Internship Proposal

Year 2024-2025 Master 2

Supervising team

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Title

Variance-based inversion scheme for imaging polycrystalline material features

Context: Polycrystalline materials have widespread industrial applications. Their microstructure is inherently complex, composed of anisotropic grains of varying sizes and shapes, each with distinct crystallographic orientations. The latter leads to heterogeneities in the stiffness within a given sample. The microstructural features of these materials have a fundamental role on their behavior at the level of structural parts [1,2,3].

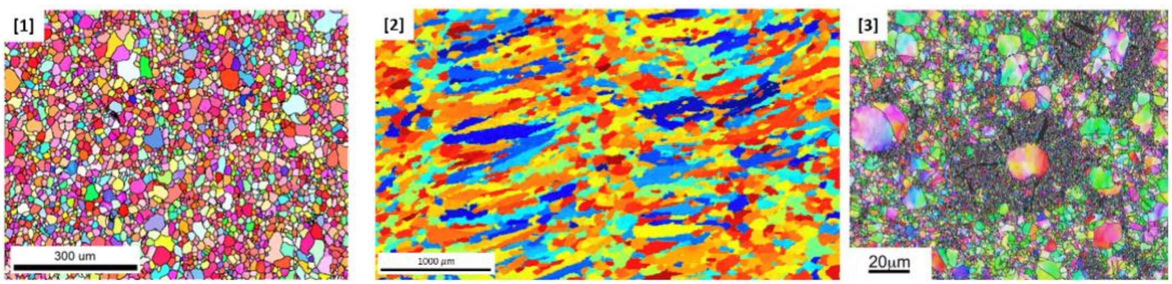

Fig 1: Equiaxed grains (left), elongated grains with preferred orientation (middle) [1], and two different types of grain sizes (right) [2]

Non-destructive evaluation (NDE) techniques are crucial for monitoring microstructural changes in real-time during manufacturing processes, such as annealing, to guarantee that the final product is in accordance with the intended design specifications. Furthermore, these methods are applicable to functionalization processes of multi-phase polycrystals, such as duplex stainless steels mainly used in the offshore oil and gas industry for pipework systems.

Variations in microstructural features including grain size distribution, crystallographic texture, and the presence of residual stresses within the material, yield uncertainties in ultrasonic parameters, such as velocity and attenuation. The latter could also be helpful to identify anomalies in the microstructure, such as the presence of macrozones (large regions of grains with similar orientations) in some titanium alloys, drastically reducing their fatigue life [4].

Fig 2: Cold dwell fatigue failure of a motor of an AIRBUS A380-861exploited by Air France, caused by macrozones [4]

Objectives: A recent study, supported by theoretical and numerical simulations, has revealed relationships between the uncertainties in ultrasonic measurements and some statistical parameters characterizing the microstructure, such as the mean and standard deviation of grain sizes, as well as crystallographic texture coefficients [3]. These results hold true for microstructures exhibiting morphological textures (elongated grains), although they have yet to be validated through numerical experiments. Furthermore, the microstructure is assumed to be perfect, *i.e.* free of voids, cracks, or other defects. The impact of such defects (e.g., crack density) on these uncertainties remains to be explored. As such, more sophisticated homogenization methods to derive effective properties will be used instead of the classical Voigt, Reuss, or Self-Consistent approaches. In this project, one of the objectives is to use the averaging scheme proposed in [5], based on asymptotic homogenization coupled with full-field simulations. A comparison will then be made with the results obtained using the classical averaging schemes.

Numerical simulation of wave propagation via the finite element method [6], as well as Monte Carlo simulation based on random walk [7], will also be conducted to estimate the variability of ultrasonic parameters (e.g., group velocity) across multiple realizations of these random heterogeneous media. This allows us to further validate the analytical framework.

This research aims to improve our understanding of the link between microstructural randomness, homogenization techniques, and the resulting uncertainties in ultrasonic measurements. It will provide insights into more reliable NDE strategies that account for the inherent variability in polycrystalline materials.

The internship will take place at the GeM laboratory (Nantes Université) in Saint-Nazaire, for a duration between 4 to 6 months. Depending on the results of the internship, a continuation with a PhD thesis would be possible within the framework of an ANR project which has already been funded.

Application

Please send your detailed CV to shahram.khazaie@univ-nantes.fr

References

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