METAL ADDITIVE MANUFACTURING

WINTER SCHOOL

WINTER SCHOOL OF METALLURGY

26-29 January 2020, University of Trento

Organized by

ASSOCIAZIONE ITALIANA DI METALLURGIA

CoMET COORDINAMENTO DELLA RICERCA E DELLA DIDATTICA IN METALLURGIA

SCOPE

The Metallurgy Winter School on Additive Manufacturing organized by CoMET aims at providing a deep understanding of fundamentals of metal additive manufacturing, with a particular focus on the metallurgical aspects known to determine the performance of AM products.
After a brief overview of the various processes and metals for AM and an analysis of the market, the various aspects related to the quality of the powders, the types of alloys for AM and how to design dedicated ones will be explained. Subsequently, the different AM processes, microstructures, and possible defects will be treated, highlighting how they are created during AM processing. Additionally, the various heat and finishing treatments aimed at improving the performance of AM products will be presented.
Modeling and simulation of additive manufacturing will also be treated and the attendees will be invited to analyze case studies, with practical use of available software.
A visit to an AM facility will allow the participants to enter in the practical aspects of AM technology.
The school is addressed mainly to PhD students, but post-docs and master students are also welcome.

Director:
Prof. Annalisa Pola - University of Brescia

Scientific and Organising committee
Prof. Paolo Ferro - University of Padova
Prof. Alessandro Morri - University of Bologna
Prof. Massimo Pellizzari - University of Trento

Local organizing secretariat:
Dr. Vanessa Maria Caleca - University of Trento

PROGRAM

SUNDAY, 26 JANUARY 2020

18.00 Registration

19.00 Welcome Aperitif

20.30 Introduction to the Winter School
Annalisa Pola - University of Brescia

MONDAY, 27 JANUARY 2020

Powders and alloys for Additive Manufacturing

9.00 **Overview on metal Additive Manufacturing**
Annalisa Pola - University of Brescia

9.50 **Powders for Additive Manufacturing**
Valentina Vicario - Mimete

10.40 Coffee break

11.10 **Design of alloys for Additive Manufacturing**
Riccardo Casati - Polytechnic of Milan

12.30 Lunch

Microstructure and Defects

14.00 **AM processes and microstructures**
Alberto Molinari - University of Trento

15.30 **Effect of rapid solidification on microstructure**
Livio Battezzati - University of Turin

16.20 Coffee break

16.40 **Defects in metal AM components**
Maurizio Vedani - Polytechnic of Milan

18.00 Conclusions

20.00 Dinner

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PROGRAM

TUESDAY, 28 JANUARY 2020

Heat and Post Treatments

8.20 Transfer from Trento to Rovereto

9.00 **Heat treatment of AM components and alloys**
Massimo Pellizzari - University of Trento

10.30 Coffee break

10.50 **Hot Isostatic Pressing and Surface finishing of AM components**
Daniele Ugues - Polytechnic of Turin

12.30 Lunch

14.30 **Visit to ProM Facility**
Paolo Bosetti - University of Trento

17.00 Conclusions

20.00 Social Dinner

WEDNESDAY, 29 JANUARY 2020

Additive Manufacturing Simulation

9.00 **Modelling of additive manufacturing processes**
Paolo Ferro - University of Padova

9.40 **Simulation of residual stress in metal AM**
Paolo Ferro - University of Padova

10.20 Coffee break

10.40 **Working groups on simulation software**
Diego Boscolo - Enginsoft

12.40 Lunch

13.40 **Working groups on simulation software**

17.30 Conclusions & Ceremony

Organising Secretariat

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DETAILED DESCRIPTION OF TOPICS

Powders and alloys for Additive Manufacturing

Overview on metal Additive Manufacturing

Annalisa Pola - University of Brescia, Department of Mechanical and Industrial Engineering

Abstract: Metal Additive Manufacturing is developing at rates that surpassed the original outlook, increasing the interest of scientific research centers and universities as well as industries. Its continue growth shows the opportunity of using this new technology to replace, enhance or represent an alternative to traditional metal parts production and repair.

The aim of this lecture is to present a brief review of the various additive manufacturing processes and applications, showing the evolution of the technology and products, the market trends and the advantages when compared to conventional manufacturing methods. Research and development priorities will be also discussed with a particular focus on alloys and products properties.

Powders for Additive Manufacturing

Valentina Vicario - Mimete

Abstract: Metal powders are the feedstock of many additive manufacturing processes. Their properties are fundamental for obtaining components without defects such as porosity, lack of fusion and adequate surface finish. This contribution will illustrate the main properties of metal powders and the techniques for their characterization.

Design of alloys for Additive Manufacturing

Riccardo Casati - Polytechnic of Milan, Department of Mechanical Engineering

Abstract: Although Laser Powder Bed Fusion (L-PBF) is spreading in several industrial fields and there is a high demand for a wide range of materials with different properties from industries, only few alloys for L-PBF are currently available on the market. Indeed, most of standard grades are not able to withstand the particular processing conditions offered by beam-based additive manufacturing processes, without forming solidification cracks or large defects. The lecture will be focused on the definition of guidelines for the design of a new generation of alloys for additive manufacturing, and a few case studies regarding the design of novel Al alloys for L-PBF will be shown and discussed.

Microstructure and Defects

AM processes and microstructures

Alberto Molinari - University of Trento, Department of Industrial Engineering

Abstract: The main Additive Manufacturing processes using metallic powders (Direct Energy Deposition, Powder Bed Fusion, Binder Jetting) are described, with emphasis on the microstructure of the different materials and its structural stability, the formation of defects, the need for any secondary treatments to improve the final properties.

Effect of rapid solidification on microstructure

Livio Battezzati - University of Turin

Abstract: Rapid solidification (or rapid quenching of the liquid) has the effect of accelerating and modifying the processes that give rise to the formation of the solid phases: heat removal, nucleation frequency, stabilization of non-equilibrium phases, dendritic, columnar, equiaxed and banded growth. Experiments and models for these processes have been reported in the last two decades of the last century and are now applied to microstructures obtained with additive manufacturing technologies in which thin alloy layers are laser or electron beam melted and rapidly solidified by the substrate.

Defects in metal AM components

Maurizio Vedani - Polytechnic of Milan, Department of Mechanical Engineering

Abstract: Metal additive manufacturing processes, such as Laser powder bed fusion and direct energy deposition are able to create 3D objects with complex shapes and high strength.

Their integrity (under static, fatigue or creep loads) depends on the ability to control the process and to select the alloy in order to limit as much as possible the occurrence of defects.

The contribution is aimed at discussing the physical mechanisms that lead to solidification and formation of 3D AM parts and at highlighting possible microstructural imperfections generated. A discussion on required material properties is also proposed, in order to identify guidelines for the development of specific alloys for AM.

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DETAILED DESCRIPTION OF TOPICS

Heat and post treatments

Heat treatment of AM components and alloys

Massimo Pellizzari - University of Trento, Department of Industrial Engineering

Abstract: The products obtained through additive manufacturing processes almost always require heat treatments. At best, a stress relieving treatment at a relatively low temperature is required to reduce the residual stress state caused by thermal gradients induced by the non-uniform heating/cooling of the component. In most cases, the heat treatment allows obtaining the microstructural characteristics and in-service properties required by the material. Unlike products obtained with traditional manufacturing processes, those produced by additive manufacturing generally require different parameters.

Hot Isostatic pressing and Surface finishing of AM components

Daniele Ugues - Polytechnic of Turin, Department of Applied Science and Technology

Abstract: Additive Manufacturing (AM) components are attracting an increasing interest in small series production of complex and small to medium size components. Clear benefits of such technologies are the widening of design possibility, the reduction of the number of assembled parts and of their weights, the improvement of microstructural features, etc. On the other hand some limitations have to mentioned, such as the residual porosity and the surface finishing. As for porosity, hot isostatic pressing (HIP) is frequently applied as post process. This enhances the mechanical properties and partially or totally increase the integrity even of complex parts. Nevertheless, traditional HIP systems have slow cooling steps, that impose a further step of heat treatment (HT) to recover the microstructural features. Nowadays, technological advances allowed for the use of rapid cooling directly in the HIP chamber, providing the possibility to combine HIP and HT steps. As for the surface finishing aspects, the high complexity of AM parts as well as the free design concepts, causes several difficulties in accessing to blind or partially covered surfaces with the traditional surface finishing practices. For this reason specific techniques have to be designed or adapted to such components. These are the topics addressed by this presentation.

Additive manufacturing simulation

Modelling of additive manufacturing processes & Simulation of residual stress in metal AM

Paolo Ferro - University of Padova, Department of Management and Engineering

Diego Boscolo - Enginsoft

Abstract: The increasing interest in additively-manufactured metallic parts from industry has issued a formidable challenge to the academic and scientific world that is asked to design new alloys, optimize process parameters and geometry, and guarantee the reliability of the new load-bearing components. Unfortunately, understanding the interaction between different phenomena associated to metal-AM processes is a very difficult task. In this scenario, numerical and analytical modeling emerges as a valid technique for better understanding the influence of process parameters on metallurgical and mechanical properties of additively-manufactured components. The contribution is aimed at summarizing the most recent advances in AM process simulation with particular reference to powder bed fusion techniques. Thermal, metallurgical as well as mechanical aspects will be covered. A case-study will be faced and the fundamentals of additive manufacturing numerical simulation will be explained in details. Finally, participants will have the chance to practice with a commercial numerical code.