UNIVERSITA' DEGLI STUDI DI NAPOLI FEDERICO II

DIPARTIMENTO DI STRUTTURE PER L'INGEGNERIA E L'ARCHITETTURA
CORSO DI DOTTORATO DI RICERCA IN
INGEGNERIA STRUTTURALE GEOTECNICA E RISCHIO SISMICO

XXXVI CICLO

Il sottoscritto prof. Elio Sacco, Professore Ordinario, afferente al Dipartimento di Strutture per l'Ingegneria e l'Architettura S.S.D. ICAR/08 Scienza delle Costruzioni

CHIEDE

di essere inserito tra i possibili tutor di studenti di dottorato per il XXXVI ciclo.

1. Curriculum sintetico del proponente (max 500 parole)
Elio Sacco (email: elio.sacco@unina.it; Web-page: https://www.docenti.unina.it/elio.sacco; ResearcherID: G-5349-2017; ORCID: https://orcid.org/0000-0002-3948-4781) is full Professor (with tenure) of Solid and Structural Mechanics at Department of Structures for Engineering and Architecture, University of Naples "Federico II". He had numerous abroad research experiences, e.g. in USA, France, UK. He was Member of the Evaluation Expert Group (GEV-ANVUR); Member of Evaluation Team of the University of Cassino; Chair of PhD Committee in Civil and Mechanical Engineering; Member of Academic Senate; Head of the Department (2 times). He has editorial responsibilities and is referee of many scientific journals. The main research fields are: Computational Mechanics of Structures, Material constitutive modeling of advanced materials (shape memory alloys); Micromechanics and homogenization techniques for composite materials characterized by nonlinear behavior of the constituents; Multiscale analysis of heterogeneous structures; Mechanics of masonry materials and structures; Analysis of plate and shells. Bibliometric data (Scopus updated at January 2020): Documents 175; Citations 3578; h-index 33.

2. Dottorandi dei quali il proponente è stato tutor nell'ultimo triennio	
n. __0__	*specificare tipologia di borsa: ateneo, pon, por, senza borsa, ecc.* ____

3. Titolo della ricerca proposta

FraMe-VEM: **Fra**cture **Me**chanics within the **V**irtual **E**lement **M**ethod

4. Area tematica

Ingegneria Geotecnica □

Ingegneria Strutturale X□

Rischio Sismico □

5. Sintesi del progetto di ricerca (max 500 parole. Stato dell'arte, obiettivi e breve programma previsto per le attività)

Computational fracture mechanics is a very active research field in solids mechanics. Several numerical techniques have been proposed and adopted in literature to study and predict the nucleation and growth of fractures in solids.
Most of the computational techniques are developed in conjunction with the finite element method (FEM), as it is the most popular numerical method in structural analysis, because of its flexibility and simplicity in the use.
However, the study of the crack growth within the FEM framework can be not trivial, as it is necessary to match the fracture geometry with edges of the discretization in order to get a satisfactory solution. Moreover, a fine mesh is needed at the crack tip in order to accurately evaluate the stresses and, thus, to correctly predict the crack evolution.
A very innovative numerical technique in the field of the computational fracture mechanics was proposed by Belytschko and coworkers in the framework of elastic fracture mechanics. They presented the so-called extended finite element method (XFEM) able to solve the crack growth problem performing a minimal remeshing and introducing discontinuous enrichment functions within the elements to account for the presence of the crack.
In the last five years, a new finite element methodology has been proposed; Brezzi, Beirao da Veiga and coworkers developed a new numerical technique named virtual element method (VEM). The VEM is more flexible than standard FEM, as it is possible to discretize the domain by polygons characterized by any number of edges, without constraints. Moreover, it has also been proved that VEM presents several advantages with respect to classical FEM, such as ability to accurately deal with complex geometries, flexibility in mesh generation, no need of a parent element, easy polynomial degree elevation, very good performances for distorted meshes. The features of the VEM appear particularly suitable for the development of a procedure able to follow the crack growth in a solid. In fact, it appears very interesting the possibility to combine the use of VEM with the minimal remeshing procedure; in other words, to extend and smartly implement the founding idea at the basis of the XFEM through an inter-element approach.

The research project is devoted to the development of a novel procedure for reproducing the nucleation and propagation of fracture in 2D cohesive media, combining the virtual element technique with a splitting methodology and a minimal remeshing procedure, suitably taking advantage of the specific features of VEM mesh adaptivity. In fact, the problem of a cohesive crack growth in an elastic solid is considered introducing an interface cohesive law which takes into account crack edges opening through the evolution of a damage variable in mode I, mode II and mixed mode. The construction of the VEM method, adopted to model the bulk part of the solid, is based on the representation of the displacements only on the boundary of its domain, without specifying the approximation in the domain itself. This, implicitly, leads to the consequence that the strain cannot be computed as the symmetric part of the gradient, so that a projection operation has to be introduced to define the strain and, hence, the stress in the element. Because of the projection operation, the stiffness matrix can be evaluated as the sum of two contributions, a consistent and a stabilizing part.
A numerical algorithm has to be developed for reproducing the crack nucleation, the fracture path generation and tracking. The procedure fundamentally consists in two steps, i.e. the nucleation and propagation criteria and the adaptive mesh refinement.
Numerical applications will be developed in order to assess the ability of the proposed procedure to satisfactorily reproduce the crack nucleation and growth in solids. After investigating the response of simple benchmark examples, the procedure will be applied to structural elements in order to verify the overall performances of the new numerical technique, performing analysis for structures of engineering interest. In particular, the mechanical response of unreinforced and FRCM reinforced masonry constructions will be investigated with the objective of elaborating suitable suggestion for rational and well established guidelines for the use of FRCM reinforcements.

6. Eventuali pubblicazioni del tutor sul tema di ricerca (max 10)

[1] Nerilli, F., Marfia, S., Sacco, E. Micromechanical modeling of the constitutive response of FRCM composites (2020) Construction and Building Materials, 236, art. no. 117539.
[2] Artioli, E., Marfia, S., Sacco, E. High-order virtual element method for the homogenization of long fiber nonlinear composites (2018) Computer Methods in Applied Mechanics and Engineering, 341, pp. 571-585.
[3] Freddi, F., Sacco, E., Serpieri, R. An enriched damage-frictional cohesive-zone model incorporating stress multi-axiality (2018) Meccanica, 53 (3), pp. 573-592.
[4] Artioli, E., Beirão da Veiga, L., Lovadina, C., Sacco, E. Arbitrary order 2D virtual elements for polygonal meshes: part II, inelastic problem (2017) Computational Mechanics, 60 (4), pp. 643-657.
[5] Artioli, E., Beirão da Veiga, L., Lovadina, C., Sacco, E. Arbitrary order 2D virtual elements for polygonal meshes: part I, elastic problem (2017) Computational Mechanics, 60 (3), pp. 355-377.
[6] Artioli, E., Marfia, S., Sacco, E. Virtual element technique for computational homogenization problems (2017) AIMETA 2017 - Proceedings of the 23rd Conference of the Italian Association of Theoretical and Applied Mechanics, 2, pp. 1686-1698.
[7] Serpieri, R., Albarella, M., Sacco, E. A 3D microstructured cohesive–frictional interface model and its rational calibration for the analysis of masonry panels (2017) International Journal of Solids and Structures, 122-123, pp. 110-127.
[8] Freddi, F., Sacco, E. An interphase model for the analysis of the masonry-FRP bond (2016) Composite Structures, 138, pp. 322-334.
[9] Alfano, G., Sacco, E. Combining interface damage and friction in a cohesive-zone model (2006) International Journal for Numerical Methods in Engineering, 68 (5), pp. 542-582.

7. Eventuali progetti di ricerca finanziati in cui l'attività si inserisce

La ricerca si inserisce nelle attività di base delle tematiche finanziate da Reluis.

8. Eventuali fondi disponibili a supporto dell'attività del dottorando (escluso finanziamento borse)

Fondi Reluis / PRIN (prossima richiesta)

9. Informazioni relative ad un periodo di ricerca all'estero (minimo tre mesi) previsto per il dottorando (*indicare Università/ente di ricerca e docente/ricercatore di riferimento* con indirizzo mail) (max 300 parole)

La tecnica del Metodo degli elementi Virtuali coniugata con la problematica della Frattura è molto innovativa e non moltissimi laboratori di ricerca e sedi universitarie al momento sono attualmente coinvolte. D'altra parte, visto le notevoli potenzialità della metodologia, l'interesse sta incrementando notevolmente negli ultimi mesi. Tra le università estere, che hanno già lavorato sulla metodologia VEM in meccanica della frattura e con le quali il proponente ha rapporto di collaborazione, certamente rientra la Leibniz Universität di Hannover. Infatti, il prof. Peter Wriggers (wriggers@ikm.uni-hannover.de) del Institutsleiter des Institutes für Kontinuumsmechanik, ha enorme competenza nella Meccanica dei Solidi, con particolare interesse alla Meccanica Computazionale, ed ha sviluppato già tecniche VEM in Meccanica della FraTtura. Di seguito sono riportate le indicazioni bibliografiche di due lavori sull'argomento.

Aldakheel, F., Hudobivnik, B., Hussein, A., (2018): Phase-field modeling of brittle fracture using an efficient virtual element scheme, Computer Methods in Applied Mechanics and Engineering, 341.

VM. Nguyen-Thanh, X. Zhuang, H. Nguyen-Xuan, T. Rabczuk, P. Wriggers (2018): A Virtual Element Method for 2D linear elastic fracture analysis., Computer Methods in Applied Mechanics and Engineering, Volume 340, 1 October 2018, Pages 366-395

10. Eventuali collaborazioni con imprese/aziende sul tema di ricerca (max 300 parole)

Napoli, 29/01/2020 FIRMA

Elio Sacco

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Il presente modulo va compilato in ogni sua parte ed inviato all'indirizzo di posta elettronica phd.dist@unina.it entro e non oltre **venerdì 14/02/2020**.