/intelligent materials/systems have multi-physics coupling behaviours such as piezoelectricity, magnetostriction and shape memory alloys in the engineering applications of actuators, sensors, energy harvesting, refrigeration, robots, etc. Recently, the concept of activeness was extended in the research of “active matter” whose behaviours are driven by not only the external multi-physics loadings, but also its self-powered constituents. Such active system composed of many self-propelled particles/elements demonstrates many interesting self-organized phenomena/behaviours. The most impressive and complex self-organized system is a biological system with living matters such as cells. While intensive research has been taken for the multi-physics coupling behaviours in classical active systems, there are few convincing theories/principles to describe/understand the essential features of active matters or biological systems because of their complex physics-chemical coupling dynamic processes. For example, the growth and division of a cell depends on the evolution of the cell’s membrane which is strongly sensitive to both mechanical force and chemical environment conditions. The current project is to extend the well-established multi-physics coupling models/principles to describe/understand the autonomous evolution of a general active system under various physics-chemical conditions. Particularly, new methods need to be developed to simplify the extremely complex coupling processes in biological systems and extract the essential features of life; for example, the criteria for developing real or artificial (synthetic) autonomous living cycles (the size of a cell cyclically increases and decreases due to cell growth and division). Finally, a general theoretical framework will be proposed to unify the dynamics of physical change and chemical reaction, which are usually treated separately in literature.



“Autonomous” (self-organized) oscillation occurred in a classical active system (The cyclic oscillation of strain amplitude of a Magnetic Shape Memory Alloy under a given magnetic field developed automatically) [4, 5].

A list of 5 (max.) representative publications of the group: (Related to the research topic)

[1] **Y.J. He**, X. Chen, Z. Moumni. "Two-dimensional analysis to improve the output stress in ferromagnetic shape memory alloys". *Journal of Applied Physics* 110, 063905 (2011).

[2] **Y.J. He**, X. Chen, Z. Moumni, "Reversible-strain criteria of ferromagnetic shape memory alloys under cyclic 3D magneto-mechanical loadings". *Journal of Applied Physics* 112, 033902 (2012).

[3] X.Chen, Z. Moumni, **Y.J. He**, W. Zhang,“A three-dimensional model of magneto-mechanical behaviors of martensite reorientation in ferromagnetic shape memory alloys”, *Journal of Mechanics and Physics of Solids* 64, 249–286 (2014).

[4] S. Zhang, X. Chen, Z. Moumni, **Y.J. He** “Thermal effects on high-frequency magnetic-field-induced martensite reorientation in ferromagnetic shape memory alloys: An experimental and theoretical investigation” *International Journal of Plasticity* 108. 1–20 (2018).

[5] S. Zhang, X. Chen, Z. Moumni, **Y.J. He** “Coexistence and compatibility of martensite reorientation and phase transformation in high-frequency magnetic-field-induced deformation of Ni-Mn-Ga single crystal” *International Journal of Plasticity* 110, 110–122 (2018).