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Applying Artificial Intelligence in Directed Energy Deposition Additive Manufacturing of Metal Matrix Composites: Lessons and Experiences for Industrial Implementation

Mutahar Safdar[1,2], Gentry Wood[3], Max Zimmermann[4], Florian Hannesen[5], Padma Paul[6], Guy Lamouche[2], Priti Wanjara[2], Yaoyao Fiona Zhao[1*]
[1]Department of Mechanical Engineering, McGill University, Montreal, Quebec, H3A 0C3 Canada
[2]National Research Council Canada, Montreal, Quebec, H3T 1J4 Canada
[3]Apollo-Clad Laser Cladding, a division of Apollo Machine and Welding Ltd., Edmonton, Alberta, T6E 5V2 Canada
[4]Fraunhofer Institute for Laser Technology, Aachen, 52074 Germany
[5]BCT Steuerungs, und DV-Systeme GmbH, Dortmund 44263, Germany
[6]Braintoy AI, Calgary, AB T3P 0B9, Canada
*yaoyao.zhao@mcgill.ca

Abstract

Additive manufacturing technologies are prone to issues of process repeatability and part quality. Artificial intelligence offers significant potential to address these quality concerns. Machine learning techniques are increasingly leveraged to support additive manufacturing process development and industrial applications. This study focuses on a real-world industrial project that applied artificial intelligence to support directed energy deposition additive manufacturing of metal matrix composites. The project timeline is divided into major development phases based on the application domain (manufacturing) and digital technology (artificial intelligence). Challenges and insights encountered during the development process are grouped into ten unique themes: five manufacturing themes and five artificial intelligence themes. These include minimizing the knowledge gap (domain understanding, artificial intelligence potential), identifying candidate concerns (application scope, relevant machine learning models), developing data and modeling workflows (data quality, data quantity, model complexity, development resources), deploying models in production (integration, validation), and maintaining artificial intelligence integration with manufacturing systems (continuous update and adaptation). These themes collectively underscore the importance of interdisciplinary collaboration to address the multifaceted challenges of integrating artificial intelligence with advanced manufacturing processes. In this context, the presentation highlights in-situ defect detection through vision-based deep learning models applied to thermal imaging as a case study to explore these challenges and insights. By leveraging real-time data from thermal cameras, the project demonstrates the potential of artificial intelligence to enhance process monitoring and defect detection in directed energy deposition additive manufacturing. This approach exemplifies how in-process data can contribute to expedited development, offering the potential to improve process repeatability, while lowering the need for post-process evaluations. The objective of this work is to support the effective and realistic implementation of artificial intelligence in additive manufacturing projects, while identifying potential research directions at the intersection of these domains. The findings aim to guide the additive manufacturing industry in addressing critical considerations for industrial implementation of artificial intelligence and future advancements.