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CHARACTERIZATION OF RVE KINEMATICS USING DIGITAL IMAGE CORRELATION AT MICRO-SCALE

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Multi-scale methods bring new perspectives to obtain detailed informations for structures with two scales in particular the methods based on the FE^2 technique introduced by [1]. These methods are very efficient for small strain but in presence of large strain, non-linear phenomena and fracture, issues about the choice and the existence of the RVE appear. The definition hypothesis of the RVE are presented in [2]. This definition may not be reached when strongly non-linear process or failure occurs at the macro-scale. This is why some authors like Geers, Feyel or Forest use the theory of second gradient or the Cosserat continuum to model the macro-scale contrary to the micro-scale model which remains classical [3]. The second gradient continuum imposes boundary conditions on the RVE's which are non-linear. In this study, we simulate experimentally a structure with two scales to characterize the strain of the RVE and to validate the use of the second gradient continuum. The experience will also give conclusions on the size of the transition zone and the periodicity of the cells deformation.

Model material : The experimental structure is a plate, 1 mm thick, with 50 by 50 holes placed along the horizontal and vertical axes and inside a circle. The holes diameter is 0.5 mm whereas the distance between their center is 1 mm in each direction. We also study two samples with a rotation of 30 and 45 degrees of the heterogeneous zone to load the RVE's (a square with a hole) in uni-axial tension or in a mixed load of tension and shear. The bulk material is a 304L stainless steel which has a known elastic-plastic constitutive behavior. Digital images are obtained using a high resolution camera of 19728×13152 pixels. These images are then processed to calculate the displacement and strain fields using a finite element kinematics by digital image correlation (DIC) [4]. To perform the analysis, a mesh of the micro-structured zone is built from a mesh of the unit cell.

Microscopic analysis : The microscopic strain field is calculated for each cell of the heterogeneous zone by DIC. We also obtain experimentally the displacement of the boundary of each cell. When the mean strain of the cell increases the higher order effects are captured. By mean of least squares minimization, we identify for all RVE's the parameters of third order displacement along the edges of the unit cells:

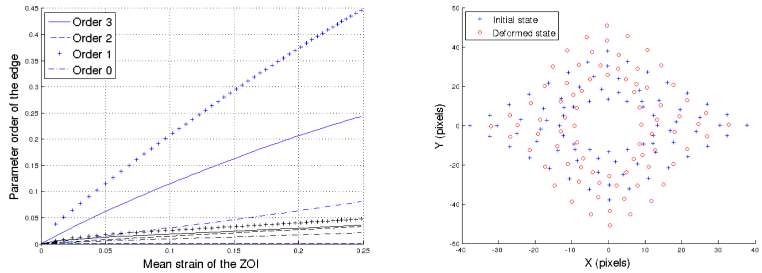

Figure 1: Curves of the mean (in blue) and the standard deviation (in black) of the four parameters of the RVE boundary deformation with an inclination of 45^o. Initial and final state of a unit cell loacated in the center of the specimen.

$$u_n = a + bs + cs^2 + ds^3$$

where s is the curvilinear abscissa of the edge and u_n the normal displacement of the edge. In figure 1, the initial RVE and the deformed state at 25% of macroscopic strain and the four parameters (a, b, c, d) in the case of a 45^o inclination of the micro-structure are represented. The interest of this work is focused on the parameters c and d which are the parameters of higher order boundary conditions. The third order parameter means that the RVE's are loaded in shear load in this case. Moreover, it is shown that a transition zone exists at the boundary of the micro-structured zone. Within this zone, non-periodic and higher order effects are captured whereas periodic boundary conditions are found in the interior. The thickness of this zone is of one unit cell layer.

Comparison with simulation problem : The experimental boundary conditions of the central RVE of the micro-structure are extracted to simulate the behavior of the RVE with a numerical simulation which has periodic boundary conditions on the edge. Boundary deformation parameters are then extracted in a way similar too the experimental fields. These parameters are then compared to those extracted from the DIC analysis.

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