

FEM-VEM crack tracking algorithms for quasi-brittle materials

Antonino Spada^{1*}, Marianna Puccia¹, Elio Sacco², Giuseppe Giambanco¹

¹University of Palermo
viale delle Scienze, 90128, Palermo
antonino.spada@unipa.it, marianna.puccia@unipa.it, giuseppe.giambanco@unipa.it

²University of Naples Federico II
Via Claudio 21, 80125 Naples
elio.sacco@unina.it

ABSTRACT

Quasi-brittle materials fail when strains localize in narrow bands. A continuous-discontinuous numerical approach introduces strong or weak discontinuities that can be inter-element or intra-element located.

In the framework of the continuous-discontinuous Augmented-FEM (A-FEM) strategy [1], the authors already validated an Advanced A-FEM (AA-FEM) approach [2], where an interphase element (IPH) substituted the common zero-thickness interface element (ZTI) in order to simulate weak discontinuity. Simultaneously, VEM-based tracking algorithms were developed to solve similar problems [3], thanks to the higher flexibility of VEM in terms of number of element edges, permitting it to deal with more complex geometries without the need for a parent element, easy polynomial degree elevation and very good performances for distorted meshes. Exploiting the advantages of the two approaches, a coupled FEM-VEM tracking algorithm was recently published [4]. Starting with a full FE discretization, the proposed numerical procedure introduced a partial crack in those elements with an average damage above a fixed threshold, and a full crack in those elements with an average damage above a critical value. As a consequence, cracked elements presented sub-elements with three, four, five or seven nodes, simulated as VEs.

In this work, the coupled FEM-VEM crack tracking algorithm in [4] has been converted into full-FEM and full-VEM algorithms, to identify the real advantages of each single approach. A weak discontinuity is introduced within the finite element in the form of an interphase element (IPH). The element is totally cracked when critical damage is reached. On the contrary, the element is partially cracked, since the method allows the presence of the crack tip within the element.

The results of the three algorithms applied to some examples are here illustrated and discussed.

References

- [1] Liu, W., Yang, Q.D., Mohammadizadeh, S., Su, X.Y., "An efficient augmented finite element method for arbitrary cracking and crack interactions in solids", *Int. J. Num. Meth. Engng.*, 99(6), pp.438-468, 2014.
- [2] Puccia, M., Spada, A., and Giambanco, G., "Finite elements with embedded interphases for strain localization in quasi-brittle materials", *Eng. Frac. Mech.*, 277: 108956, 2023.
- [3] Artioli, E., Marfia, S., Sacco, E., "VEM-based tracking algorithm for cohesive/frictional 2D fracture", *Comput. Meth. Appl. Mech. Engrg.*, 365: 112956, 2020
- [4] Spada, A., Puccia, M., Sacco, E., and Giambanco, G., "A coupled FEM-VEM approach for crack tracking in quasi-brittle materials", *Comput. Methods Appl. Mech. Eng.*, 437: 117756, 2025