The role of kinematic boundary conditions in micromechanical parameter identification

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The Role of Kinematic Boundary Conditions in Micromechanical Parameter Identification

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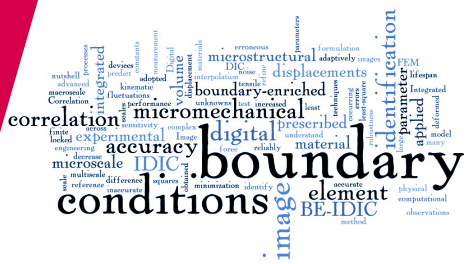

1. Introduction

Accurate identification of micromechanical parameters helps to

- **predict** lifespan and performance of many engineering devices
- **understand** complex physical processes in materials occurring across the scales [1]

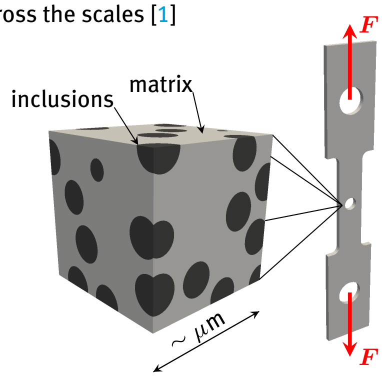

Fig. 1: Micromechanical parameter identification

GOAL: Accurate micromechanical parameter identification.

2. Challenges

Experimental observations at the microscale

- μ-dimensions $\rightarrow$ advanced experimental techniques such as Integrated Digital Image Correlation (IDIC)
- BCs applied on large scale $\rightarrow$ no μ-force measurements

IDIC IN A NUTSHELL. Minimize in the least-square sense the difference between reference f and deformed g images

$$\boldsymbol{\lambda} \in \underset{\widehat{\boldsymbol{\lambda}} \in \mathbb{R}^{n_\lambda}}{\arg\min} \ \frac{1}{2} \int_{\Omega_{\text{roi}}} [f(\boldsymbol{X}) - g(\boldsymbol{X} + \boldsymbol{u}(\boldsymbol{X}, \widehat{\boldsymbol{\lambda}}))]^2 \, \mathrm{d}\boldsymbol{X} \qquad (1)$$

Displacements $\boldsymbol{u}$ are obtained through a FE model of Microstructural Volume Element (MVE).

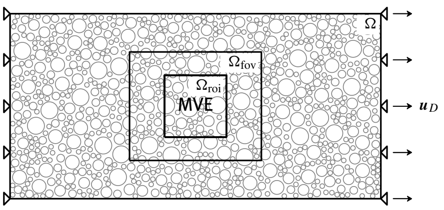

Fig. 2: A sketch of experimental micro-to-macro set-up, tensile test

CHALLENGE: What boundary conditions apply on ∂MVE?
...high sensitivity to erroneous fluctuations!

3. Methods

Boundary-Enriched Integrated Digital Image Correlation (BE-IDIC), [2]. Consider material constants and boundary displacements as unknowns in IDIC formulation (1), i.e.

$$\widehat{\boldsymbol{\lambda}} = [\widehat{\boldsymbol{\lambda}}_{\text{mat}}, \widehat{\boldsymbol{\lambda}}_{\text{kin}}]^{\mathsf{T}} \Rightarrow \begin{cases} \widehat{\boldsymbol{\lambda}}_{\text{mat}} = [G_1, K_1, \dots]^{\mathsf{T}} \\ \widehat{\boldsymbol{\lambda}}_{\text{kin}} = \boldsymbol{u}(\boldsymbol{X}), \quad \boldsymbol{X} \in \partial\text{MVE} \end{cases}$$

4. Results

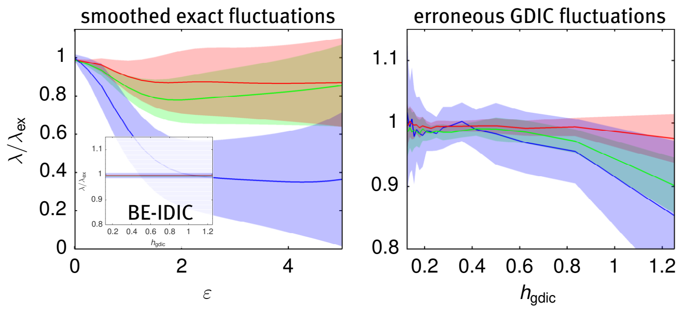

Fig. 3: Effect of smoothing, erroneous fluctuations, and BE-IDIC

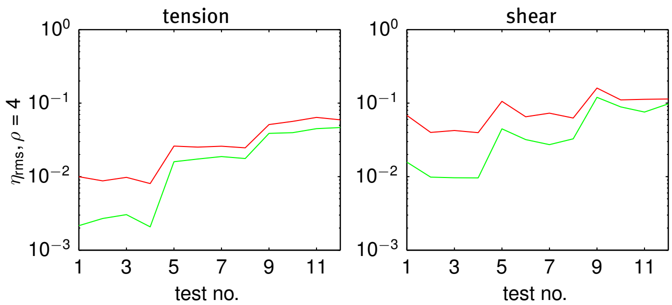

Fig. 4: RMS errors for 12 tests; BE-IDIC in green, the best GDIC-IDIC in red

5. Conclusions

In order to accurately and reliably identify micromechanical parameters, it is crucial to eliminate erroneous fluctuations in boundary conditions applied to adopted microstructural volume element. To this end, boundary-enriched integrated digital image correlation methodology has been introduced, which has the ability to

- remove adverse effects caused by errors in prescribed BCs
- adaptively refine boundary displacement interpolation and thereby guarantee a required level of accuracy
- decrease sensitivity to image noise, which results in increased robustness

MESSAGE: Accuracy in prescribed BCs matters.
BE-IDIC method automatically corrects for inaccurate BCs.

6. Acknowledgements

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7. References

[1] M. Shakoor, A. Buljac, J. Neggers, F. Hild, T.F. Morgeneyer, L. Helfen, M. Bernacki, P.O. Bouchard (2017). On the choice of boundary conditions for micromechanical simulations based on 3D imaging. *International Journal of Solids and Structures*, 112, 83–96.

[2] O. Rokoš, J.P.M. Hoefnagels, R.H.J. Peerlings, M.G.D. Geers (Submitted). On Micromechanical Parameter Identification and the Role of (In)Accuracy in Kinematic Boundary Conditions.

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