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COMPARISON BETWEEN SIMULATION AND EXPERIMENTS ON FRACTURED SAMPLES USING X-FEM KINEMATICS

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ABSTRACT

For validation or identification purposes, numerical simulations are to be compared to experiments. Full-field measurements provide experimental data that may be written in the same basis as those used in numerical simulations. Recently, a digital image correlation technique was extended to X-FEM kinematics to measure discontinuous displacement fields [1]. One possibility is to use identification techniques that allow for the direct estimation of material parameters from the measurements, however, measurement noise is a critical issue. To circumvent this difficulty, noise robust identification techniques are devised, see for instance Ref. [2] for stress intensity factors estimates. A second possibility that will be presented consists in developing a measurement technique that directly extracts a mechanically admissible displacement field. In other words, a mechanical filter is proposed to measure a displacement field in the space of the mechanically admissible solutions.

Computing the numerical solution to a mechanical problem or measuring a displacement field by digital image correlation relies on the minimization of an appropriate functional. Digital image correlation is based on the evaluation of a displacement field, $\mathbf{u}$, which advects passively the texture of a reference image f onto a deformed one g, so that

$$g(\mathbf{x}) = f(\mathbf{x} + \mathbf{u}(\mathbf{x})) \tag{1}$$

where $\mathbf{u}(\mathbf{x})$ is the unknown displacement field. Then a global residual is formed by integrating over the domain Ω

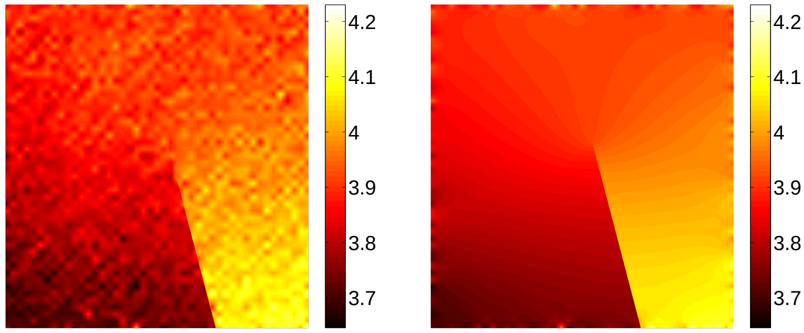
$$\mathrm{R}_{cor} = \iint_{\Omega} \left(f(\mathbf{x} + [\mathbf{\Psi}(\mathbf{x})]\{\mathbf{U}\}) - g(\mathbf{x})\right)^2 \, \mathrm{d}\mathbf{x} \tag{2}$$

where $\boldsymbol{\psi}_n$ are the vector shape functions (that may include enriched functions) and a_n their associated degrees of freedom collected in $\{\mathbf{U}\}$. Following Ref. [1], the solution minimizing this residual is obtained by using a Newton algorithm. In the present case, a mixed functional R_{tot} is defined

$$\mathrm{R}_{tot} = (1 - \lambda)\,\mathrm{R}_{mec} + \lambda\,\mathrm{R}_{cor} \tag{3}$$

where R_{mec} is associated to the minimization of the Equilibrium Gap [3]

$$\mathrm{R}_{mec} = (1/2)\{\mathbf{U}\}^T[\bar{\mathbf{K}}]^{\mathrm{T}}[\bar{\mathbf{K}}]\{\mathbf{U}\} \tag{4}$$



-a- -b-

Figure 1: Horizontal displacement map in pixels for a SiC specimen for 16-pixel elements: (a), correlation, (b), correlation + mechanical admissibility. $p = 1.85\ \mu\mathrm{m/pixel}$.

where $[\bar{\mathbf{K}}]$ is the rectangular part of the usual stiffness matrix involved in the computation of the internal forces at the internal nodes of the mesh (*i.e.*, all nodes except those on the mesh boundary). In practice, those residuals are normalized. Depending on the value of the coupling parameter λ, the solution of the minimization of R_{tot} satisfies not only the passive advection of the texture of the images but also the balance of momentum. The technique is referred to eXtended and Integrated Digital Image Correlation (or XI-DIC), where "Integrated" means that the mechanical constitutive laws and the mechanical admissibility of the solution are prescribed.

The results presented hereafter concern displacement measurements on a Silicium Carbide specimen in a pre-cracking experiment. A displacement basis in the spirit of X-FEM [4] is used. Figure 1 shows the comparison of the displacement field obtained using a pure correlation functional and a mixed correlation / mechanical functional. XI-DIC enables one to obtain a mechanical solution directly from experiments. Then the validation and/ or identification can be carried out directly from the measured displacement field. Furthermore, the displacement field obtained by XI-DIC is not perturbed by measurement uncertainties, thereby leading to a more robust identification (of stress intensity factors in the present case).

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