Preface

Additive manufacturing also referred as 3D printing has come forth as a transformative approach in industrial production for the creation of lighter, more potent and flexible components. In the past few years, metal additive manufacturing technologies have revolutionized the manufacturing industry due to its potential to produce complex geometries with special connections in contrast to the traditional production techniques. In particular, components that are multi-functional can be modelled to provide solutions to structural, protective engineering and insulation problems at the same time. Expiration of earlier patents on 3D printing technologies, cost reduction of 3D printers, continuous encouragement from the government and the flexibility in mass manufacturing of customized parts are key factors in driving the AM industry so fast. A recent survey by Wohlers Associates indicates about 50% of 3D printing will evolve around the manufacturing of commercial products in 2020 and an increase of the AM market to 2% in the world manufacturing economy of 12 trillion US dollars in the year 2030. (Ngo et al., 2018)

The demand for AM technologies in aerospace, automotive and medical fields is due to limitations of traditional processes such as long lead time, lack of flexibility and expensive tooling.(Culmone et al., 2019; Fasel et al., 2020; Gisario et al., 2019; Ngo et al., 2018) Among various AM technologies for producing metal parts, processes such as powder bed fusion (PBF) and direct energy depositions (DED) techniques are finding their place in industrial applications (Adeyemi et al., 2018). High-quality metal powder and wire feedstock are critical to the successful building of parts in AM. A number of new and dissimilar metals in powdered form to suit exact process requirements that are included in library of materials are aluminium, steel, copper, titanium, stainless steel and copper, cobalt chrome, nickel and titanium-based alloys in addition to precious metals like platinum, amber, silver and palladium. A broad range of wire feedstock options is also available like those of steel and stainless-steel alloys as well as pure metals like aluminium, niobium, titanium, molybdenum and tungsten are available as wire feedstock (Ngo et al., 2018).

Due to the emergence of additive manufacturing, designers were able to come up with complicated design like never before and manufacturers were able to produce components at ease. Additive manufacturing is desirable when the variation in production is high and design tends to be more complicated like those of aerospace and naval application. Additive techniques render huge benefits in case of new invention where it calls for a deal of money due to the need of preparation of moulds in case of traditional procedures, therefore enabling the producers to be amply competent in the securities industry. Based on the place of usage the additive techniques like those of Selective Laser Melting/ Selective Laser Sintering (SLM/SLS), binder jetting, Direct Metal Deposition (DMD), wire arc additive manufacturing (WAAM), powder based and wire -based Direct Energy Deposition (DED), Laser Engineering Net Shaping (LENS) and Laser Metal Deposition (LMD) are used. (Azarniya et al., 2019; Froes & Dutta, 2014)

Composite materials have been used widely due to their inheriting superior mechanical strength and high performance in various applications. Metal matrix composites offer production of light weight component which make them as a better alternative to their metal counterparts. Application of AM techniques that are used for the production of metals with minor modification make them suitable for producing composites; some commonly used techniques are Selective Laser Melting/ Selective Laser Sintering (SLM/SLS), powder based and wire -based Direct Energy Deposition (DED), Laser Metal Deposition (LMD), Direct Metal Deposition (DMD), Laser Engineering Net Shaping (LENS), Plasma Deposition Manufacturing (PDM), and sheet lamination (Fasel et al., 2020; Froes & Dutta, 2014; Kirka et al., 2018)

Though parts can be produced in AM in various sizes from micro and macro scale, constraints on anisotropic behaviour, residual stress built in and its associated residual stress, post processing required for altering microstructure and poor fatigue life are challenged in the field (Liu et al., 2018; Munford et al., 2020). This book will bea unique guide to additive manufacturing/ three-dimensional (3D) printing of metals and composites. Examining a range of manufacturing technologies and their capability to manufacture both functional live scale products as wells as prototypes, the chapters that are discussed in the book address metal components and explore some of the main research issues associated with the use of these technologies. The newer technologies that are currently under development are also explored here. The book also presents unique real-life case studies from industry, the contents specified here offers the perspective of engineers who are associated in the fields of aerospace and transportation systems; it is also intent to help engineers to design components and manufacturing networks. Written by the leading university and industry experts, the book is aimed at providing a comprehensive insight for students and practitioners in the field.

The book consists of 14 chapters formulated by experts and the following sections briefly outline various chapters enclosed in the book.

Chapter 1 represents an introduction to metal AM techniques and its benefits in the fabrication process over conventional methods. It also explains about the conventional CNC and AM processes which are detailed. Chapter 2 throws light o nthree AM processes, namely, Powder Bed Fusion (PBF), Electron Beam Melting (EBM), Binder Jetting (BJ) which are majorly used for commercial purposes and their advantage and disadvantages are also detailed. The contents also explain about the role of 3D printing in future manufacturing industries.

Chapter 3 discusses briefly about the advancements in additive manufacturing of Ni-based superalloys which are used in aero-engines. The influence of pre-alloyed powder, process parameters, and scanning strategy on the microstructure and mechanical properties in as-built condition are also explained. Chapter 4 summarises the process-structure-property relationships in laser powder-bed fusion of Invar 36. The process parameters for L-PBF of Invar 36 to obtain optimum properties were also detailed. Chapter 5 details the fundamental concepts of the three arc welding technologies, namely metal arc, tungsten arc and plasma arc welding methods which are explained in detail, the chapter also provides information about the various modifications that can be introduced into these methods to create their capabilities as additive manufacturing processes.

Chapter 6 elucidates the production of complex shapes using WAAM technique. The technique of WAAM automation and modelling advancements has known to improve the process penetration into the market for producing a wide range of products. It also deciphers the reason why CMT has become a popular heat source for WAAM processes, which is followed by Chapter7 that expounds the development of products with multi-material and composite structures using different additive manufacturing techniques. The mechanical, metallurgical and functional properties enhanced through various AM processes are discussed in brief with their results. The chapter also details the benefits of functionally graded materials developed through hybrid AM process rather than the existing additive manufacturing systems. Chapter 8 briefs about the Direct Laser Fabrication (DLF) which provides benefits to the healthcare sector for the development towards the creation of high-quality prosthetic devices/implants. This technique can be used to repair/remanufacture damaged components within an assembly such as tool/dies and turbine blades and thus avoiding the necessity of the fabrication of new components. The future perspectives of DLF as a tool for the fabrication of high-quality, high-end components, including the development of efficient laser sources, improved powder utilization during the deposition process, the design of flexible/protective process chambers for DLF platforms and effective powder recycling strategies to reduce the environmental impacts of the process are detailed. Chapter 9 discusses the current status of the AM process simulation software, and the AM process simulation. It also states that the AM process simulation must be performed when the shape of the stacked output is large and complex. The chapter ends with a marvellous postulation claiming that despite the promising results reported, one must keep in mind the key challenges in additive manufacturing technology. The topology optimization and cutting-edge AM simulation technologies is presented in Chapter 10. Applications in these two directions were cited with case study examples. Despite the promising results reported, one must keep in mind of the key challenges in additive manufacturing technology. Chapter 11 describes about a compensation that can minimize deformation and predict the deformation due to high thermal source (Laser) in manufacturing cranial implants with a 3D printer. Chapter 12 focuses on the importance of multiscale modelling in AM processes. It states that using phase field and atomistic modelling, simulations are performed to understand the necking behaviour of AlSi10Mg in one of the AM processes (DMLS). The chapter ends by giving out a few areas where additional scope of research is required proceeded by Chapter 13 that briefs on PBF technology, which brings to light about the fact that it is important to note that due to the inherent nature of the processes, additive manufacturing may lead to new process and supply chains as well as new manufacturability problems related to high residual stresses and leading deformations, inferior surface quality and dimensional accuracy in contrast to machining, anisotropic material properties, etc. Chapter 14 compiles the evolution and global status of LAM technology, highlighting its advantages and freedoms for various industrial applications. It discusses how LAM is contributing to Industry 4.0 for the fabrication of tailored parts for engineering and prosthetic applications through case studies. It compiles research, development and deployment scenarios of this new technology in developing economies along with the future scope of the technology.

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