European Training Network
H2020 Marie Skłodowska-Curie Actions (ITN)

RE-FRACTURE2
"Modelling and optimal design of refractories for high temperature industrial applications for a low carbon society"

GA n° 955944

OPEN PhD POSITIONS

1 – The research project

The **RE-FRACTURE2** project is an Innovative Training Network (ITN) funded within the Marie Sklodowska-Curie action by the Framework Programme of the European Union for Research and Innovation Horizon2020. Innovative Training Networks (ITN) drive scientific excellence and innovation. They bring together universities, research institutes and other sectors from across the world to train researchers to doctorate level.

This project aims to train motivated international **Early Stage Researchers (ESRs)**, through the international collaboration of Industry and Academia. At the end of the project, the participating researchers are awarded with the PhD title - **European Industrial Doctorate (EID)**.

The PhD title will be awarded by one of these Universities:

- the University of Trento (Department of Civil, Environmental and Mechanical Engineering)
- the University of Belgrade (Faculty of Mechanical Engineering).

The objective of the project is to derive new computational models for refractory materials, which will make possible for the first time to simulate in-silico their behaviour over the whole of working temperature range. These models will be a breakthrough in the design of components like refractory nozzles, plates, ladle and tundish slide gate systems, which will directly translate to energy savings, waste reduction and decreases in pollution and CO2 emission, together with safety improvements.

3 – The consortium

About UNITN: The Department of Civil, Environmental and Mechanical Engineering (DICAM) at the University of Trento (UNITN) pursues high level scientific and teaching objectives, regarding research and training, in line with the most important research-intensive universities. DICAM also promotes significant interrelations with public authorities and private companies, at local, national and international level. DICAM's mission is laid down in the following specific targets: i) the promotion of research in key areas of Engineering; ii) the training of engineers and researchers of the future generations. It has

achieved an excellent position, in the 251-300 group, in the World University Ranking 2019 and it is 36th in the University in the Europe Teaching Rankings.

About BU: University of Belgrade (BU) is the oldest and largest university in Serbia and the in the ex-Yugoslavia area. Mechanical Engineering Faculty is formed as separate faculty (from previous Technical faculty) in 1948, since when it became the largest engineering faculty. Mechanical engineering faculty by that time consisted of three departments: department of general machines, railway and naval department and aeronautical department. In the year 1955 first time the doctoral studies were introduced. Nowadays the Faculty consists of 24 departments, which represent the main educational and research units, with total number of students in all 5 years of undergraduate studies equal to about 3000. Majority of the departments are having research connected with computational mechanics, optimization of mechanical systems, structural analysis, experimental methods for assessment of structural damages etc.

About VESUVIUS: Vesuvius Group SA (VESUVIUS) is a global leader in the supply of specialized refractory products and packaged technology solutions to the steel making, foundry and glass industries, employing more than 12,000 people in 90 different countries. Vesuvius develops and produces highly specialized Flow Control Systems packages which contain advanced refractories and devices for the controlled casting of liquid steel mainly for the process of continuous casting in steel plants. R&D activities at Vesuvius Ghlin site include fundamental research in refractory material characterization on thermomechanical behaviour and material modelling by finite element analysis, in addition to continuous research to advance the state-of-the-art in flow control equipment and technology. These activities support the essential contribution of Vesuvius towards realizing the targets of the steel industry to produce high quality steel at the lowest possible energy consumption, hence reducing CO2 emission and production cost.

About CAEmate: CAEmate Srl (CAEmate) is a rapidly growing hi-tech company active in the development of innovative software solutions and cloud applications targeted to engineering workflow automation. The company employs the most advanced technologies in object oriented programming, cloud-computing and numerical simulation (FEA, CFD, DEM) to improve efficiency and safety in the engineering design procedures. CAEmate contributes to the project with the development of innovative software technologies and custom numerical simulation tools.

4 – Open PhD Positions (3-year fellowships; for full description and application details see below**)**

Project Code	Recruiting Host Institution	Secondment Institution	Title of the project
ESR1	**Vesuvius Group SA (Belgium)**	**University of Trento (Italy)**	*Experimental material characterization of refractory materials at high temperature*
ESR2	**Vesuvius Group SA (Belgium)**	**University of Trento (Italy)**	*Rate-dependent constitutive modelling of heat resisting materials*
ESR3	**University of Trento (Italy)**	**Vesuvius Group SA (Belgium)**	*Thermoplastic material instabilities*
ESR4	**CAEmate Srl**	**University of**	*Computational*

	(Italy)	**Belgrade (Serbia)**	*implementation and validation of constitutive models and fracture mechanics applications for heat resistant devices*
ESR5	**University of Belgrade (Serbia)**	**CAEmate Srl (Italy)**	*Inverse analysis procedure for calibration of constitutive models for mechanical behaviour at high temperature*
ESR6	**University of Belgrade (Serbia)**	**CAEmate Srl (Italy)**	*Topology and geometry optimization of refractory devices*

5 – Fellowships

Successful candidates will receive a salary/fellowship in accordance with the MSCA regulations for Early Stage Researchers. The exact salary/fellowship will be confirmed upon appointment and will amount:

- **living allowance**: € 3,270.00 per month (before employer and employee deductions), corrected by the country correction coefficient (CCC)[1]
- an additional taxable monthly **mobility allowance** of € 600.00
- if applicable an additional taxable monthly **family allowance** of € 500.00 subject to family status of the appointee.

Funding is guaranteed for 36 months. In addition to their individual scientific projects, the successful candidates will benefit from further continuing education, which includes internships and secondments, a variety of training modules, as well as courses on transferable skills and active participation in workshops and conferences.

6 – Applicants' eligibility requirements

Candidates must demonstrate eligibility according to the Marie Sklodowska-Curie Actions[2] eligibility requirements as follows:

- **Researcher status:** Early-Stage Researchers (ESRs) are young researchers who, at the date of recruitment[3], are in the first four years (full-time equivalent research experience) of their research careers and have not been awarded a doctoral degree.
- **Nationality**: Applicant ESRs can be of any nationality.
- **Mobility requirements**: Applicant ESRs must not have resided or carried out their main activity (work, studies, etc.) in the country of the recruiting beneficiary for more than 12 months in the 3 years immediately prior to the date of recruitment[4].

[1] see Work Programme 2018-2020 available on the Participant Portal Reference Documents page http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-msca_en.pdf (Italy CCC 104.4%, Belgium CCC 100%, Serbia CCC 67.3%)

[2] See details in the Guide for applicants Marie Skłodowska-Curie Actions Innovative Training Networks (ITN) 2018, at the link http://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/h2020-guide-appl-msca-itn_en.pdf

[3] The first day of employment of the Fellow for the purposes of the project (i.e. the starting date indicated in the employment /fellowship contract or equivalent direct contract).

[4] Compulsory national service, short stays such as holidays, and time spent as part of a procedure for obtaining refugee status under

7 – ESRs Project description, ESRs profile and application

ESR[n°]:	*ESR1*
Host institution:	*Vesuvius Group SA, Mons, Belgium*
Supervisor:	*Severine Romero-Baivier*
Co-supervisor(s):	*Prof. Davide Bigoni, University of Trento, Italy*
Project title:	*Experimental material characterization of refractory materials at high temperature*
Description and Objectives:	*The PhD student will develop innovative protocols for experiments aimed at investigating the mechanical properties of materials deformed at room and high temperature. Here, new technologies will be developed, under the supervision of VESUVIUS and UNITN, to provide thermal shocks to material elements and measure the induced damage. Moreover, simple prototypes will be built to highlight the features of the mechanical behaviour under consideration and to show up cyclic and dynamic effects. Since refractory linings of furnace ladles are assembled in masonry-like structures, models of these will be replicated in a laboratory environment to analyse stress distributions and mechanical weaknesses.*
Expected Results:	*- Set-up of innovative testing methods for refractory materials, both at room and high temperature;* *- Development of reliable testing procedures and design or improvement of testing devices;* *- Scientific publication on the results of the material characterization.*
Planned secondment:	*The student will spend the initial 22 months after his enrolment at VESUVIUS and a secondment period of 14 months at UNITN, under the supervision of Prof D. Bigoni. At UNITN the student will be enrolled in the doctorate school, will be supported in the analysis and publication of the achieved experimental results and followed in the development of the PhD thesis.*
Enrolment in Doctoral degree(s):	*The ESR will be enrolled in the Doctoral School "Engineering of Civil and Mechanical Structural Systems" at the University of Trento.*
Profile of the fellow:	*The candidate skills/qualifications required for the position are listed below:* • *A first-class Master's degree (or equivalent) in Solid and Structural Mechanics, Civil/Structural/Mechanical Engineering or a related discipline.* • *A sound background in solid mechanics, material mechanics, and experience in coding.* • *Excellent written and verbal communication, including presentation skills.*

the Geneva Convention are not taken into account.

	• *Highly proficient English language skills.* • *Excellent organisational skills, attention to detail and the ability to meet deadlines.* • *Ability to think logically, create solutions and make informed decisions.* • *Willingness to work collaboratively in a research environment.* • *A strong commitment to your own continuous professional development.* • *Ability to travel and work across Europe.*
Link to application:	*Application must be submitted to severine.romero.baivier@vesuvius.com with the subject "Application for RE-FRACTURE2 ESR1 position"*
Deadline for application:	*30 June 2021 12:00:00 Brussels time*
Starting day of the contract:	*1st November 2021*

ESR[n°]:	*ESR2*
Host institution:	*Vesuvius Group SA, Mons, Belgium*
Supervisor:	*Severine Romero-Baivier*
Co-supervisor(s):	*Prof. Francesco Dal Corso, University of Trento, Italy*
Project title:	*Rate-dependent constitutive modelling of heat resisting materials*
Description and Objectives:	*In parallel to the experimental activity of ESR1, the PhD student will be taught elasto-visco-plasticity theory and thermomechanics for solids subject to large strain, so that he will be able to develop a new constitutive model for the simulation of the behaviour of ceramic materials subject to high temperature. Model features will be tailored using data from the experiments developed by ESR1, with particular attention given to the coupling effects involving elastic and plastic deformation and thermal laws. Cyclic behaviour and possibly wave propagation will be considered in the model.*
Expected Results:	*- Formulation of the thermo-visco-elastic material model for ceramic materials;* *- Formulation of the rate-independent micro-mechanical constitutive model at high temperature;* *- Formulation of the rate-dependent thermoplastic constitutive model for refractories.*
Planned secondment:	*After his enrolment, the student will spend a secondment period of 18 months at UNITN, under the supervision of Prof F. Dal*

	Corso. At UNITN the fellow will be introduced to the most advanced theories on material modelling, which will be adapted and verified during the following period of 18 months which will be spent in VESUVIUS.
Enrolment in Doctoral degree(s):	*The ESR will be enrolled in the Doctoral School "Engineering of Civil and Mechanical Structural Systems" at the University of Trento.*
Profile of the fellow:	*The candidate skills/qualifications required for the position are listed below:* • *A first-class Master's degree (or equivalent) in Solid and Structural Mechanics, Civil/Structural/Mechanical Engineering or a related discipline.* • *A sound background in solid mechanics, material mechanics, and experience in coding.* • *Excellent written and verbal communication, including presentation skills.* • *Highly proficient English language skills.* • *Excellent organisational skills, attention to detail and the ability to meet deadlines.* • *Ability to think logically, create solutions and make informed decisions.* • *Willingness to work collaboratively in a research environment.* • *A strong commitment to your own continuous professional development.* • *Ability to travel and work across Europe.*
Link to application:	*Application must be submitted to severine.romero.baivier@vesuvius.com with the subject "Application for RE-FRACTURE2 ESR1 position"*
Deadline for application:	*30 June 2021 12:00:00 Brussels time*
Starting day of the contract:	*1st November 2021*

ESR[n°]:	*ESR3*
Host institution:	*University of Trento, Trento, Italy*
Supervisor:	*Prof. Andrea Piccolroaz*
Co-supervisor(s):	*Vincent Boisdequin, Vesuvius Group SA, Belgium*
Project title:	*Thermoplastic material instabilities*
Description and Objectives:	*The PhD student will analyse material instabilities for thermoplastic materials, which are fundamental tools to predict failure initiation, while fracture mechanics dominates at later*

	stages of deformation. The analysis of material instability and crack propagation will be developed in view of the application to the ceramic materials and refractories. Loss of ellipticity of the developed constitutive thermoplastic operator will be addressed together with the perturbative approach for homogeneous states near failure and with techniques developed in fracture mechanics.
Expected Results:	*- Analysis of the loss of ellipticity of the developed constitutive thermoplastic operator;* *- Formulation of a micromechanical damage mechanism influenced by high temperature and thermal couplings;* *- Application of the perturbative approach to deformation states close to failure conditions.*
Planned secondment:	*The student will spend the initial 18 months after his enrolment at UNITN, in order to deepen his/her knowledge in this field. During the following secondment period of 18 months at VESUVIUS, the fellow will investigate the industrial applications of the proposed approaches.*
Enrolment in Doctoral degree(s):	*The ESR will be enrolled in the Doctoral School "Engineering of Civil and Mechanical Structural Systems" at the University of Trento.*
Profile of the fellow:	*The candidate skills/qualifications required for the position are listed below:* • *A first-class Master's degree (or equivalent) in Solid and Structural Mechanics, Civil/Structural/Mechanical Engineering or a related discipline.* • *A sound background in solid mechanics, material mechanics, and experience in coding.* • *Excellent written and verbal communication, including presentation skills.* • *Highly proficient English language skills.* • *Excellent organisational skills, attention to detail and the ability to meet deadlines.* • *Ability to think logically, create solutions and make informed decisions.* • *Willingness to work collaboratively in a research environment.* • *A strong commitment to your own continuous professional development.* • *Ability to travel and work across Europe.*
Link to application:	*https://www.unitn.it/en/ateneo/bando/67161/department-of-civil-environmental-and-mechanical-engineering-call-for-the-selections-for-the-awardin*
Deadline for application:	*30 June 2021 12:00:00 Brussels time*
Starting day of the contract:	*1st November 2021*

ESR[n°]:	*ESR4*
Host institution:	*CAEmate Srl, Bolzano, Italy*
Supervisor:	*Massimo Penasa*
Co-supervisor(s):	*Prof. Vladimir Buljak, University of Belgrade, Serbia*
Project title:	*Computational implementation and validation of constitutive models and fracture mechanics applications for heat resistant devices*
Description and Objectives:	*The PhD student will implement the constitutive models formulated by ESR2 for the high temperature behaviour of refractory materials in routines for finite elements computations. Moreover, open-source FE software will be extended to allow the description of the thermoplastic instabilities analysed by ESR3. CAEMATE and BU will introduce the fellow to the most advanced techniques for efficient solution of highly nonlinear problems and mathematical programming, in order to ensure high computational performance of the developed applications. These will be tested to judge the numerical stability and accuracy. The software will subsequently be employed in the design of innovative systems for foundry industry applications. These systems will be tested by VESUVIUS to verify the optimality of the design and to judge the reliability and safety factors of the elements. The possibility of using photoelastic techniques to analyse these structural elements will also be explored by UNITN and applied to relevant situations.*
Expected Results:	*- Computational implementation and validation of user material subroutines to be linked to commercial/open-source FE software;* *- Extension of open-source software (e.g. implementation of new FE) for simulation of thermoplastic material instabilities;* *- Numerical simulation of experimental tests at high temperature and thermal shock of industrial components.*
Planned secondment:	*The initial training period of 18 months will be spent principally at CAEMATE, with one month secondment at VESUVIUS. The fellow will then start a secondment period of 18 months at BU, during which he/she will deepen his knowledge on numerical analysis. At BU the fellow will be supported in the submission of scientific publications and in the development of his PhD thesis by Prof Buljak.*
Enrolment in Doctoral degree(s):	*The ESR will be enrolled in the Doctoral School "Mechanical engineering" at the University of Belgrade.*
Profile of the fellow:	*The candidate skills/qualifications required for the position are listed below:* • *A first-class Master's degree (or equivalent) in Solid and Structural Mechanics, Civil/Structural/Mechanical*

	Engineering, Software Engineering or a related discipline. • *Experience with material and structural modelling, programming languages (e.g. Python, C++, FORTRAN, JavaScript) and numerical simulations.* • *Excellent written and verbal communication, including presentation skills.* • *Highly proficient English language skills.* • *Excellent organisational skills, attention to detail and the ability to meet deadlines.* • *Ability to think logically, create solutions and make informed decisions.* • *Willingness to work collaboratively in a research environment.* • *A strong commitment to your own continuous professional development.* • *Ability to travel and work across Europe.*
Link to application:	*Application must be submitted to info@caemate.com with the subject "Application for RE-FRACTURE2 ESR position"*
Deadline for application:	*30 June 2021 12:00:00 Brussels time*
Starting day of the contract:	*1st November 2021*

ESR[n°]:	*ESR5*
Host institution:	*University of Belgrade, Belgrade, Serbia*
Supervisor:	*Prof. Vladimir Buljak*
Co-supervisor(s):	*Massimo Penasa, CAEmate Srl, Italy, Severine Romero-Baivier, Vesuvius Group SA, Belgium*
Project title:	*Inverse analysis procedure for calibration of constitutive models for mechanical behaviour at high temperature*
Description and Objectives:	*The PhD student will develop a procedure for the calibration of newly developed constitutive models apt for modelling of material mechanical behaviour at high temperature. The work should include sensitivity analysis through the simulation of tests to optimize testing configurations and develop characterization procedures for further industrial routine use. The designed procedure should synergically combine numerical simulations with experiments (link with ESR1) and mathematical programming in order to build fast computing tool capable of establishing transition from experimentally measured quantities to material properties. In a view of large nonlinearities present in the model, reduced order techniques based on Proper Orthogonal Decomposition will be studied for the acceleration of*

	numerical simulations.
Expected Results:	*- Optimization of testing protocols in terms of experimental setups and selection of measurable quantities;* *- Development of reduced order model for the acceleration of nonlinear simulations of selected tests;* *- Design and implementation of an automatic calibration procedure centred on inverse analysis for routine industrial use.*
Planned secondment:	*Approximately 6 months after the enrolment at BU, the ESR will spend a secondment period of one month at VESUVIUS, during which he/she is going to be involved in the setup of the experimental tests (tutor S. Baivier). At month 22 (M22) the student will start a secondment period of 18 months at CAEMATE with the aim of implementing the designed inverse analysis procedures.*
Enrolment in Doctoral degree(s):	*The ESR will be enrolled in the Doctoral School "Mechanical engineering" at the University of Belgrade.*
Profile of the fellow:	*The candidate skills/qualifications required for the position are listed below:* • *A first-class Master's degree (or equivalent) in Solid and Structural Mechanics, Civil/Structural/Mechanical Engineering or a related discipline.* • *A sound background in solid mechanics, material mechanics, and experience in coding.* • *Excellent written and verbal communication, including presentation skills.* • *Highly proficient English language skills.* • *Excellent organisational skills, attention to detail and the ability to meet deadlines.* • *Ability to think logically, create solutions and make informed decisions.* • *Willingness to work collaboratively in a research environment.* • *A strong commitment to your own continuous professional development.* • *Ability to travel and work across Europe.*
Link to application:	*Application must be submitted to* *vbuljak@mas.bg.ac.rs* *with the subject "Application for RE-FRACTURE2 ESR position"* *The link to the requirements for the enrolment at doctoral studies at the University of Belgrade will be available from beginning of May.*
Deadline for application:	*30 June 2021 12:00:00 Brussels time*
Starting day of the contract:	*1st November 2021*

ESR[n°]:	*ESR6*
Host institution:	*University of Belgrade, Belgrade, Serbia*
Supervisor:	*Prof. I Balak*
Co-supervisor(s):	*Massimo Penasa, CAEmate Srl, Italy*
Project title:	*Topology and geometry optimization of refractory devices*
Description and Objectives:	*The PhD student will focus on the study, the development and the implementation of Topology Optimization (TO) techniques in order to apply them to the optimization of refractory products. Loads, boundary conditions and constrains will be taken from realistic refractory products, supplied by VESUVIUS, with the main goal to maximize their selected performance. For finding the optimal solution to the formulated nonlinear programming problem, different methods will be tested, including sequential quadratic programming, method of moving asymptotes, as well as derivative free, soft computing techniques based on genetic algorithms. In order to accelerate the conventionally adopted approaches, where highly nonlinear FEM simulations are used, reduced order models will be implemented. Developed novelties are going to be on methodological side and therefore not restricted to the application only on selected products.*
Expected Results:	*- Development and implementation of novel Topology Optimization (TO) procedures for iterative optimization of refractory devices;* *- Application of the designed TO procedure to improve the performance of selected refractory products.*
Planned secondment:	*The student will spend the first half of the training program principally at the host institution (BU, 17 months), with one month secondment at VESUVIUS. In this phase, he/she will be introduced to the most recent theories and applications of TO. The following secondment period of 18 months at CAEMATE will focus on the computational implementation of the developed techniques and their industrial use.*
Enrolment in Doctoral degree(s):	*The ESR will be enrolled in the Doctoral School "Mechanical engineering" at the University of Belgrade.*
Profile of the fellow:	*The candidate skills/qualifications required for the position are listed below:* • *A first-class Master's degree (or equivalent) in Solid and Structural Mechanics, Civil/Structural/Mechanical Engineering or a related discipline.* • *A sound background in solid mechanics, material mechanics, and experience in coding.* • *Excellent written and verbal communication, including presentation skills.* • *Highly proficient English language skills.*

	• *Excellent organisational skills, attention to detail and the ability to meet deadlines.* • *Ability to think logically, create solutions and make informed decisions.* • *Willingness to work collaboratively in a research environment.* • *A strong commitment to your own continuous professional development.* • *Ability to travel and work across Europe.*
Link to application:	*Application must be submitted to vbuljak@mas.bg.ac.rs with the subject "Application for RE-FRACTURE2 ESR position"* *The link to the requirements for the enrolment at doctoral studies at the University of Belgrade will be available from beginning of May.*
Deadline for application:	*30 June 2021 12:00:00 Brussels time*
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