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

MACoMa: Multiscale **A**nalysis of **Co**mposite **Ma**terials

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)

Composite materials often present internally complex microstructures, therefore, they require specific formulations to be developed in order to take into account the mechanical behavior of each component and its topological distribution. In particular, if the constituents are characterized by a nonlinear response the study becomes more complex as the nonlinear effect occurring in the material should also be modeled. Lately, the interest around the modeling of composite materials has increased significantly.
A large class of composite media are made of constituents that exhibit plastic and time-dependent behavior that requires the use of nonlinear elastoplastic and elasto-viscoplastic material models.

One possibility to evaluate the overall mechanical response of these composite materials, which have complex microstructures and viscoplastic effects in its constituents, is to adopt micromechanical procedures, that study a representative volume element (RVE), determining the behavior of the homogenized equivalent material. Very recently, micromechanical numerical investigation have been presented, for example, in 2D plasticity or in 3D viscoplasticity framework for composites materials.

In order to perform analyses of structural elements, made of composite materials, a multiscale approach can be adopted considering the complex nonlinear response of these composites directly derived from a micromechanical analysis. The multiscale technique consists in the modeling of the structure taking into account two different scales: the macro-scale, i.e. the scale at the structural level, and the micro-scale, i.e. the scale at the material level, where the single heterogeneity can be distinguished in the material. If the heterogeneity size is significantly smaller than the structural size, the two scales can be considered separated and it is possible to solve the micromechanical problem at each point of the structure and to adopt the obtained results for deriving the constitutive response to be used for the structural analysis.

A major problem in the multiscale analysis is the development of an effective, i.e. simple and accurate, solution of the micromechanical problem. In fact, the multiscale problem can be solved using nonlinear finite element (FE) analyses both at the material and at the structural level, i.e. the FE^2 multiscale scheme.

The FE^2 is developed inducing a large number of history variables that can lead to very high computational burden and time. In order to improve the multiscale approach and to reduce the number of history variables, the nonlinear overall response of the composite can be derived adopting simplified homogenization techniques. In literature, several techniques have been presented for solving the homogenization problem of plastic and viscoplastic composites.

An efficient homogenization approach for nonlinear material is the Transformation Field Analysis (TFA), originally proposed by Dvorak in1992, that determines the behavior of the composite taking into account the nonlinear phenomena considering the presence of inelastic strain fields. Lately, the TFA approach has been adopted to derive the response of several nonlinear composites considering a uniform, piecewise uniform or nonuniform distribution of the inelastic strain.

A high computational efficiency is required for these multiscale approaches in order to be able to perform structural analyses of composite materials without having too long time of computation and too high number of history variables. For this reason, a compromise between accuracy and computational effort should be fulfilled. Hence, the research is very active in this field, aimed at developing efficient multiscale algorithms.

Starting from these considerations, the research has the scope of proposing a new and efficient multiscale procedure for studying the response of structural elements made of composite materials whose constituents present plastic or viscoplastic behavior. In particular, periodic composite will be studied, thus a repetitive Unit Cell (UC) containing all the properties of the heterogeneous material is analyzed by means of a PieceWise Uniform TFA (PWUTFA) homogenization technique. This choice is made with the aim to obtain a satisfactorily accurate homogenization technique, resulting particularly efficient from the computational point of view for the multiscale analysis.
The UC is divided in subsets and in each one the inelastic strain is considered uniform, i.e. constant. Elastoplastic and elasto-viscoplastic models with isotropic hardening are introduced in order to describe the nonlinear response of the constituents.

A numerical procedure will be developed solving the evolutive problem in all the subsets simultaneously, adopting a predictor-corrector technique. The corrector phase is solved by means of a modified Newton-Raphson iterative procedure. In order to obtain an efficient numerical tool, the tangent consistent with the algorithm is evaluated and adopted in the computations.

Numerical applications will be developed in order to assess the efficiency of the proposed multiscale approach. In particular, the proposed procedure is implemented in 2D and 3D frameworks.

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

[1] Alaimo, G., Auricchio, F., Marfia, S., Sacco, E. Optimization clustering technique for PieceWise Uniform Transformation Field Analysis homogenization of viscoplastic composites (2019) Computational Mechanics, 64 (6), pp. 1495-1516.
[2] Covezzi, F., de Miranda, S., Marfia, S., Sacco, E. Multiscale analysis of nonlinear composites via a mixed reduced order formulation (2018) Composite Structures, 203, pp. 810-825.
[3] Covezzi, F., de Miranda, S., Fritzen, F., Marfia, S., Sacco, E. Comparison of reduced order homogenization techniques: pRBMOR, NUTFA and MxTFA (2018) Meccanica, 53 (6), pp. 1291-1312.

[4] Marfia, S., Sacco, E. Multiscale technique for nonlinear analysis of elastoplastic and viscoplastic composites (2018) Composites Part B: Engineering, 136, pp. 241-253.
[5] Addessi, D., Sacco, E., Di Re, P. Multi-scale analysis of masonry structures (2018) Proceedings of the International Masonry Society Conferences, 0 (222279), pp. 307-323.
[6] Covezzi, F., de Miranda, S., Marfia, S., Sacco, E. Homogenization of elastic–viscoplastic composites by the Mixed TFA (2017) Computer Methods in Applied Mechanics and Engineering, 318, pp. 701-723.
[7] Covezzi, F., de Miranda, S., Marfia, S., Sacco, E. Complementary formulation of the TFA for the elasto-plastic analysis of composites (2016) Composite Structures, 156, pp. 93-100.
[8] Marfia, S., Sacco, E. Computational homogenization of composites experiencing plasticity, cracking and debonding phenomena (2016) Computer Methods in Applied Mechanics and Engineering, 304, pp. 319-341.
[9] Sepe, V., Auricchio, F., Marfia, S., Sacco, E. Homogenization techniques for the analysis of porous SMA (2016) Computational Mechanics, 57 (5), pp. 755-772.
[10] Covezzi, F., De Miranda, S., Marfia, S., Sacco, E. A homogenization technique for elasto-plastic composites (2016) ECCOMAS Congress 2016 - Proceedings of the 7th European Congress on Computational Methods in Applied Sciences and Engineering, 2, pp. 2316-2322.

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 PRIN

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)

L'analisi multiscale è di grande interesse nella comunità scientifica sia relativamente ai problemi della Meccanica dei Solidi che in altri ambiti dell'Ingegneria e della Fisica. Attualmente, numerose sono le sedi universitarie e gli enti di ricerca impegnati nello studio di metodi multiscala. Il proponente ha diverse collaborazioni nell'ambito dell'omogeneizzazione e tecniche multiscala; tra queste rientra la collaborazione con il professor Felix Fritzen (felix.fritzen@mechbau.uni-stuttgart.de) del Institut für Technische Mechanik, Leitung der Emmy-Noether-Gruppe EMMA, Universität Stuttgart in Germania. Il prof. Fritzen è particolarmente esperto di metodi di riduzione dell'ordine per l'omogeneizzazione non lineare di materiali eterogenei, modellazione della termoplasticità dei materiali metallici, di implementazione numerica di problemi multi-campo con il metodo degli elementi finiti.
Di seguito sono riportate le indicazioni bibliografiche di due lavori sull'argomento.

M. Leuschner, F. Fritzen, Reduced order homogenization for viscoplastic composite materials including dissipative imperfect interfaces, Mechanics of Materials, Volume 104, 2017, Pages 121-138.
Felix Fritzen, Oliver Kunc, Two-stage data-driven homogenization for nonlinear solids using a reduced order model, European Journal of Mechanics - A/Solids, Volume 69, 2018, Pages 201-220.

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

Napoli, 29/01/2020 FIRMA

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**.