

# Metal additive manufacturing

BERTINORO (FC) | 30 JUNE - 1-2-3 JULY 2024

The Metallurgy Summer School Metal Additive Manufacturing, organized by CoMET, is the 2nd edition of the event. The first one (2020), held in Trento, focused the attention on the additive manufacturing (AM) techniques and general features of metals prepared in this way. On the basis of that experience and suggestions of participants, the scope of this school is to provide a deeper insight into advantages and problems arising in different types of metallic alloys.

After an introductory section devoted to present the state of art of AM metal processing, powder production, experimental techniques for part characterization, and simulations for predicting the mechanical properties of metals produced by AM, the lectures will treat the specific cases of several alloys of industrial interest. They include tool steels, FeSi alloys for electric applications, Ni base superalloys, Al alloys for aerospace and other applications, Ti alloys for "racing" and "aerospace", CoCr alloys, biodegradable Zn alloys and duplex stainless steels for biomedical uses, and metamaterials for nuclear sector. Trends and opportunities of design for AM, lattice and cellular structures (Auxetic and TPMS) with porosity gradient will be also presented and discussed. In conclusion, the program will provide an overview on current scientific and technological challenges.

The school is mainly addressed to PhD students of engineering, materials science, physics and chemistry and technical personnel from industry but post-docs and master students are also welcomed. The lectures, given by experts in the field, aim to stimulate exchange of ideas and favour future research cooperation of participants.



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## PROGRAMME

### Sunday, 30th June 2024

19.30 Welcome buffet

### Monday, 1st July 2024

9.00 M. Vedani (Politecnico di Milano)  
**AM OF METALLIC ALLOYS: STATE OF ART AND PERSPECTIVES**

The fundamental principles of solidification encountered in additively manufactured parts according to the different processes are first described. The resulting alloy structure is then discussed, providing examples for different alloys and for the generation of specific types of defects. Moreover, methods for the tuning on microstructure are presented

9.45 A. Pola (Università degli Studi di Brescia)  
**METAL POWDERS PRODUCTION AND CHARACTERIZATION**

As in any production process, the properties of the starting material influence the performance of the final product. It is therefore essential to know how powders are obtained, how they are controlled and how their quality is assessed. The aim of this presentation is therefore to provide an overview of the different production methods of metal powders (from atomization to mechanical systems) and their characterization techniques (chemical composition and purity, powder size distribution, morphology, density, specific surface area, fluidity)

10.30 Coffee break

11.00 M. Actis Grande, F.S. Gobber (Politecnico di Torino)  
**SIMULATIONS FOR PREDICTING THE EFFECTS OF OPERATIONAL PARAMETERS IN THE PRODUCTION OF GAS ATOMIZED POWDERS**  
Emerging Additive Manufacturing (AM) technology typically needs specifically tailored materials and particles, especially metal powders with precisely optimized size, shape, and morphology. The fine metal powders for AM are produced primarily through gas atomization. The process of gas atomization can be affected by many factors such as the geometry of the atomization equipment (gas nozzle, melt tube, spray chamber), operating parameters (melt flow rate, gas pressure, melt superheat temperature), and material properties (density, viscosity, and surface tension). CFD-based numerical modeling framework can be developed to simulate the gas atomization process, both the primary breakup of the melt stream by a high-pressured inert gas flow jet and the secondary breakup of the melt droplets generated at the primary breakup stage inside the atomization chamber.

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### Monday, 1st July 2024

- 11.45** R. Montanari (Università di Roma Tor Vergata)  
**EXPERIMENTAL TECHNIQUES FOR CHARACTERIZATION OF AM COMPONENTS**  
The most common experimental techniques for microstructural characterization will be examined by focusing the attention on various problems related to the specific features of these materials. Other less common techniques such as mechanical spectroscopy, AFM and XPS will be also presented.
- 12.30** Lunch
- 14.00** M. Pellizzari (Università degli Studi di Trento), F. Deirmina (Sandvik Additive Manufacturing, Sandvik AB, Sweden)  
**DEVELOPMENT, PRODUCTION AND CHARACTERIZATION OF TOOL STEELS THROUGH 3D PRINTING**  
Since the early steps of additive manufacturing (AM), tool steels represented interesting and technically evaluable materials to realize 3D components as tools and dies. After an initial period during which mostly standard steel grades have been used, now tailored, leaner steels have been introduced, looking for improved printability and properties. Aim of this work is to present some alloy design criteria of tool steels for AM as well as the some technically relevant research results on the development of tool steels.
- 14.45** A. Lanzutti (Università di Udine)  
**EFFECTS OF RECYCLED POWDERS ON 3D PRINT OF STEELS AND METAL ALLOYS**  
The lecture aims to provide some information on powder reuse during metal 3D printing using the powder bed fusion process. The lecture will focus on the effect of metal cleanliness, geometry and distribution on the final mechanical properties of the 3D printed components.
- 15.30** Coffee break
- 16.00** A. Di Schino (Università di Perugia)  
**FeSi ALLOYS FOR ELECTRIC APPLICATIONS**  
In this presentation the possibility to use the Direct Melting Laser Sintering (DMLS) technology to produce ferromagnetic cores with high Si content with high performances, providing a competitive alternative for industrial applications, will be shown. In particular, the results of a feasibility study for the production of two FeSi steels with Si content of 3.0 and 6.5 wt.% and the metallurgical characteristics in relation to the process technological parameters will be reported. The magnetic behavior has been studied on different geometries of the transverse section of the samples. For both steels, three different types of section have been examined to suitably optimize the effect of the geometry on the mitigation of the eddy current losses.
- 16.45** D. Ugues (Politecnico di Torino)  
**Ni BASE SUPERALLOYS**  
Nickel based alloys are high added value materials with outstanding mechanical performance and corrosion resistance from medium to high temperature. The use of such materials in aeronautic propulsion and land turbine productions is a key factor to determine the efficiency of such engineering systems. On the other hand, the incredibly properties of these material grades result in severe limitations in their forging capability, mechanical workability and weldability. As a consequence of all these aspects, additive manufacturing is a highly appealing technology that can further drive the design and development of components constituted by these high temperature materials. However, the large amount of alloying elements and the variety of microstructural features characterizing them is even increased by the unique heating and cooling histories provided by AM. AM processing of such complex alloys, as well as potential synergy of AM with post Hot Isostatic Pressing and Heat Treatment will be discussed defining best practice to process and treat different Ni-superalloys.
- 19.30** Aperitif

### Tuesday, 2nd July 2024

- 9.00** R. Montanari (Università di Roma Tor Vergata)  
**Al ALLOYS FOR AEROSPACE APPLICATIONS**  
In aeronautics additive manufacturing (AM) leads specific benefits mainly connected to the topological optimization for weight reduction, the decrease of "buy-to-fly" ratio and the operations of maintenance, repair, and overhaul. Therefore, Al alloys processed by AM are extensively investigated and play an increasing role in the production of aircraft structural parts. The lecture examines advantages and drawbacks involved in the printing of Al alloys. Defects, microstructure, mechanical properties, development of new alloys, post-process treatments are described and discussed.

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### Tuesday, 2nd July 2024

- 9.45** M. Tocci (Università degli Studi di Brescia)  
**Al ALLOYS FOR OTHER APPLICATIONS**  
The number of alloys used in Additive Manufacturing is continuously increasing and this holds also for Al alloys. The lecture will present an overview of the Al alloys that can be manufactured via Additive Manufacturing and their main applications. The approaches that are used for developing new Al alloys to better exploit the potential of the AM technologies and widen their fields of application will be discussed.
- 10.30** Coffee break
- 11.00** A. Saboori, D. Ugues (Politecnico di Torino)  
**Ti ALLOYS FOR "RACING" AND "AEROSPACE"**  
Titanium alloys have become indispensable in both racing and aerospace, playing a pivotal role in pushing the boundaries of performance and innovation. In the area of racing, these alloys, renowned for their exceptional strength-to-weight ratio, contribute to the development of high-speed vehicles. Their lightweight yet robust nature enhances not only speed but also durability and fuel efficiency. In aerospace, Titanium alloys redefine aircraft design by offering unparalleled strength, corrosion and fatigue resistances. From structural components to engine parts, these alloys are instrumental in creating aircraft that are not only safer but also more fuel-efficient. The application of Titanium alloys in racing and aerospace stands as a testament to their versatility, shaping the forefront of technological advancements in these dynamic industries.
- 11.45** R. Casati, M. Vedani (Politecnico di Milano)  
**ADDITIVE MANUFACTURING AND POST-TREATMENTS OF Ti ALLOYS**  
An overview of the main Ti alloys currently used for the production of AM parts will be provided and novel material developments will be discussed. The effects of rapid solidification and post-processing heat treatments on the microstructure and mechanical properties of Ti alloys will be reviewed. Finally, novel insights into Ti MMCs will be described, with a focus on the effect of reinforcing particles on the alloy solidification behavior and resulting material properties.
- 12.30** Lunch
- 14.00** L. Emanuelli (Università degli Studi di Trento)  
**Ti BETA ALLOYS FOR BIOMEDICAL APPLICATIONS: USE OF CELLULAR STRUCTURES (AUXETIC AND TPMS) WITH POROSITY GRADIENT FOR OPTIMIZING MECHANICAL AND BIOLOGIC PROPERTIES**  
The Ti beta alloy presents a significantly lower elastic modulus compare with Ti-6Al-4V ELI, maintaining robust mechanical strength and high ductility. To reduce stress shielding, incorporating cellular structures in prosthetics is crucial. Auxetic and TPMS graded porous structures enhance mechanical and biological properties in femoral implants, ensuring continuous adhesion to bone. In quasi-static compression tests, auxetic structures exhibit elastic moduli ranging from 0.96 GPa to 0.08 GPa, while TPMS structures show values around 6 GPa. Compression-compression fatigue tests reveal TPMS's superior fatigue resistance. Ultimately, all cellular structures are non-toxic and support cell proliferation.
- 14.45** L. Tonelli (Università di Bologna)  
**CoCr ALLOYS FOR BIOMEDICAL APPLICATIONS**  
AM technologies can be proficiently applied to CoCr alloys for the manufacturing of tailored medical implants. In this view, the focus is driven to the understanding of the peculiar microstructure resulting from AM, along with its correlation to mechanical properties and process and post-process (e.g. heat treatment) condition.
- 15.30** Coffee break
- 16.00** M. Tocci (Università degli Studi di Brescia)  
**LATTICE STRUCTURES OF Ti AND CoCr ALLOYS**  
Lattice structures consist in the repetition of a unit cell following a specific pattern. The geometry of the unit cell is one the main elements that defines the type of lattice structure and can be used for their classification. Additive Manufacturing represents the most suitable technology to manufacture lattice structures due to their complex geometries. The main features and applications of lattice structures will be presented focusing on the use of Ti and Co-Cr alloys.

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### Tuesday, 2nd July 2024

**16.45** M. L. Gatto (Università Politecnica delle Marche)  
**STAINLESS STEELS BY LASER POWDER BED FUSION FOR TISSUE ENGINEERING APPLICATIONS**  
Among the AM processes, laser powder bed fusion (LPBF) technology is particularly suitable to produce graded lattice structures, designed to guide implant biomechanical response for bone tissue regeneration. The most cost-effective solution for short-term implants is 316L stainless steels (SS), widely used in the bone repair and replacement. Nevertheless, F53 duplex stainless steel is emerging as a promising alternative to austenitic SS, sensitive to localized corrosion in contact with body fluids. In this perspective, the focus is on programming the deformation behavior of 316L SS scaffold, by controlling the local relative density of unit cells, and developing a potential alternative to 316L SS for the manufacturing of temporary bone substitutes.

**20.00** Social dinner

### Wednesday, 3rd July 2024

**9.00** A. Ceruti (Università degli Studi di Bologna)  
**DESIGN FOR ADDITIVE MANUFACTURING: TRENDS AND OPPORTUNITIES**  
Taking advantage of the Additive Manufacturing processes which allow to manufacture complex geometries, in many cases technically unfeasible using conventional manufacturing methods, the lecture aims to introduce the basic concepts of the Design for Additive Manufacturing. In particular, Topology Optimization and Generative Design methods used in the design of custom-made advanced, lightweight structures will be presented.

**9.45** A. Pola (Università degli Studi di Brescia)  
**ADDITIVE MANUFACTURING OF Zn AND Zn ALLOYS**  
Zinc-based alloys have been emerging in recent years as interesting opportunities for the production of biodegradable parts. At the same time, additive manufacturing techniques represent promising production methods precisely for the manufacture of components for the biomedical sector. In this presentation, the latest developments in the field of 3D printing of parts made of Zn-based alloys will be shown, analysing their applications and performance for the biomedical as well as for the challenging fields.

**10.30** Coffee break

**11.00** P. Fanelli (Università della Tuscia)  
**AM OF METAMATERIALS FOR NUCLEAR APPLICATIONS**  
In fusion reactors, components exposed to burning plasma are subject to extreme conditions due to short and extremely strong thermal transients, which impact their lifetime and functional integrity. Extreme heat loads above may lead to excessive wall degradation by exceeding the limits of existing materials. W-lattice structures can contribute to these applications, since they can be optimized to have a thermal conductivity that ensures, at steady state, effective heat dissipation and, at the same time, a thermal diffusivity that, in transients, maximizes the vapour shielding effect. Parametric models and simulations that can lead to the identification of optimized configurations to maximize the functional effectiveness of these elements, which can be realized with a peculiar additive manufacturing process, are presented.

**11.45** Z. Zhao, M. Pellizzari (Università degli Studi di Trento)  
**MULTI-MATERIAL STRUCTURES DEPOSITED BY METAL ADDITIVE MANUFACTURING**  
Metal additive manufacturing (AM) has revolutionized traditional manufacturing processes by enabling the creation of complex structures with unprecedented design flexibility. One significant advancement in this field is the development of multi-material structures (MMSs), where different metal alloys or materials are selectively deposited within a single component. This breakthrough not only optimizes mechanical and thermal properties within printed objects but also opens doors to groundbreaking engineering designs. The speaker will provide a brief overview of the state of the art in multi-material structures within metal AM. Plus, dive into a case study on molding redesign.

**12.30** Final remarks and closure

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## 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](http://www.ceub.it)

### Registration information

The Summer School has a limited number of available places. Registrations will close **on June 7, 2024** 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 fees (par person)

#### AIM MEMBERS FEES

Single Room*	€ 580,00* (revenue stamp included)
Double Room*	€ 530,00* (revenue stamp included)
NO Room**	€ 415,00* (revenue stamp included)

**AIM JUNIOR MEMBERS** are required to pay the registration fee.

**NON MEMBERS** are required to subscribe AIM membership fee for the year 2024, before or at the same time of the registration to the summer school, as:

- Ordinary member (€ 70,00 revenue stamp included)
- Junior member (€ 15,00 revenue stamp included), if they are undergraduate or graduate students under 32 years of age and who are not employed. A valid proof of student status is required.

\* *SINGLE and DOUBLE ROOM registration fees include admittance to the Summer School, half board accommodation (breakfast and lunch), coffee breaks, welcome buffet on 30 June, aperitif on 1 July and social dinner on 2 July.*

\*\* *NO ROOM registration fee includes admittance to the Summer School, lunches, coffee breaks, welcome buffet on 30 June, aperitif on 1 July and social dinner on 2 July.*

### ACCOMPANYING PERSON

Double Room € 330,00 (22% VAT included)

*The fee includes half board accommodation in double room, welcome buffet on 30 June, aperitif on 1 July and social dinner on 2 July.*

### Payment and remittance

- by bank transfer, to the order of Associazione Italiana di Metallurgia - AIM at "CREDITO EMILIANO SpA", Branch no. 052 Milano - Via Andegari, 14 - 20121 Milano - Italy, account no. 010000480455 - cod. ABI 03032 - CAB 01600 - - cin M IBAN: IT33M0303201600010000480455, swift code BACRIT22MIL. The transfer order must specify the name of the participant and the reference "Summer School 2024". A copy of the transfer order must be sent to AIM, together with the Registration Form.
- by credit card online: [www.aimnet.it](http://www.aimnet.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 3 CTS.

### Language

The Summer School will be held in English.

### Cancellation and refund policy

A refund, less 20% deduction for administrative costs, will be issued for written cancellations received by June 7, 2024. For attendees who notify their cancellation after June 7, 2024 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.

## ORGANISING SECRETARIAT



**ASSOCIAZIONE  
ITALIANA DI  
METALLURGIA**

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## REGISTRATION FORM

Please use BLOCK letters throughout form

### Participant data

family name \_\_\_\_\_

first name \_\_\_\_\_

e-mail (correspondence) \_\_\_\_\_

telephone \_\_\_\_\_

mobile phone \_\_\_\_\_

dietary requirements (allergies, intolerance, particular diet, etc) \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

### Invoicing data

company name /university \_\_\_\_\_

fiscal address \_\_\_\_\_

town \_\_\_\_\_ zip code \_\_\_\_\_

VAT and fiscal code (if different) \_\_\_\_\_

Order ref. number (if requested on the invoice) \_\_\_\_\_

PEC (only for italian societies) \_\_\_\_\_

Codice destinatario (only for italian societies) \_\_\_\_\_

Date

\_\_\_\_\_

### Registration and payment

#### I will attend as

Attendee in Single Room € \_\_\_\_\_

Attendee in Double Room (per person) € \_\_\_\_\_

Attendee not needing accommodation € \_\_\_\_\_

Accompanying person (double room) € \_\_\_\_\_

TOTAL AMOUNT BEING PAID: € \_\_\_\_\_

name for sharing double room \_\_\_\_\_

NON MEMBERS are required to subscribe AIM membership fee for the year 2024

#### Payment

by bank transfer

by credit card online at [www.aimnet.it](http://www.aimnet.it)

Registration fee's payment must be made before the beginning of the school. Registration fees and data for payment are detailed in the general information above.

### Privacy information

By signing this registration form, I declare to have read and accepted the Privacy notice at the following page.

I, the undersigned, have read the Privacy notice at the following page and I accept that AIM processes my personal data in accordance with articles 13-14 of EU Regulation no. 679/2016 (GDPR).

#### Furthermore, I authorize AIM:

- to insert my name in the list of event participants: Yes  No

- to send any invitations to events of interest from other worldwide metallurgical associations: : Yes  No

**Complete and return to organising secretariat**

Signature (leggibile)

\_\_\_\_\_

# INFORMATIVA PRIVACY

## Pursuant to artt. 13-14 EU REG. n. 679/2016 (GDPR)

AIM, Associazione Italiana di Metallurgia (VAT number 00825780158), in person of the legal representative Silvano Panza (hereinafter the "Data Controller"), current in Milan, via Turati n. 8, informs you that, pursuant to art. 13 of the EU Regulation n. 2016/679 (hereinafter "GDPR"), your data will be processed in the manner and for the following purposes.

### 1. Personal Data.

The Data Controller processes personal identifying data (i.e.: name, surname, company name, address, telephone number, e-mail address, username, bank and payment details, hereinafter referred to as "Personal Data") that you have communicated on the occasion of the paper registration or through the website [www.aimnet.it](http://www.aimnet.it).

### 2. Purpose of the treatment.

Your data will be processed by the Data Controller for the following possible purposes:

- transmission of periodic communications by e-mail;
- invitation to activities and/or events promoted by the Data Controller;
- in case of registration on the website [www.aimnet.it](http://www.aimnet.it), registration on the site and creation of a user (username and password);
- in case of registration for events, inclusion in the list of participants at the event, receipt of invitations for relevant events from other worldwide metallurgical associations and invoicing of the fee for the participation at the event, if due;
- in case of association with AIM, sending of the membership card;
- in case of purchase of books or other material, delivery of the same and invoicing.

### 3. Processing methods.

The processing of your personal data is carried out by means of the operations indicated in art. 4 n. 2) GDPR and more precisely: collection, registration, organization, storage, consultation, processing, modification, selection, extraction, comparison, use, interconnection, blocking, communication, cancellation and destruction of data.

Your personal data are subjected to both paper and electronic processing. The Data Controller will process personal data for the time necessary to fulfill the aforementioned purposes and in any case for no more than 10 years from the termination of the relationship.

### 4. Access to the Data.

Your data may be made accessible, for the purposes referred to in art. 2, to the employees and collaborators of the Data Controller, in their capacity as persons in charge and/or internal managers of the processing and/or system administrators.

### 5. Data communication and data transfer abroad.

The Data Controller may communicate your name, nationality and e-mail address to foreign associations, exclusively in the case of participation in itinerant congress editions.

The aforementioned associations, operating in countries located in or outside the EU, may not provide adequate data protection safeguards (a complete list of countries providing adequate data protection safeguards is available on the EU Guarantor's website for the Protection of Personal Data). In such cases, the transfer of your data will be carried out in compliance with the applicable international rules and agreements, as well as with the adoption of appropriate measures (e.g. standard contractual clauses).

Personal data are stored on servers located in Milan (IT), within the European Union. In any case, it is understood that the Data Controller, if necessary, will have the right to move the servers even outside the EU. In this case, the Data Controller hereby ensures that the transfer of non-EU data will take place in accordance with the applicable legal provisions, subject to the stipulation of the standard contractual clauses provided by the European Commission.

### 6. Rights of the Data Subject.

In your capacity as a Data Subject, you have the rights set forth in art. 15 GDPR and, precisely, the rights of:

- to obtain confirmation of the existence or not of personal data concerning you, even if not yet registered, and their communication in an intelligible form;
- to obtain the indication: a) of the origin of personal data; b) of the purposes and methods of the processing; c) of the logic applied in case of treatment carried out with the aid of electronic instruments; d) of the identification details of the Data Controller, the data processors and the designated representative pursuant to art. 3, paragraph 1, GDPR; e) the subjects or categories of subjects to whom the personal data may be communicated or who may become aware of it in their capacity as designated representative in the territory of the State, managers or agents;
- to obtain: a) updating, rectification or, when interested, integration of data; b) the cancellation, transformation into anonymous form or blocking of data processed unlawfully, including data whose retention is unnecessary for the purposes for which the data were collected or subsequently processed; c) the attestation that the operations referred to in letters a) and b) have been brought to the attention, also as regards their content, of those to whom the data have been communicated or disseminated, except in the case where such fulfillment is it proves impossible or involves a use of means manifestly disproportionate to the protected right;
- to object, in whole or in part, for legitimate reasons to the processing of personal data concerning you, even if pertinent to the purpose of the collection.

Where applicable, it also has the rights referred to in articles 16-21 GDPR (right of rectification, right to be forgotten, right of limitation of treatment, right to data portability, right of opposition), as well as the right of complaint to the Guarantor Authority.

### 7. How to exercise rights.

You can exercise your rights at any time by sending: a registered letter to AIM, Italian Association for Metallurgy, via Turati n. 8, Milan or an e-mail to [aim@aimnet.it](mailto:aim@aimnet.it).

### 8. Data Controller and person in charge.

The Data Controller is AIM, Italian Association of Metallurgy, via Turati n. 8, Milan. The person in charge of data processing is Ms. Federica Bassani, via Turati n. 8, Milan - e-mail [aim@aimnet.it](mailto:aim@aimnet.it). The updated list of data processors is kept at the Data Controller's headquarters.