Session on

Digital Twin Additive Manufacturing (AM)

Wednesday, October 16th 2024
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Milan Time	Beijing Time	Agendas
15:00	21:00	**AM-1 Service oriented digital twin for additive manufacturing process** Yunlong TANG
15:30	21:30	**AM-2 Deep Learning Empowered Additive Manufacturing Online Monitoring and Control** Zhibin ZHAO
16:00	22:00	**AM-3 Digital Twin-driven On-line Monitoring Method of Laser Powder Bed Fusion Process** Xianyin DUAN
16:30	22:30	**AM-4 Building Digital Twins for Additive Manufacturing Processes: from Macro to Micro Scale** Yi CAI
17:00	23:00	**AM-5 A digital twin framework for melt pool monitoring of LPBF using machine learning with high-speed coaxial imaging and simulation data** Yingjie ZHANG
17:30	23:30	**AM-6 A digital twin for track's morphology prediction by combining melt pool simulations with in-situ monitoring in metal additive manufacturing** Xin LIN

Digital Twin Additive Manufacturing (AM)

Chair

Kunpeng ZHU
Professor
Hefei Institutes of Physical Science, Chinese Academy of Sciences
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Co-Chair

Xin LIN
Professor
Wuhan university of science and technology (China)

Digital Twin Additive Manufacturing (AM-1)

Yunlong TANG

Lecturer,

Monash University (Australia)

Title:

Service oriented digital twin for additive manufacturing process

Abstract

Currently, Industry 4.0 is rapidly developing, empowered by IoT, cloud computing and AI. As two crucial components of Industry 4.0, digital twins and additive manufacturing (AM) are attracting increasing attention. Despite considerable research in recent years on developing digital twins for AM, the field still faces discrepancies in definition and confusion in development processes, making the development of AM digital twins expensive. The reason behind this is the uniqueness of each AM process, leading to low adaptability in AM digital twins. To address this issue, this talk summarises AM digital twins found in the literature review and proposes a novel, service-oriented framework comprising four layers: service, model, data, and interface. This framework aims to enhance the reusability of developed AM digital twins across various levels. The commonly used components in each layer are also summarised to assist developers in rapidly constructing AM digital twins tailored to their specific needs. A case study is included to demonstrate the framework's effectiveness and potential.

Digital Twin Additive Manufacturing (AM-2)

Zhibin ZHAO

Associate Professor,

Xi'an Jiaotong University (China)

Title:

Deep Learning Empowered Additive Manufacturing Online Monitoring and Control

Abstract

Although Deep Learning (DL) has shown great potential in the online monitoring and control of AM, the complexity of multi-physical field coupling and process flexibility in the AM process lacks a mature monitoring and control framework. To overcome these challenges, we propose a vision-based online monitoring and quality evaluation system for AM, as well as corresponding multi-parameter control strategies. This system innovatively integrates the following key technologies. First, a privacy-protected federated transfer learning framework is used to ensure data privacy while achieving effective knowledge transfer. Second, a multi-task collaborative online quality evaluation method is developed to improve the accuracy of the evaluation. Third, lightweight model via reparameterization is proposed to meet the real-time requirements of online monitoring. In addition, the system utilizes DL to achieve accurate prediction of the process parameters, and then combined with transfer learning technology, the system can effectively transfer the learned knowledge to new process parameter adjustments, significantly improving the quality stability of additive manufacturing by adjusting multiple key parameters online. Finally, we demonstrate the effectiveness and application potential of the proposed method through practical cases, including online monitoring and control of Laser Powder Bed Fusion (LPBF) powder spreading and Fused Deposition Modeling (FDM) systems, providing new perspectives and solutions for the further development of AM.

Digital Twin Additive Manufacturing (AM-3)

Xianyin DUAN

Associate Professor,
Wuhan University of Science and Technology (China)

Title:
Digital Twin-driven On-line Monitoring Method of Laser Powder Bed Fusion Process

Abstract

The field of laser powder bed fusion (LPBF) of metals is advancing towards greater precision, efficiency, and intelligence. However, the extreme thermal conditions of the laser melting process have led to persistent quality defects in the fabricated parts, limiting the widespread application of LPBF technology. To address these challenges and produce high-quality parts, it is crucial to implement on-line monitoring and process control during manufacturing. This talk describes a digital twin-driven on-line monitoring method for the metal LPBF process. This method aims to establish an intelligent manufacturing system and perform case analysis. By integrating physical and virtual models of the powder melting process, on-line process monitoring, and big data analysis, a comprehensive digital twin system for the on-line monitoring of the building process is developed. This system encompasses the equipment layer, data conversion layer, network layer, control layer, and application layer. The talk details the functions and key technologies of each layer and provides analysis of typical application examples in selective laser melting (SLM) process monitoring. This approach offers theoretical and technical support for the intelligent manufacturing based on LPBF technology.

Digital Twin Additive Manufacturing (AM-4)

Yi CAI

Associate Professor,
The Hong Kong University of Science and Technology (China)

Title:
Building Digital Twins for Additive Manufacturing Processes: from Macro to Micro Scale

Abstract

This presentation covers two representative projects of building digital twins for different additive manufacturing processes. The first project is focused on macro-scale additive manufacturing using multi-robot collaboration. A virtual manufacturing system is developed where different configurations of multiple robots can be created and simulated for concurrent deposition. A method based on augmented reality is developed to connect physical robots and virtual robots so that simulation scenarios can be automatically established, and simulation results can be efficiently implemented. The second project is developed upon micro-scale inkjet-based additive manufacturing process. Based on in-situ video data, a tri-level digital twin framework is established for inkjet-based additive manufacturing. Inspection and closed-loop control are implemented to ink droplets, printed patterns, and final product, respectively.

Digital Twin Additive Manufacturing (AM-5)

Yuxin ZHANG

Associate Professor,
South China University of Technology (China)

Title:

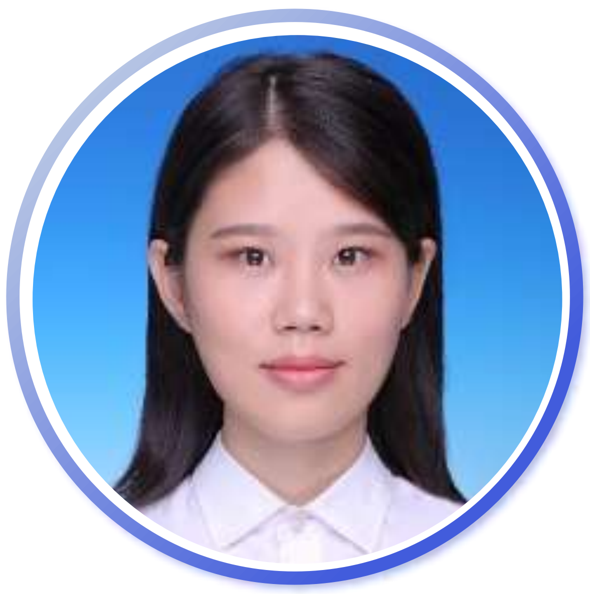
A digital twin framework for melt pool monitoring of LPBF using machine learning with high-speed coaxial imaging and simulation data

Abstract

Digital twin technology is crucial for advancing intelligent manufacturing by ensuring product quality, reducing costs, and enhancing efficiency. In Laser Powder Bed Fusion (LPBF), Digital Twin technology provides a robust solution for predicting part characteristics, diagnosing defects, and controlling processes. This study introduces a sensor and simulation combined digital twin (SSC-DT) framework that monitors molten pool characteristics—such as width, depth, and mean temperature—by integrating in-situ sensor data with physical simulation data.

Experimental results show that the SSC-DT framework achieves a mean relative error of less than 10% compared to optical microscope (OM) measurements. Notably, the predicted molten pool depth error from SSC-DT is lower than those calculated by the Eagar-Tsai model, keyhole empirical model, and finite element method (FEM). Consequently, SSC-DT predictions closely align with actual sensor data under conduction and slight keyhole modes of the molten pool, supporting intelligent control, predictive maintenance, and quality assurance in future LPBF processes.

Digital Twin Additive Manufacturing (AM-6)



Xin LIN

Professor,
Wuhan university of science and technology (China)

Title:

A digital twin for track's morphology prediction by combining melt pool simulations with in-situ monitoring in metal additive manufacturing

Abstract

Although many works have created so-called 'digital twins' for Laser Powder Bed Fusion (LPBF) that track changes during processing in response to in-situ monitoring data, these predictions cannot satisfy online control requirements due to the uncertainty of the model and data, as well as the absence of bidirectional communication between the digital and physical twins. We propose a digital twin (DT) framework that integrates in-situ monitoring data and simulation to predict real-time imperfections of the as-built track. The graph convolutional network (GCN) is proposed to predict the as-built track's morphology based on images collected by a CMOS camera. Simulation is utilized to imitate a series of physical phenomena such as melting, solidification, evaporation, and track morphology via a coupled Computational Fluid Dynamics-Discrete Element Method (CFD-DEM) approach. Furthermore, a Bayesian probability method is proposed to estimate simulation model parameters and the track' s imperfections. This approach aims to address the problem of unmeasured state variable values and uncertainty in digital simulation models, subsequently bidirectionally correcting the parameters of both the simulation and prediction models based on in-situ monitoring data. Ultimately, the goal is to achieve online defect prediction, process adjustment, and minimization of imperfections.