### 1st Winter School on Trends on Additive Manufacturing for Engineering Applications

**Polytechnical University of Timișoara (UPT)**  
Timisoara, Romania, 24-28 January 2021  
*in presence & online*

#### Time Table

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<td>Opening of the Winter School (UPT library &amp; online)</td>
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<td>9.30 – 10.00</td>
<td>Greetings and introduction of the organizers (UPT library &amp; online)</td>
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<td>17.30 – 18.00</td>
<td>Discussion session for Q&amp;A</td>
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**In presence & Online**
Winter school info

The winter school on Trends on Additive Manufacturing for Engineering Applications will be held in Timisoara, 24-28 January 2021. The main aim of the Winter School is to involve PhDs and young researchers in the field of AM with an engineering perspective. The winter school is an annual key activity of the European Twinning Project SIRAMM, funded by the European Union's Horizon 2020, H2020-WIDESPREAD-2018-03 under the grant agreement No. 857124.

The winter school will consider both scientific aspects concerning Additive Manufacturing as well as soft skills in research such as scientific and grant proposal writing, gender aspects, etc. Practical sessions concerning designing, manufacturing and testing of 3D-printed objects will be organized.

Venue

Univ. Politehnica Timisoara (UPT), Central Library & Online
4 Bulevardul Vasile Pârvan, Timișoara, Romania
http://library.upt.ro/
http://www.siramm.unipr.it/Events.htm

Winter school Fees

Participation in the winter school is free!

Coffee breaks will be included

A limited number of places are available (max. 30)

The selection process for participating to the winter school will be based on the participant's country, with a preference for east European countries. Participation of PhDs, post-docs and young researchers as well as women will be especially preferred. Gender equality and equal opportunities will be key-aspects in the selection of the participants.

Prospective Key Dates

Registration: 15 January 2021
Confirmation to participants: 20 January 2021

Speakers

Prof. Liviu Marsavina, UPT Timișoara, Romania
Prof. Jan Torgensen, NTNU Trondheim, Norway
Prof. Dan Constantinescu, UP Bucharest, Romania
Prof. Roberto Brighenti, Univ. of Parma, Italy
Prof. Andrea Spagnoli, Univ. of Parma, Italy
Prof. Aleksender Sedmak, Univ. of Belgrade, Serbia
Dr. Aleksander Grbovic, Univ. of Belgrade, Serbia
Prof. Ferdinando Auricchio, Univ. of Pavia, Italy
Dr. Silvia Tavernini, Univ. of Parma, Italy
Prof. F. Berto, NTNU Trondheim, Norway
Prof. Ludvík Kunz, IPM Brno, Czech Rep.
Prof. Dan Constantinescu, UP Bucharest, Romania
Dr. Roxana Ghita, UPT Timișoara, Romania

Accommodation

In Timișoara there are plenty of possibilities for accommodation. Please refer to http://hoteltimisoara.ro/ for more info. Affordable accommodation are provided by the UPT hotels:
- Casa Casa Politehnicii 1
- Casa Casa Politehnicii 2
  https://www.upt.ro/Informatii_casa-politehnicii-2_413_ro.html
- Hotel Perla http://hotelperla.ro/

Registration (Winter School Office)

For registration & info please send an email to:
Prof. Liviu Marsavina: liviu.marsavina@upt.ro
University Politehnica Timișoara,
Dept. of Mechanics and Strength of Materials
Blvd. M. Viteazu, No. 1, Timișoara 300222, Romania
or to the SIRAMM staff: SIRAMM.Twin@gmail.com

Lectures

All lectures will be given in English.

ECTS credits

3 ECTS will be recognized for the participation (for at least 70% of the lectures) to the winter school.
2 more ECTS will be recognized upon the positive evaluation of the final assessment test.
which is the most commonly used powder bed AM method. The advantages and disadvantages of AM production will be presented. The content of the course will be devoted to static, but mainly fatigue properties, which are critical for the reliability of load bearing components exposed to cyclic loading. It will be demonstrated that in contrast to the static performance, the fatigue behavior of AM materials is much more susceptible to the details of microstructure, surface quality, residual stresses and material defects, which are directly related to the AM process parameters and post-processing treatment. Examples of the fatigue properties and microstructure of DMLS manufactured lightweight Ti6Al4V alloy, which dominates in the aerospace industry and biomedical applications and a high-strength corrosion resistant nickel chromium superalloy IN 718 for high temperature applications will be presented.

Opening the design space by removing constraints with Additive Manufacturing and Topology Optimization
Additive Manufacturing (AM) has found its way towards major industrial utilization. Particularly the manufacturing of end use parts with unprecedented performance triggers interest from the major players in aerospace, automotive and biomedical engineering. The manufacturing technology is mature enough, however, the process of infusing innovation into future designs possible with AM is yet limited. The lack of user friendly design software, poor interfaces to the AM process chain and, particularly, the limited amount of people capable of working with respective tools can be seen as the main challenges. After a short intro into AM, and the related potential of design innovation, this lecture will present two types of topology optimization (TO) methods, namely stress level homogenization and compliance-based optimization. The lecture will give an intro in how to construct a simple code performing Topology Optimization in 2D, where the objective function and boundary conditions will be explained. Furthermore, it will be shown how to treat numerical problems such as mesh dependency and the checkerboard problem. At the end of the lecture, software environments for TO will be presented. If time permits, the attendees will also get a hands-on experience on one software tool getting an idea of what weight savings are possible when optimizing a simple real world component. Bring your own laptop! Please make sure that you install the tools before class. Instructions will follow.

Review on AM of polymeric materials
Nowadays, AM technology is applied in a variety of engineering and industrial fields ranging from aerospace, automotive, human organs production and medical implants, stimuli-responsive materials, etc. This review focuses on the AM techniques related to polymers and polymers-like materials, which have attracted much less attention compared to metallic counterparts. In particular, Fusion Deposition Modeling (FDM), Selective Laser Sintering (SLS) and Stereolithography (SL) are considered. Firstly, in this review lecture, several empirical studies aiming at investigating the effects of AM process parameters on the mechanical behaviour of the printed component are discussed. Then, some engineering approaches based on mathematical formulations of AM processes are reviewed. The main goal of this review is to highlight the importance of theoretical models recently proposed, aiming at predicting the mechanical properties of an AM component by describing the real chemical-physical mechanisms occurring in the AM process. The lecture is organized as follows: overview on AM technologies for polymers; state of art on the effect of AM process parameters on mechanical properties of components; review on theoretical models available in the literature for predicting mechanical properties of AM components.

Fatigue properties of metallic materials produced by AM
Participants of the course will become familiar with the issue of properties and microstructure of metallic additively manufactured (AM) materials depending on manufacturing parameters. The attention will be focused on materials prepared by direct metal laser sintering (DMLS), which is the most commonly used powder bed AM method. The advantages and disadvantages of AM production will be presented. The content of the course will be devoted to static, but mainly fatigue properties, which are critical for the reliability of load bearing components exposed to cyclic loading. It will be demonstrated that in contrast to the static performance, the fatigue behavior of AM materials is much more susceptible to the details of microstructure, surface quality, residual stresses and material defects, which are directly related to the AM process parameters and post-processing treatment. Examples of the fatigue properties and microstructure of DMLS manufactured lightweight Ti6Al4V alloy, which dominates in the aerospace industry and biomedical applications and a high-strength corrosion resistant nickel chromium superalloy IN 718 for high temperature applications will be presented.

How to apply for research funding: funding opportunities for Early Stage Researchers and grant writing tips
The lecture will deal with the main research European and international funding opportunities for PhD and Post-Doc fellows considering grants and fellowships to help early stage researcher carry out their research projects, get additional skills, and boost their career. Subsequently some basic best practices on grant writing process, from prospecting to final draft, will be discussed, with a special focus on the European Marie Skłodowska-Curie actions.

Numerical simulation of fatigue crack growth
In this lecture, the fatigue life of structural elements with single and multiple discontinuities (holes, cracks, and inclusions) under cyclic loading conditions will be evaluated by extended finite element method (XFEM) and finite element method (FEM). The goal is to show to winter school participants how numerical models are nowadays used for evaluation of stress intensity factors (SIFs) and, consequently, the remaining life of the damaged structure. Initially, SIFs will be evaluated for standard specimens' models (three-point bending, compact tension, etc.) and results will be compared to analytical solutions and values proved in experiments. Then, single and multiple discontinuities of arbitrary sizes in the actual elements (mostly parts of airframe structures) will be presented and numerically analyzed. The SIFs values will be extracted from the XFEM and FEM solutions and standard Paris fatigue crack growth law will be used for the life estimation of various models. The effect of the cracks' sizes, boundary conditions, and loads' sequences on the fatigue life of the structural elements will be discussed in detail.
Simulation for additive manufacturing: opportunities and challenges

Additive Manufacturing (AM) – also known as 3D printing – is taking off in many industrial realms. In particular, powder bed fusion for metal manufacturing has definitively changed the way of prototyping metal parts but also plastic 3D printing is changing modern engineering in many aspects. Accordingly, AM is opening the doors to new innovative applications and to a different way of approaching, designing, solving modern engineering problems.

On the other hand, AM is a complex process, involving different physical phenomena at very different scales, resulting in a complex coupled thermo-mechanical physics and simulation is fundamental to predict temperature and stress distributions during and after the printing process. Furthermore, AM allows for new unknown freedom in terms of complex shapes which can be manufactured, opening the door to a new set of optimization problems, requirements, and constraints. After a short introduction to the technology and possible applications, the presentation will focus on the experience of the University of Pavia strategic theme (entitled “3D@UniPV. Virtual modeling and additive manufacturing for advanced materials”) and in particular on some research directions on the design of industrial components as well as on innovative computational approach to describe the complex physics (in particular on a technique related to the Fat Boundary method as a possible alternative to describe the different scales present in AM processes) and to solve optimization problems related to the new freedom now possible thanks to AM (introducing a novel graded-material design based on phase-field and topology optimization).

Application of fracture mechanics parameters on structural integrity assessment

Basic fracture mechanics parameters under static loading are introduced and explained, such as $K$, CTOD and $J$ integral, as well as their roles in fracture mechanics triangle, i.e. in structural integrity assessment (crack driving force vs. material resistance to cracking). Critical values of these parameters are defined and explained as material property. Linear elastic vs. elastic-plastic fracture mechanics is explained, with reference to more complex material behavior (visco-plastic). In the scope of linear elastic material behavior, the stress intensity factor, $K_I = \frac{\sigma a}{\sqrt{\pi a}}$, is elaborated and its evaluation by use analytical and numerical methods explained with examples. Standard procedure for fracture toughness testing is introduced and explained. Plasticity has been introduced to explain Crack Tip Opening Displacement (CTOD) and $J$ integral, both as crack driving force and material resistance to crack initiation and growth. Analytical and numerical methods used for CTOD and $J$ integral evaluation are introduced, as well as standard procedures for their critical values. As for dynamic loading, fatigue crack growth is analyzed in the scope of Paris law, correlating crack growth rate with the stress intensity factor amplitude. Both experimental and numerical evaluation methods are explained. For all aforementioned methods and procedures examples are provided, including AM components.

Local approaches in fatigue

The first part of the course will be a brief introduction to fracture and notch mechanics. Starting from a deep historical overview the concepts of elastic stress intensity factor, Griffith energy, $J$ integral will be introduced. Attention will be given to the experimental determination of the fracture toughness and of the threshold stress intensity factor range under cyclic loading. Emphasis will be placed on modern numerical methods for determination of stress intensity factors, critical crack sizes and fatigue crack propagation rate. Some aspects related to three-dimensional effects will be discussed. The second part of the course will treat notch mechanics in more detail presenting different advanced local criteria for fracture and fatigue assessment under static and fatigue loadings. Starting from traditional solutions the course will give a complete overview of the analytical and numerical tools available up to now also discussing some practical example of engineering interest.