The Metallurgy Summer School on Simulation of Phase Transformations in Metal Processing organized by CoMET aims to provide a deep understanding of fundamentals of simulation techniques for metallic materials processing. In particular, the description of phase transformations in different metal processes will be described. After an introduction on fundamentals of thermodynamics and kinetics of phase transformations, a detailed description of available databases for metallic materials will be provided. The simulation of welding processes will be presented in details. Finally, the simulation of casting in foundry and of heat treatments in different alloy systems will be outlined. The school is organized in lectures on both theoretical aspects and applications. The attendees will be invited to analyze case studies, with practical use of available software. The school is addressed mainly to PhD students, but post-docs and master students are also welcome.

**Director:**
Prof. Marcello Baricco - Università degli Studi di Torino

**Scientific and Organising committee:**
Prof. Paolo Ferro - Università degli Studi di Padova
Prof. Paola Leo - Università degli Studi del Salento
Prof. Annalisa Pola - Università degli Studi di Brescia
Dott. Alessandro Morri - Alma Mater Studiorum - Università degli Studi di Bologna

**ASSOCIAZIONE ITALIANA DI METALLURGIA**
Via F. Turati, 8 · 20121 Milano
Tel. 02-76021132 / 02-76397770
Fax. 02-76020551
E-mail: met@aimnet.it · www.aimnet.it

# Metallurgy Summer School

## Simulation of phase transformations in metal processing

## 22-25 July 2018

## Bertinoro (FC)

## Centro Residenziale Universitario

Organized by
**CoMET**
**Coordinamento della Ricerca e della Didattica in Metallurgia**
of

**ASSOCIAZIONE ITALIANA DI METALLURGIA**

#summerschool
#metallurgy

# Program

## Sunday, 22 July 2018

**19.30**  Arrivals

**19.30**  Welcome buffet

**19.30**  Introduction to the Summer School
M. Baricco - Università di Torino

## Monday, 23 July 2018

**THERMODYNAMICS AND KINETICS OF PHASE TRANSFORMATIONS IN METALLIC SYSTEMS**

**8.45**  Registrazione dei partecipanti

**9.00**  Fundamentals
M. Baricco - Università degli Studi di Torino

**9.45**  The Calphad Method - Simulation of Phase Diagrams
M. Baricco - Università degli Studi di Torino

**10.30**  Coffee break

**11.00**  Applications and case studies

**13.00**  Lunch

**MATERIALS DATABASE**

**14.30**  Introduction to the use of materials database
A. Morri - Alma Mater Studiorum - Università degli Studi di Bologna

**15.15**  Applications of the materials database
M. Vottari - Key to Metals AG

**16.00**  Coffee break

**16.30**  Demonstration and workshop
M. Vottari - Key to Metals AG

**18.00**  Conclusions

**19.30**  Aperitif

## Tuesday, 24 July 2018

**SIMULATION OF WELDING**

**9.00**  Solid state microstructure transformations in weldings
P. Ferro - Università degli Studi di Padova
P. Leo - Università degli Studi del Salento

**9.45**  Parameters affecting the welding thermal cycles
P. Ferro - Università degli Studi di Padova
P. Leo - Università degli Studi del Salento

**10.30**  Coffee break

**11.00**  Thermal analysis by Finite Element Method
P. Ferro - Università degli Studi di Padova
P. Leo - Università degli Studi del Salento

**13.00**  Lunch

**14.30**  Working groups on simulation software (SIMUFACT WELDING)
P. Ferro - Università degli Studi di Padova
P. Leo - Università degli Studi del Salento

**16.00**  Coffee break

**16.30**  Analysis and discussion of the working groups results
P. Ferro - Università degli Studi di Padova
P. Leo - Università degli Studi del Salento

**18.00**  Conclusions

**20.00**  Social Dinner

## Wednesday, 25 July 2018

**CASTING (FILLING AND SOLIDIFICATION) SIMULATION**

**9.00**  Phenomena during filling and solidification of the alloys
A. Pola - Università degli Studi di Brescia

**9.45**  Needed input data in foundry simulation
A. Pola - Università degli Studi di Brescia

**10.30**  Coffee break

**11.00**  Case studies and exercises with simulation software
A. Pola - Università degli Studi di Brescia

**12.30**  Analysis and discussion of the obtained results
A. Pola - Università degli Studi di Brescia

**13.00**  Lunch

**HEAT TREATMENTS SIMULATION**

**14.00**  Heat treatment steel theory and exercises with simulation software
A. Pola – Università degli Studi di Brescia

**15.30**  Heat treatment of Ni-base alloys: theory and exercises with simulation software
A. Pola - Università degli Studi di Brescia

**17.00**  Conclusions & Ceremony

## THERMODYNAMICS AND KINETICS OF PHASE TRANSFORMATIONS IN METALLIC SYSTEMS
Marcello Baricco – Università degli Studi di Torino

**Aim**
The lectures are aimed to present the fundamentals of phase transformations in metallic systems. In particular, the CALPHAD method for the optimization and calculation of thermodynamic properties and phase diagrams will be described. Examples will be given for various systems, including aqueous solutions, semiconductors, oxides, metals and alloys, etc.

**Scheme**
Theoretical lessons and computer applications.

**Program**
Lecture 1: Fundamentals. Role of thermodynamics and kinetics of phase transformations on the optimisation of materials and processes. Basic thermodynamics. Phase diagrams. Free energy-composition curves and phase diagram construction. Basic of kinetics of phase transformations.

Lecture 2. The Calphad Method - Simulation of Phase Diagrams. The CALPHAD method. Ab initio modelling of thermodynamic properties: an overview. Parametric description of thermodynamic functions. Composition and temperature dependence. Mobility and diffusion coefficients. Thermodynamic and kinetic databases. Computing techniques. Softwares available.

**Computer applications and case studies**
Calculations of phase diagrams and thermodynamic properties for phase transformations. Applications to industrial problems.

**Softwares available**
Pandat

## MATERIALS DATABASE
Alessandro Morri - Alma Mater Studiorum - Università degli Studi di Bologna
Mariagrazia Vottari - Key to Metals AG

**Aim**
Materials databases are powerful tools to have a fast access to materials properties. To date, however, their potential is not completely exploited. Aim of the lectures is to show some of the most widely used materials databases highlighting their main functions and tools.

**Scheme**
Theoretical lessons and computer applications.

**Program**
Lecture 1: Introduction to the use of materials database. Materials selection and graphical analysis of materials properties by means of Ashby approach. Use of tools of free database for identifying materials with proper performance.

Lecture 2: Applications of the materials database. General overview of the structure of the Total Materia database. Review of properties and sources and of the most common searching tools and functionalities for material selection. Use case analysis: how Total Materia is used in the industry.

**Computer applications and case studies**
Overview on how to navigate Total Materia by using the main functionalities. Workshop: Finding properties and navigating Total Materia. Application to industrial problems.

**Database available**
Total Materia

## SIMULATION OF WELDING
Paola Leo - Università degli Studi del Salento
Paolo Ferro - Università degli Studi di Padova

**Aim**
Heat flow during welding can strongly affect microstructure and properties of the heat affected zone (HAZ). It is also responsible for weld residual stresses and distortion.

**Scheme**
Theoretical lessons and computer applications.

**Program**
Lecture 1: Solid state microstructure transformations in weldings. The main microstructural evolutions induced by thermal cycle in the Heat Affected zone of welds will be analyzed and discussed. Those evolutions are a function of both the operative strengthening mechanism in the base material (work hardening, aging, solution strengthening and alloy exhibiting phase transformation) as well as the temperatures values and time in temperature due to welding thermal cycle. The goal is on the importance of defining the welding thermal cycle in order to avoid or limit undesiderable phase transformations.

Lecture 2: Parameters affecting the welding thermal cycles. The lecture will define and clarify all the parameters affecting the welding thermal cycle that are also input data for simulation of welding.

Lecture 3: Thermal analysis by Finite Element Method. The lecture will discuss the numerical method of Finite element ab initio. Starting from the governing equations for thermal analysis, the discretization of the domain, the role of shape functions, the weak form of governing equations in order to arrive to define the "stiffness" matrix and the algebraic system. The coefficients of the algebraic system will be also obtained in an easy example of unidimensional and stationary heat flux in order to clarify the methodology.

Lecture 4: Thermal analysis by Finite Element Method: Geometrical modelling, Meshing and boundary condition, heat source modelling, material modelling, calibration and validation.
Examples of pre-processing step and results will be described using simulation software.

**Computer applications and case studies**
Role of heat source on welding thermal cycle (energy density)
Role of material Properties on welding thermal cycle
Role of welding Geometry (thickness) on welding thermal cycle
Role of welding parameter (welding speed) on welding thermal cycle

**Softwares available**
SIMUFACT Welding

## CASTING (FILLING AND SOLIDIFICATION) SIMULATION
Annalisa Pola – Università degli Studi di Brescia

**Aim**
The theoretical lecture aims at presenting the fundamentals of foundry simulation, useful both as predictive tool, for the correct design of the mold, and as diagnostic instrument, to understand the source of defects. In particular, the importance of the proper materials input data for the obtainment of reliable results will be shown.
Case studies and exercises will be given to allow a critical evaluation of the correlation between input and output data.

**Scheme**
Theoretical lessons and computer applications.

**Program**
Lecture 1: Filling and solidification modeling. The equations able to describe the phenomena involved during mold filling and casting solidification and cooling will be shown and explained.

Lecture 2: Input data. The lecture will define and clarify all the data needed for the calculation, whose proper definition can improve the quality of the results (material properties, heat transfer coefficient and boundary conditions).

**Computer applications and case studies**
Case studies will be shown about the role of material properties and HTC on simulation results.
Exercises will be done to understand the output analysis

**Softwares available**
Procast-VisualCast

## HEAT TREATMENTS SIMULATION
Annalisa Pola – Università degli Studi di Brescia

**Aim**
The aim of the lecture is to briefly describe the phenomena involved during the heat treatment of metals and how they can be modelled in simulation software in order to predict structural evolution and mechanical properties. Again, the importance of the proper input data for the obtainment of reliable results will be shown.
Case studies and examples will be given to allow a critical evaluation of the correlation between input and output data.

**Scheme**
Theoretical lessons and practical computer applications.

**Program**
Lecture1: Heat treatment of steels. In the first part of the lecture, the transformations occurring during quenching of steels will be analyzed and the needed information for the proper definition of the simulation able to take into account the phase transformation will be shown. Subsequently, exercises about quenching treatment using simulation software will be performed

Lecture2: Heat treatment of Ni-base alloys. In the first part of the lecture, the recrystallization and precipitation phenomena during heat treatment of Ni-base will be analyzed, from theoretical point of view, in order to understand the needed information for the proper definition of the simulation. Subsequently, exercises using simulation software will be performed

**Computer applications and case studies**
Case studies will be shown about the role of material properties on simulation results.
Exercises on quenching treatments and corresponding output analysis will be performed

**Softwares available**
Deform

# General information

## Location
The Course will be held in Ce.U.B - Centro Residenziale Universitario Bertinoro
Via Frangipane, 6 Bertinoro (FC), Italy - www.ceub.it

## Accommodation
Half board (Breakfast and Lunch) in the old seminary (included in the registration fee).
(Please communicate any dietary requirements: allergies, intolerance, particular diet, etc)

## Laptop
Attendees to the Summer School are requested to bring a personal laptop.

## CTS
The attendance to the School will provide 5 CTS.

## Language
The Summer School will be held in English.

## Registration information
The Summer School has a limited number of available places. **Registrations will close on June 14 or as soon as the maximum number of participants will be reached.** Therefore, in case of interest, we strongly recommend to register as soon as possible.

## Registration fee (per person)
**AIM MEMBERS FEES**

| | | |
|---|---|---|
| Single Room | 350,00 | (revenue stamp included) |
| Double Room | 320,00 | (revenue stamp included) |

**NON MEMBER FEES**

| | | |
|---|---|---|
| Single Room | 440,00 | (22% VAT included) |
| Double Room | 400,00 | (22% VAT included) |

**ACCOMPANYING PERSON**

| | | |
|---|---|---|
| Double Room | 210,00 | (22% VAT included) |

Registration fees include admittance to the Summer School, half board accommodation (breakfast and lunch), coffee breaks, welcome buffet on July 22nd, aperitif on July 23th and social dinner on July 24.

## Payment and remittance
· by bank transfer, to the order of AIM at UBI Banca S.p.A. - C/C 000000022325
  Cod. ABI 03111 - CAB 01604 - CIN O.
  Cod. IBAN IT49O0311101604000000022325.
  The transfer order must specify the name of the participant and the reference "Summer School 2018". A copy of the transfer order must be sent to AIM, together with the Registration Form.
· by credit card online: www.aimnet.it

## Cancellation and refund policy
A refund, less 20% deduction for administrative costs, will be issued for written cancellations received **by June 29, 2018**. For attendees who notify their cancellation **after June 29, 2018** or will not attend the Summer School, a charge of 100% of the registration fee will be withheld and a copy of the documentation will be sent after the event.

## Insurance
The Organising Secretariat cannot assume any responsibility for personal accident, loss or damage to the private property of participants and accompanying persons, which may either occur during or arise from the Summer School. Participants should therefore take whatever steps they consider necessary as regards insurance.

## Secretariat
Associazione Italiana di Metallurgia
Via F. Turati, 8 · 20121 Milano
Partita IVA: 00825780158
Tel. 02-76021132 / 02-76397770 · Fax. 02-76020551
e-mail: met@aimnet.it
www.aimnet.it

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Fax. 02-76020551
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# Registration form

# Metallurgy Summer School

## Bertinoro (FC), 22-25 July 2018

## PARTICIPANT DATA

Family Name

First Name

E-mail for correspondence

tel.

ruolo aziendale

## INVOICING DATA

Company Name / University

Company / University Fiscal Address

town

zip code                    country

VAT and FISCAL CODE (if different)

Order ref. number (if requested on the invoice)

e-mail for invoicing and billing information

## REGISTRATION AND PAYMENT

**I will attend as:**        ☐ AIM Member        ☐ Non Member

☐ Single room                    € _____

☐ Double room                    € _____

☐ Accompaning Person             € _____

**Total amount being paid:**      € _____

Name for sharing double room _____

## Payment

☐ by bank transfer

☐ by credit card online: www.aimnet.it

## PRIVACY INFORMATION

In accordance to article 13 of the D.lgs n. 196/03 we inform you that: personal data are required, collected and treated following the normal institutional activity of AIM and according to law; in every moment the interested party can exercise the rights foreseen in the in article 7 of the D.lgs n. 196/03; data controller is AIM in Milan - V. Turati 8; data processor is AIM President, Ing. Federico Mazzolari.

You authorize AIM to the sending:

of newsletters/ communications concerning institutional activities carried out by the Association:                    **yes** ☐ no ☐;

also through other metallurgic associations worldwide, of invitations to events of interest:                    **yes** ☐ no ☐;

to the input of your name in the list of the participants to the event:                    **yes** ☐ no ☐.

Date                    Signature _____

### COMPLETE AND RETURN TO ORGANISING SECRETARIAT BY JUNE 14, 2018