A NEW MODELING STRATEGY ACCOUNTING FOR MATERIAL TEXTURE

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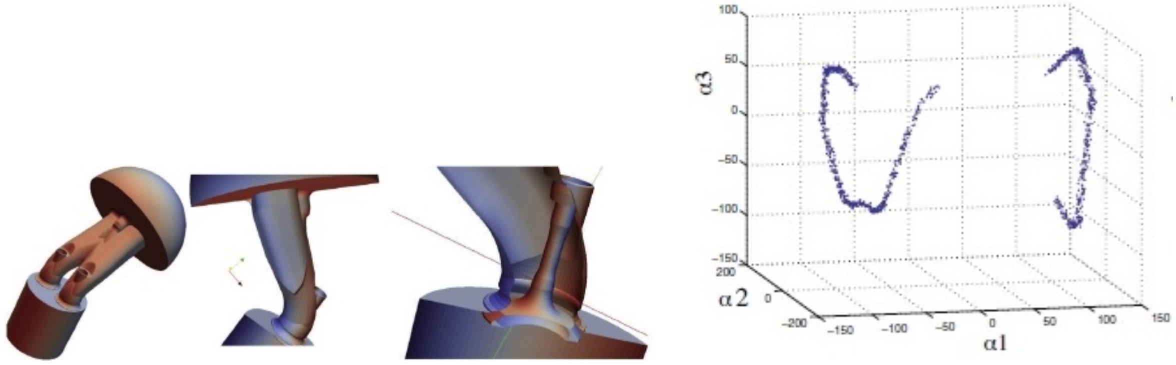
Due to their forming process and to their microstructure, metals with a compact hexagonal crystallographic structure (HCP) exhibit significant mechanical anisotropy. As the aspect ratio c/a (=1.856) of hexagonal crystal in zinc metal and its alloys is high compared to ideal structure (i.e. 1.633), the anisotropy in these metals is even more significant. Despite its wide industrial use, the literature devoted to the modeling of the mechanical anisotropy of the zinc and its alloys is still limited and most of these studies are based on phenomenological approaches [1]. This approaches consider the anisotropy through a "plasticity criterion" and strain hardening laws. The parameters of the elastic behavior are generally identified from experiments, while the work hardening parameters are determined by finite element simulations. Another modeling approach, which is more related to the physic of the material, is based on micromechanical models. The Visco-Plastic Self-Consistent (VPSC) model developed by Lebensohn and Tome [2] which is based on the self consistent scheme is particularly suitable to estimate the behavior of anisotropic materials. Indeed this model considers 3 scales: the slip systems whose sliding is controlled by a chosen law, the grain in which the contribution of each slip system is taken into account and finally the macroscopic scale where the behavior of all the grains is used in a homogenization scheme, taking into account the initial texture of the material and the loading process. This VPSC code provides many local and macroscopic outputs like mechanical macroscopic response, texture evolution and activities of each slip system. As the loading process is under control, VPSC results could be considered in the integration points of a finite element model. VPSC has been used in many studies. For example, Cauvin et al [3] used it to study the anisotropic response of a zinc alloy.
Even if micromechanical models offer many advantages especially in the context of the plasticity in polycristal materials, the time cost of these models makes impossible or at least very complicated their use in finite element simulations of real structures. To overcome this limitation, we developed a numerical strategy based on reduce order model to take into account microstructural information in finite element model of complex structures.
"Manifold learning" was introduced by Raghavan et al in 2013 [4] for the reduced order representation of complex shapes encountered in mechanical problems, such as industrial structural optimization [4], springback during stamping [5], indentation characterization of metals [6, 7], re-parameterization of microstructures [8, 9] or tomograph segmentation correction for woven composites [10]. The idea is to define the "latent space" solution space of the problem in which the solution evolves. The reduced representation is usually obtained by determining the intrinsic dimensionality of the problem, often independent of the original parameters, and by approximating a hypersurface, i.e. a variety connecting all "admissible" solutions. In Figure 1, an example of reduced order representation of complex shapes is illustrated. Figure 1 (a) shows the 3D geometry of an engine intake defined by 93 geometric design variables. As these 93 parameters can vary, one can think that all the parameters are needed to well define the geometry. However, Ragavan et al [4] have shown, see Figure 1 (b), that, when technical constraints are considered, all the admissible shapes of the intake depend only on one intrinsic parameter.



(a) (b)

Figure 1: (a) 3D geometry of an engine intake; (b) Representation of the admissible shapes in the feature space [4].

In this communication, we will first illustrate the potential of a multicale model of polycristal plasticity, like VPSC. In a second step, we will present the fundation of a new paradigm based on manifold learning to take into account microstructural information in finite element simulations. These information can be obtained by experimental characterization or simulation using a code like VPSC. In finite element simulation of structures, our new modeling strategy could take into account material texture, plasticity or damage that may evolve in all model elements and at each time increment of the simulation.

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