A survey of additive manufacturing reviews

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Abstract

Nowadays, additive manufacturing (AM) technologies have been widely used in construction, medical, military, aerospace, fashion, etc. The advantages of AM (e.g., more design freedom, no restriction on the complexity of parts, and rapid prototyping) have attracted a growing number of researchers. Increasing number of papers are published each year. Until now, thousands of review papers have already been published in the field of AM. It is, therefore, perhaps timely to perform a survey on AM review papers so as to provide an overview and guidance for readers to choose their interested reviews on some specific topics. This survey gives detailed analysis on these reviews, divides these reviews into different groups based on the AM techniques and materials used, highlights some important reviews in this area, and provides some discussions and insights.

Keywords: Additive manufacturing; 3D printing; Review

1. Introduction

Thirty years into its development, additive manufacturing (AM, also known as 3D printing) has become a mainstream manufacturing process. AM fabricates parts by adding materials layer-by-layer directly based on a 3D model. It is able to manufacture complex parts and allows more freedom of design optimization compared with traditional manufacturing techniques. According to ISO/ASTM, AM can be divided into seven groups: vat photopolymerization, material jetting, binder jetting, powder bed fusion, material extrusion, directed energy deposition, and sheet lamination. AM has its distinctive advantages over conventional manufacturing processes, for example, reduced product development time, lower cost, and ability to fabricate almost any complex shape. Therefore, AM has now been widely used in construction, medical, military, aerospace, fashion, etc. Until now, thousands of review papers have already been published in the field of AM, let alone the published research papers in this field. Figure 1 shows the number of published review papers in AM in each year. As can be seen, there are too many AM review papers published in recent years, with huge increasing rate. It is, therefore, perhaps timely to conduct a survey on AM review papers so as to provide an overview and guidance for readers to choose their interested reviews on some specific topics. This survey gives detailed analysis on these reviews, divides these reviews into different groups, and highlights some important reviews in this area along with discussions.
2. Additive manufacturing technologies

This section gives a brief introduction on AM technologies. According to ISO/ASTM[2], AM can be divided into seven categories: (i) Material extrusion, (ii) powder bed fusion, (iii) material jetting, (iv) binder jetting, (v) directed energy deposition, (vi) vat photopolymerization, and (vii) sheet lamination. Each AM technique will be introduced briefly before going into the review papers published in this area.

2.1. Material extrusion

Material extrusion is an AM process that selectively distributes material through nozzles or orifices[3,4]. In 1988, Scott Crump, co-founder of Stratasys Ltd., developed the AM process, which forms a layer by mechanically extruding molten thermoplastic materials (e.g., acrylonitrile butadiene styrene (ABS) and polyactic acid (PLA)) onto the substrate[8]. This AM process was subsequently coined as fused deposition modeling (FDM), which requires a high operating temperature to melt the material[9]. The manufacturing process of FDM starts from a 3D model, which is then translated into gcode data that can be read by FDM machines. After the data is sent to the machine, the machine can manufacture parts in a point-by-point and then layer-by-layer manner, from the bottom of the part to the top, until the whole part is completed. The material (filament) is first melted in the liquefier/extrusion head and then deposited carefully through a nozzle to platform of the printer. The extrusion head moves along the X and Y axes, while the construction platform operates up and down on the Z axis. At present, a lot of materials have been developed for material extrusion AM, including acrylonitrile-butadiene-styrene (ABS), nylon, high impact polystyrene (HIPS), polyethylene terephthalate (PET), polyactic acid (PLA), polyethylene terephthalate glycol (PETG), polyether ether ketone (PEEK), and thermoplastic polyester (TPC). In general, support removal and post-processing may be needed after fabrication[10].

2.2. Powder bed fusion

Powder bed fusion is another AM process. Typically, powder bed fusion selectively melts the powder in the tank using an energy beam (laser or electron)[10]. After scanning and finishing one layer of powder, the rolling mechanism helps spread the next layer of the powder. Then, the next layer is scanned, melted, and fused, until the entire part is completed. In the mid-1980s, Deckard and Beaman developed the polymer powder bed fusion technology, which is used to process polymer powders[11]. Now, more materials can also be used in this technology, such as ceramics or metals[12,13]. Selective laser melting (SLM)[14,15], selective laser sintering (SLS)[16], direct metal laser sintering (DMLS)[17,18], and electron beam melting (EBM)[19] are among the most popular metal powder bed fusion technologies. DMLS and SLM use focused laser beams as power sources[20-22], while EBM uses scanning electron beams (up to 60 kV) as the power source[23]. The actual printing process is completed in a vacuum or inert environment to avoid powder oxidation.

2.3. Material jetting

Material jetting is similar to inkjet printing. Inkjet printing deposits ink droplets onto a substrate drop by drop, while material jetting process directly deposits wax and/or photopolymer droplets onto the substrate by on-demand inkjet[24,25]. Light curing or heating is the driving force of the phase change of the sprayed droplets. A lot of research has been carried out on material jetting, including direct ink jetting of nanoink suspensions of ceramics[26,27], semiconductor[28], and metals[29].

2.4. Binder jetting

In binder jetting, a liquid polymer is selectively deposited onto a bed of powder[30]. The jetted polymer droplet infiltrates the powder surface, leading to a printed powder agglomerate primitive. Powder spreading promotes recoating, as is done in powder bed fusion processes. The finished parts are composed of bound powder, which requires infiltration through post-processing to gain enough strength. Any powdered material that can be successfully spread and wet by the jetted binder can be used in this technique. Different materials have been studied using this technique, for example, foundry sand[31,32], metal[32], polymer materials[33], and ceramic[34]. The binding mechanism of this technique is chemical and/or thermal reaction bonding. Depending on the bonding agent, chemical reaction is generally the source of activation. After completing the fabrication, post-processing may be necessary, including removal of loose powder and impregnation/infiltiration of
suitable liquid material depending on the powder material and intended application.

2.5. Directed energy deposition
In directed energy deposition (DED), metallic powder or wire is fed directly into the focal point of an energy beam to create a molten pool[30]. Laser Engineered Net Shaping (LENS), belonging to DED, was first developed at Sandia National Laboratories in 1995 and commercialized by Optomec[36]. Parts printed by LENS accommodate graded multi-materials[37] and allow microstructures with complex inner features[18]. DED systems with wire-fed methods have been achieved[39], and DED of powder directly has also been successful[40,41]. Lasers and electron beams are the most commonly used energy source.

2.6. Vat photopolymerization
The definition of Vat photopolymerization is an “additive manufacturing process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization”[32]. Vat photopolymerization uses a (liquid) photopolymer resin which is able to cure (solidify) under a light source[42,43]. Stereolithography (SLA) and digital light processing (DLP) are the most used techniques which belong to Vat photopolymerization. The scanning speed of vat photopolymerization is relatively high and minimum layer thickness is adjustable depending on the curing depth[44]. Once finishing the printing, post-processing may be needed, for example, support material removal and/or post-curing by further UV exposure.

2.7. Sheet lamination
Sheet lamination is an AM process in which sheets of material are bonded to form a part[45]. The process works by scrubbing each layer together with pressure and/or binders continuously. In this technique, the raw material typically is paper, metal foil, polymers or composite sheets predominately formed of metal, or ceramic powder material. Thermal reaction, chemical reaction bonding, or ultrasound can be used for binding. The source of activation includes localized or large-scale heating, chemical reaction, and ultrasonic transducers.

3. Analysis and discussion of AM review papers
This section gives the detailed analysis of review papers published within the field of AM. Top authors, source journals, affiliations of authors, and countries, are discussed. Then, the review papers are analyzed and discussed based on their different focuses, for example, different AM techniques (as briefly introduced in the previous section) and materials used. The database used is Scopus. Scopus is one of the most used databases, and it includes more papers than the Web of science.

3.1. Top 10 authors
As shown in Figure 2, Ramakrishna Seeram from National University of Singapore has the most review papers (21) published within AM field, followed by Chua Chee Kai from Singapore University of Technology and Design, and Yeong Wai Yee from Nanyang Technological University. It is interesting that all the top three authors are from Singapore. Researchers may refer their publications to catch up the up-to-date research in the AM field.

3.2. Top ten journals
Looking at the sources of these review papers (Figure 3), most of these AM review papers are published in journal Additive Manufacturing, followed by Materials and International Journal of Advanced Manufacturing Technology. Researchers may check these journals’ websites to see the state-of-the-art developments of AM technologies.

3.3. Top 10 affiliations
As shown in Figure 4, most of the review papers in additive manufacturing are from Nanyang Technological University, followed by Singapore Centre for 3D Printing.

3.4. Top ten countries
Looking at the countries of the authors from, United States has the most review papers in AM, with 756 review papers published, followed by China with 617 publications (Figure 5).

3.5. Review papers in the seven AM techniques
Dividing these review papers into the seven AM techniques as introduced in section 2, it can be found that most review papers are about powder bed fusion, and no review paper is found in sheet lamination (Figure 6). This is probably because powder bed fusion is the most focused research area within AM, due to its application potential in aerospace, engineering, and biomedicine. While, sheet lamination seems a little bit out of focus at this moment. Note that, the review papers collected in this subsection only consider the broad review in these seven AM techniques, excluding the review papers focused on a specific topic (e.g., process parameters’ influence, fatigue analysis, and path planning). For the broad reviews in these seven AM techniques, the most cited papers are listed in Table 1. Readers can check these papers based on their interests. Table 2 gives more review papers focusing on the specific topics in each AM technique. For example, Nohut and Schwentenwein[46] focuses on functionally graded materials in vat photopolymerization, while Xu et al.[47] focuses on drug
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delivery and medical device in Vat photopolymerization. In terms of powder bed fusion, Luo and Zhao [48] focuses on thermal stress, while McCann et al. [49] focuses on process monitoring and machine control. More details on the topics these review papers focus on are shown in Table 2.

3.6. Review paper categories based on materials
From the point view of materials, there are also various review papers in additive manufacturing focusing on different materials. In this survey, the materials are categorized into ten groups, including metal, ceramic, polymer, biomaterial, concrete, fiber, food, smart material, glass, and wood for AM. As shown in Figure 7, most review papers revolve around polymer and metal. This is probably because both polymer and metal are the most commonly used materials and have already been studied a lot. Table 3 lists the most cited review papers in each type of material. Table 4 presents more review papers in

Figure 2. Top ten authors of AM review papers (statistics from Scopus database; search keywords: “additive manufacturing” in the title, abstract or keywords, then limited to review; access date: October 19, 2022).

Figure 3. Top ten journals of AM review papers published in (statistics from Scopus database; search keywords: “additive manufacturing” in the title, abstract or keywords, then limited to review; access date: October 19, 2022).

Figure 4. Top ten affiliations of authors of AM review papers (statistics from Scopus database; search keywords: “additive manufacturing” in the title, abstract or keywords, then limited to review; access date: October 19, 2022).

Figure 5. Top ten countries of authors of AM review papers (statistics from Scopus database; search keywords: “additive manufacturing” in the title, abstract or keywords, then limited to review; access date: October 19, 2022).
### Table 1. Top cited review papers in the seven AM categories

| Category                  | First author       | Published year | Article title                                                                 | No. of citations | References |
|---------------------------|--------------------|----------------|-------------------------------------------------------------------------------|------------------|------------|
| Material extrusion        | Wickramasinghe et al. | 2020          | FDM-Based 3D printing of polymer and associated composite: A review on mechanical properties, defects and treatments | 199              | [50]       |
|                           | Dey and Yodo       | 2019          | A systematic survey of FDM process parameter optimization and their influence on part characteristics | 173              | [51]       |
| Binder jetting            | Ziaee and Crane    | 2019          | Binder jetting: A review of process, materials, and methods                    | 221              | [52]       |
| Vat photopolymerization   | Pagac et al.       | 2021          | A review of vat photopolymerization technology: Materials, applications, challenges, and future trends of 3d printing | 74               | [53]       |
| Material jetting          | Gülcan et al.      | 2021          | The state of the art of material jetting-a critical review                    | 18               | [54]       |
| Powder bed fusion         | Grasso and Colosimo| 2017          | Process defects and in situ monitoring methods in metal powder bed fusion: A review | 384              | [55]       |
| Directed energy deposition| Dass and Moridi    | 2019          | State of the art in directed energy deposition: From additive manufacturing to materials design | 150              | [56]       |
|                           | Ahn                | 2021          | Directed Energy Deposition (DED) Process: State of the Art                    | 44               | [57]       |

Statistics from Scopus database; access date: October 19, 2022

### Table 2. AM review papers with different topics in each AM technique

| Category                  | Keywords                   | Article title                                                                 | First author     | References |
|---------------------------|----------------------------|-------------------------------------------------------------------------------|------------------|------------|
| Vat photopolymerization   | Tissue scaffolds           | A review on fabricating tissue scaffolds using vat photopolymerization        | Chartrain et al. | [58]       |
|                           | Drug delivery; medical device | Vat photopolymerization 3D printing for advanced drug delivery and medical device applications | Xu et al.        | [47]       |
|                           | 4D printing                | 4D printing materials for vat photopolymerization                           | Andreu et al.    | [59]       |
|                           | Functionally graded materials | Vat Photopolymerization Additive Manufacturing of Functionally Graded Materials: A Review | Nohut and Schwentenwein | [46]       |
|                           | Shape-conformable batteries | Toward High Resolution 3D Printing of Shape-Conformable Batteries via Vat Photopolymerization: Review and Perspective | Maurel et al.    | [60]       |
|                           | Functional materials       | A Review of Multi-Material 3D Printing of Functional Materials via Vat Photopolymerization | Shaukat et al.   | [61]       |
| Powder bed fusion         | Residual stress            | An overview of residual stresses in metal powder bed fusion                  | Bartlett et al.  | [62]       |
|                           | Thermal stress             | A survey of finite element analysis of temperature and thermal stress fields in powder bed fusion Additive Manufacturing | Luo and Zhao     | [48]       |
|                           | Process physics; material screening | A review of the process physics and material screening methods for polymer powder bed fusion additive manufacturing | Chatham et al.   | [63]       |
|                           | Aluminum alloys            | New aluminum alloys specifically designed for laser powder bed fusion: A review | Aversa et al.    | [64]       |
|                           | Repeatability; reproducibility | A review of critical repeatability and reproducibility issues in powder bed fusion | Dowling et al.   | [65]       |
|                           | Formation and impact of flaws | Invited Review Article: Review of the formation and impact of flaws in powder bed fusion additive manufacturing | Snow et al.      | [66]       |

(Contd...)
Table 2. (Continued)

| Category                          | Keywords                          | Article title                                                                 | First author         | References |
|-----------------------------------|-----------------------------------|-------------------------------------------------------------------------------|----------------------|------------|
| drug delivery; healthcare         |                                   | Advances in powder bed fusion 3D printing in drug delivery and healthcare      | Awad et al.          | [67]       |
| Process monitoring; machine control |                                   | In-situ sensing, process monitoring and machine control in Laser Powder Bed Fusion: A review | McCann et al.        | [49]       |
| Binder jetting                    | Stainless steel                   | A review on binder jet additive manufacturing of 316L stainless steel         | Mirzababaei and Pasebani | [68]       |
| Material extrusion                | Process–Structure–Properties       | Process–Structure–Properties in Polymer Additive Manufacturing via Material Extrusion: A Review | Goh et al.           | [69]       |
|                                   | Dimensional inaccuracy; warpage    | Material extrusion-based additive manufacturing of polypropylene: A review on how to improve dimensional inaccuracy and warpage | Spoerl et al.        | [70]       |
|                                   | Fiber-reinforced polymers          | Fused filament fabrication of fiber-reinforced polymers: A review              | Brenken et al.       | [71]       |
|                                   | Plant biopolymers                  | Material extrusion of plant biopolymers: Opportunities & challenges for 3D printing | Chaunier et al.      | [72]       |
|                                   | Design methods                     | A survey of design methods for material extrusion polymer 3D printing         | Huang et al.         | [73]       |
|                                   | Continuous fiber                   | Material extrusion additive manufacturing of continuous fiber reinforced polymer matrix composites: A review and outlook | Zhuo et al.          | [5]        |
|                                   | Wood; lignocellulosic              | Material extrusion additive manufacturing of wood and lignocellulosic filled composites | Lamm et al.          | [74]       |
|                                   | Process monitoring                 | Process monitoring for material extrusion additive manufacturing: a state-of-the-art review | Oleff et al.         | [75]       |
|                                   | Plant protein                      | Plant protein in material extrusion 3D printing: Formation, plasticization, prospects, and challenges | Rowat et al.         | [76]       |
| Directed energy deposition        | Repair                             | Application of directed energy deposition-based additive manufacturing in repair | Saboori et al.       | [77]       |
|                                   | In situ monitoring                 | A review on in situ monitoring technology for directed energy deposition of metals | Tang et al.          | [78]       |
|                                   | Slicing                            | A review of slicing methods for directed energy deposition based additive manufacturing | Xu et al.            | [79]       |
|                                   | Adaptive control                   | Review on adaptive control of laser-directed energy deposition                | Wang et al.          | [80]       |
|                                   | High-quality                       | Preventing evaporation products for high-quality metal film in directed energy deposition: A review | Kim et al.           | [81]       |
|                                   | Process parameters; Ti            | Selective laser manufacturing of Ti-based alloys and composites: impact of process parameters, application trends, and future prospects | Singh et al.         | [82]       |
|                                   | Heat treatments; quality; residual stress | A review of heat treatments on improving the quality and residual stresses of the Ti-6Al-4V parts produced by additive manufacturing | Teixeira et al.      | [83]       |

Statistics from Scopus database; access date: October 19, 2022

AM, focusing on different materials. We have concluded and listed some of the typical review papers in different materials. For the category of materials in Table 4, ABS, PLA, and PEEK are listed separately as these three types of materials are widely used nowadays and there are a lot of published review papers on these three materials. Note that not all review papers are listed in this table as there are too many papers published nowadays. However, Tables 3 and 4 should be enough for readers to obtain the essential information.
Table 3. Top cited review papers in different materials

| Category       | First author | Published year | Article title                                                                 | No. of citations | Reference |
|----------------|--------------|----------------|-------------------------------------------------------------------------------|------------------|-----------|
| Metal          | Frazier      | 2014           | Metal additive manufacturing: A review                                        | 3289             | [84]      |
|                | Sames et al. | 2016           | The metallurgy and processing science of metal additive manufacturing         | 1320             | [85]      |
| Ceramics       | Deckers et al.| 2014           | Additive manufacturing of ceramics: A review                                  | 294              | [86]      |
|                | Sing et al.  | 2017           | Direct selective laser sintering and melting of ceramics: A review            | 197              | [87]      |
| Polymer        | Ligon et al. | 2017           | Polymers for 3D printing and customized additive manufacturing                | 1626             | [88]      |
| Stainless steel| Kong et al.  | 2021           | About metastable cellular structure in additively manufactured austenitic stainless steels | 92              | [89]      |
|                | Jin et al.   | 2020           | Wire arc additive manufacturing of stainless steels: A review                | 83               | [90]      |
| Ni-based alloys| Attallah et al.| 2016         | Additive manufacturing of Ni-based super alloys: The outstanding issues     | 130              | [91]      |
| Ti-based alloys| Shipley et al.| 2018          | Optimization of process parameters to address fundamental challenges during selective laser melting of Ti-6Al-4V: A review | 273             | [92]      |
| Biomaterial    | Murphy and Atala | 2014     | 3D bioprinting of tissues and organs                                          | 3847             | [93]      |
| Concrete       | Buswell et al.| 2018          | 3D printing using concrete extrusion: A roadmap for research                  | 557             | [94]      |
| Fibre          | Parandoush and Lin  | 2017      | A review on additive manufacturing of polymer-fiber composites               | 581             | [95]      |
|                | Kabir et al. | 2020           | A critical review on 3D printed continuous fiber-reinforced composites: History, mechanism, materials and properties | 176             | [4]       |
| Multi-material | Bandyopadhyay and Heer | 2018      | Additive manufacturing of multi-material structures                           | 349             | [96]      |
| ABS            | Torrado Perez et al. | 2014     | Fracture surface analysis of 3D-printed tensile specimens of novel ABS-based materials | 285             | [97]      |
| PLA            | Ilyas et al. | 2021           | Polylactic acid (Pla) biocomposite: Processing, additive manufacturing and advanced applications | 73              | [98]      |
| PEEK           | Zanjaniijam et al. | 2020    | Fused filament fabrication of peek: A review of process-structure-property relationships | 54             | [99]      |
| Aluminium alloys| Aboulkhair et al.| 2019      | 3D printing of aluminum alloys: Additive Manufacturing of aluminum alloys using selective laser melting | 507             | [100]     |
| Copper         | Tran et al.  | 2019           | 3D printing of highly pure copper                                            | 83               | [101]     |
| Food           | Godoi et al. | 2016           | 3d printing technologies applied for food design: Status and prospects        | 424             | [102]     |
| Smart Material | Mendes-Felipe et al.| 2019     | State-of-the-art and future challenges of UV curable polymer-based smart materials for printing technologies | 128             | [103]     |
| Glass          | Zhang et al. | 2021           | 3D printing of glass by additive manufacturing techniques: a review          | 16               | [104]     |
| Wood           | Lamm et al.  | 2020           | Material extrusion additive manufacturing of wood and lignocellulosic filled composites | 21              | [74]      |

Statistics from Scopus database; access date: October 19, 2022

3.7. Review paper categories based on research area

In this section, AM review papers that focus on key/hottest areas (e.g., aerospace, tissue engineering) will be discussed. Nowadays, AM is widely used in different fields, including aerospace, tissue engineering, construction, drug delivery, topology optimization, etc. The most cited review papers focused on these areas are provided in this subsection, as shown in Table 5.
### Table 4. Typical review papers in different materials

| Category               | Keywords                        | Article title                                                                 | First author                  | Reference |
|------------------------|---------------------------------|-------------------------------------------------------------------------------|-----------------------------|-----------|
| Metal                  | Aerospace                       | A review on metal additive manufacturing for intricately shaped aerospace components | Madhavadas et al.          | [105]     |
| Hybrid FDM             | Additive manufacturing of metals and ceramics using hybrid fused filament fabrication | Ramkumar and Rijwani        |                           | [106]     |
| Defects                | Multi-scale defects in powder-based additively manufactured metals and alloys | Fu et al.                    |                           | [107]     |
| Symmetry               | Symmetry and its application in metal additive manufacturing (MAM) | Uralde et al.                 |                           | [108]     |
| Properties             | Influence of powder characteristics on properties of parts manufactured by metal additive manufacturing | Muthuswamy                   |                           | [109]     |
| Digital twin           | A digital twin hierarchy for metal additive manufacturing | Phua et al.                  |                           | [110]     |
| Modeling; simulation   | Modeling and simulation of metal selective laser melting process: A critical review | Zhou et al.                  |                           | [111]     |
| Hybrid AM              | Metal hybrid additive manufacturing: state-of-the-art | Sefene et al.                |                           | [112]     |
| Functionally Graded Materials | Review of additive manufacturing techniques for large-scale metal functionally graded materials | Zhang et al.                 |                           | [113]     |
| Electro polishing      | Review-electro polishing of additive manufactured metal parts | Chaghradizi and Wüthrich    |                           | [114]     |
| Defects; anomalies     | Defects and anomalies in powder bed fusion metal additive manufacturing | Mostafaei et al.             |                           | [115]     |
| Fatigue                | Ultrasonic fatigue of laser beam powder bed fused metals: A state-of-the-art review | Avarieffazeli and Haghshenas |                           | [116]     |
| Machine learning; defect detection | Machine learning algorithms for defect detection in metal laser-based additive manufacturing: A review | Fu et al.                    |                           | [117]     |
| Microstructure         | Additive manufacturing of metals: Microstructure evolution and multistage control | Liu et al.                   |                           | [118]     |
| Electrical Machines    | Metal additive manufacturing for electrical machines: Technology review and latest advancements | Selema et al.                |                           | [119]     |
| Surface characteristics | Surface characteristics improvement methods for metal additively manufactured parts: A review | Hashmi et al.                |                           | [120]     |
| Load-Bearing Implants  | Metal additive manufacturing for load-bearing implants | Bandypadhy and Heer          |                           | [121]     |
| Mirror                 | Design and fabrication technology of metal mirrors based on additive manufacturing: A review | Zhang et al.                 |                           | [122]     |
| In situ monitoring     | In-situ measurement and monitoring methods for metal powder bed fusion: An updated review | Grasso and Colosimo          |                           | [123]     |
| Fracture; fatigue      | Fracture and fatigue in additively manufactured metals | Becker et al.                |                           | [124]     |
| AI; machine learning   | Applications of artificial intelligence and machine learning in metal additive manufacturing | Ladani                       |                           | [125]     |
| Digital twin           | The case for digital twins in metal additive manufacturing | Gunasegaram et al.           |                           | [126]     |
| Surface finish; porosity; residual stresses; fatigue | Effects of post-processing on the surface finish, porosity, residual stresses, and fatigue performance of additive manufactured metals: A review | Ye et al.                    |                           | [127]     |
| Biomedical             | Biomedical applications of metal 3D printing | Velásquez-Garcia and Kornbluth |                           | [128]     |
| Renewable energy       | 3D printing of metal-based materials for renewable energy applications | Mooraj et al.                |                           | [129]     |
| Liquid metal           | Current status of liquid metal printing | Ansell                       |                           | [130]     |
| Machine learning       | Perspectives of using machine learning in laser powder bed fusion for metal additive manufacturing | Sing et al.                  |                           | [131]     |

(Contd...)
Table 4. (Continued)

| Category                  | Keywords            | Article title                                                                 | First author       | Reference |
|---------------------------|---------------------|-------------------------------------------------------------------------------|--------------------|-----------|
| Ceramic                   | Dental              | Additive manufacturing of ceramics for dental applications: A review          | Galante et al.     | [132]     |
| Bone tissue               | 3D printing         | Ceramic-based scaffolds for bone tissue engineering: An overview              | Du et al.          | [133]     |
| SiC ceramic               | Progress and        | Challenges toward additive manufacturing of SiC ceramic                      | He et al.          | [134]     |
| Graphene                  | Direct ink writing  | Technology (3d printing) of graphene-based ceramic nanocomposites: A review   | Pinargote et al.   | [135]     |
| Ceramic membrane          | A comprehensive     | Review of recent developments in 3D printing technique for ceramic membrane   | Dommati et al.     | [136]     |
| Cellular ceramic          | Cellular ceramic    | Architectures produced by hybrid additive manufacturing: A review            | Pelanconi et al.   | [137]     |
| Polymer                   | Mechanical          | Characterization of 3D-printed polymers                                      | Dizon et al.       | [138]     |
| Polymer-fiber             | A review            | Additive manufacturing of polymer-fiber composites                           | Parandoush and Lin| [95]      |
| Nanocomposites            | High performance    | Polymer nanocomposites for additive manufacturing applications               | De Leon et al.     | [139]     |
|                          | 3D printing         | of polymer nanocomposites via stereolithography                              | Manapat et al.     | [140]     |
| Natural fiber             | Additive manufacturing of natural fiber reinforced polymer composites | Processing and prospects                                                    | Balla et al.       | [141]     |
| Gradient scaffolds        | 3D printing         | for the design and fabrication of polymer-based gradient scaffolds            | Bracaglia et al.   | [142]     |
| Stainless steel           | Corrosion           | Performance of additively manufactured stainless steel parts: A review        | Ettefagh et al.    | [143]     |
|                          | The corrosion of    | Stainless steel made by additive manufacturing: A review                     | Ko et al.          | [144]     |
|                          | Mechanical; thermal | Mechanical and thermal properties of stainless steel parts, manufactured      | Eshkabilov et al.   | [145]     |
|                          | Surface tension     | by various technologies, in relation to their microstructure                 | Klapcynski et al.  | [146]     |
|                          | Mechanical;         | Microstructural properties of 316 stainless steel processed by pulsed micro- | Yuan et al.        | [147]     |
|                          | macrostructure      | plasma additive manufacturing                                                |                    |           |
| Pitting Corrosion         | Pitting corrosion   | in 316L stainless steel fabricated by laser powder bed fusion additive      | Voisin et al.      | [148]     |
|                          | in 316L stainless   | additive manufacturing: A review and perspective                            |                    |           |
|                          | Steel fabricated    | by laser powder bed fusion                                                  | Douglas et al.     | [149]     |
| Powder Reuse              | The influence of    | Powder reuse on the properties of laser powder bed-fused stainless steel     |                    |           |
|                          | Powder reuse        | 316L: A review                                                               |                    |           |
| Solidification            | Solidification      | Behaviour of austenitic stainless steels during welding and directed energy   | Hossein Nedjad et al.| [150]     |
| Ni-based alloys           | Fatigue             | Overview: Additive manufacturing enabled accelerated design of Ni-based      | Shao et al.        | [151]     |
|                          | Microstructural     | Ni-alloys for improved fatigue life                                          |                    |           |
|                          | constituent         | Powder bed fusion additive manufacturing of Ni-based super alloys: A review  | Haines et al.      | [152]     |
|                          | Cracking resistance | of the main microstructural constituents and characterization techniques      |                    |           |
|                          | Residual stress     | Applications of alloy design to cracking resistance of additively manufactured | Markanday          | [153]     |
|                          | Crack               | Ni-based alloys: Residual stress, mechanisms of crack formation and strategies | Guo et al.         | [154]     |

(Contd...)
### Table 4. (Continued)

| Category            | Keywords     | Article title                                                                 | First author       | Reference |
|---------------------|--------------|-------------------------------------------------------------------------------|--------------------|-----------|
| Ti-based alloys     | Mechanical   | Additive manufacturing and post-processing of Ti-6Al-4V for superior mechanical properties | Qian et al.        | [155]     |
|                     | Fatigue      | A review of the as-built SLM Ti-6Al-4V mechanical properties towards achieving fatigue resistant designs | Agius et al.       | [156]     |
|                     | Biomedical   | A review of powderized additive manufacturing techniques for Ti-6al-4v biomedical applications | Harun et al.       | [157]     |
|                     | Chemical polishing | Chemical polishing of scaffolds made of Ti-6Al-7Nb alloy by additive manufacturing | Lyczkowska et al.  | [158]     |
|                     | Mechanical   | Mechanical properties of titanium-based Ti–6Al–4V alloys manufactured by powder bed additive manufacture | Tong et al.        | [159]     |
|                     | Process parameters | Selective laser manufacturing of Ti-based alloys and composites: impact of process parameters, application trends, and future prospects | Singh et al.       | [82]      |
|                     | Heat treatment | A review of heat treatments on improving the quality and residual stresses of the Ti–6Al–4V parts produced by additive manufacturing | Teixeira et al.    | [83]      |
|                     | Surface roughness | A review on the influence of process variables on the surface roughness of Ti-6Al-4V by electron beam powder bed fusion | de Campos Carolo and Ordoñez | [160]     |
| Biomaterial         | Bioink       | Bioink properties before, during and after 3D bioprinting                     | Hölzl et al.       | [161]     |
|                     | Biomedical; tissue | 3D bioprinting for biomedical devices and tissue engineering: A review of recent trends and advances | Derakhshanfar et al. | [162]     |
|                     | Printability  | Printability and Shape Fidelity of Bioinks in 3D Bioprinting                  | Schwab et al.      | [163]     |
|                     | Cell-Hydrogels | Design and printing strategies in 3D bioprinting of cell-hydrogels: A review | Lee et al.         | [164]     |
|                     | Skin         | 3D bioprinting of skin: A state-of-the-art review on modeling, materials, and processes | Vijayavenkataraman et al. | [165]     |
|                     | Hydrogel     | 3D bioprinting of photo crosslinkable hydrogel constructs                     | Pereira et al.     | [166]     |
|                     | Cardiac tissue; cell | 3D Bioprinting of cardiac tissue and cardiac stem cell therapy              | Alonzo et al.      | [167]     |
|                     | Machine learning | A perspective on using machine learning in 3D bioprinting                   | Yu et al.          | [168]     |
|                     | Organ        | The emergence of 3D bioprinting in organ-on-chip systems                     | Fetah et al.       | [169]     |
|                     | Liver transplantation | Bioprinting for liver transplantation                                      | Kryou et al.       | [170]     |
|                     | Process parameters | Effects of processing parameters of 3D bioprinting on the cellular activity of bioinks | Adhikari et al.    | [171]     |
| Concrete            | Simulation   | Numerical simulations of concrete processing: From standard formative casting to additive manufacturing | Roussel et al.     | [172]     |
|                     | Extrusion-based | Extrusion-based additive manufacturing of concrete products: Revolutionizing and remodeling the construction industry | Valente et al.     | [173]     |
|                     | Biomimicry   | Biomimicry for 3D concrete printing: A review and perspective                | du Plessis et al.  | [174]     |
|                     | Functionally graded concrete | On-demand additive manufacturing of functionally graded concrete | Ahmed et al.       | [175]     |
| Fiber               | Carbon fiber | Additively manufactured carbon fiber-reinforced composites: State of the art and perspective | van de Werken et al. | [176]     |
|                     | Natural fiber | Recent advancements of plant-based natural fiber–reinforced composites and their applications | Li et al.          | [177]     |
|                     | Mechanical   | The mechanical testing and performance analysis of polymer-fiber composites prepared through the additive manufacturing | Shanmugam et al.   | [178]     |
|                     | FDM          | A review on fiber reinforced composite printing via FFF                       | Ferreira et al.    | [179]     |
|                     | Continuous fiber | Material extrusion additive manufacturing of continuous fiber reinforced polymer matrix composites: A review and outlook | Zhuo et al.        | [5]       |
### Table 4. (Continued)

| Category                        | Keywords                   | Article title                                                                 | First author       | Reference |
|---------------------------------|----------------------------|-------------------------------------------------------------------------------|--------------------|-----------|
| Process parameter               | Influence of process parameters on the properties of additively manufactured fiber-reinforced polymer composite materials: A review | Ramesh et al.       | [180]    |
| Multi-material Electronics      | 3D printing of multilayered and multimaterial electronics: A review          | Goh et al.          | [181]    |
| Powder bed fusion               | Multimaterial powder bed fusion techniques                                | Mehrpouya et al.  | [182]    |
| Direct ink writing              | Direct ink writing advances in multi-material structures for a sustainable future | Rocha et al.       | [183]    |
| Architecture; construction      | Multi-material additive manufacturing in architecture and construction: A review | Pajonk et al.      | [184]    |
| Polymer                         | Advances in polymers based multi-material additive-manufacturing techniques: State-of-art review on properties and applications | García-Collado et al. | [185]   |
| Functional material             | A review of multi-material 3D printing of functional materials through vat photopolymerization | Shaukat et al.     | [61]     |
| ABS                             | Fracture surface analysis of 3D-printed tensile specimens of novel ABS-based materials | Torrado Perez      | [97]     |
| FDM                             | Review of acrylonitrile butadiene styrene in fused filament fabrication: A plastics engineering-focused perspective | Peterson         | [186]    |
| PLA                             | Polyactic acid (Pla) biocomposite: Processing, additive manufacturing and advanced applications | Ilyas et al.       | [98]     |
| Bone repair                     | Recent progress on 3D-printed polyactic acid and its applications in bone repair | Chen et al.        | [187]    |
| 4D printing                     | 4D printing of shape memory polylactic acid (PLA)                           | Mehrpouya et al.  | [188]    |
| Process Parameter; Mechanical   | The influence of the process parameters on the mechanical properties of PLA specimens produced by fused filament fabrication—A review | Cojocaru et al.    | [189]    |
| PEEK                            | An overview on the influence of process parameters through the characteristic of 3D-printed PEEK and PEI parts | El Magri et al.    | [190]    |
| FDM                             | Applications of 3D-printed peek via fused filament fabrication: A systematic review | Dua et al.        | [191]    |
| Aluminum alloys                 | Microstructure and mechanical property considerations in additive manufacturing of aluminum alloys | Ding et al.       | [192]    |
| Mechanical                      | Mechanical properties of SLM-printed aluminium alloys: A review             | Ponnusamy et al.  | [193]    |
| Heat treatment                  | Heat treatment of aluminium alloys produced by laser powder bed fusion: A review | Fiocchi et al.    | [194]    |
| WAAM                            | Challenges associated with the wire arc additive manufacturing (WAAM) of aluminium alloys | Thapliyal        | [195]    |
| Corrosion                       | Corrosion and corrosion protection of additively manufactured aluminium alloys—a critical review | Revilla et al.    | [196]    |
| Copper                          | A review on additive manufacturing of pure copper                          | Jiang et al.      | [197]    |
| Food                            | Toward the design of functional foods and biobased products by 3D printing; A review | Portanguen et al. | [198]    |
| Functional                      | 3D food printing: Applications of plant-based materials in extrusion-based food printing | Wang et al.      | [199]    |
| Plant-based                     | A review on 3D printable food materials: types and development trends       | Li et al.         | [200]    |
| Food material                   | 4D printing: a new approach for food printing; effect of various stimuli on 4D printed food properties. A comprehensive review | Navaf et al.     | [201]    |

(Contd...)
Table 4. (Continued)

| Category      | Keywords     | Article title                                                                 | First author | Reference |
|---------------|--------------|-------------------------------------------------------------------------------|--------------|-----------|
| Smart materials | Manufacturing | Significant roles of 4D printing using smart materials in the field of manufacturing | Haleem et al. | [202]     |
| Wearable application |             | Potentials of additive manufacturing with smart materials for chemical biomarkers in wearable applications | Kwon et al. | [203]     |
| Glass         | Crystallization | Crystallization in additive manufacturing of metallic glasses: A review       | Liu et al.   | [204]     |
| Silica Glass  |             | Overview of 3D-printed silica glass                                           | Zhang et al. | [205]     |
| Wood          | Wood powders  | A review on wood powders in 3D printing: processes, properties and potential applications | Das et al.   | [206]     |

Statistics from Scopus database; access date: October 19, 2022

Table 5. Most cited review papers in key/hottest areas

| Area               | Article title                                                                 | Citation | First author | References |
|--------------------|-------------------------------------------------------------------------------|----------|--------------|------------|
| Machine learning   | Machine learning in additive manufacturing: State-of-the-art and perspectives | 153      | Wang et al.  | [207]      |
| Construction       | 3D printing using concrete extrusion: A roadmap for research                  | 560      | Buswell et al. | [94]      |
| Biomedical         | Bioink properties before, during and after 3D bioprinting                    | 567      | Höld et al.  | [161]      |
| Tissue engineering | 3D bioprinting of tissues and organs                                          | 3872     | Murphy and Atala | [93]      |
| Topology optimization | Current and future trends in topology optimization for additive manufacturing | 383      | Liu et al.   | [208]      |
| Electrochemical    | 3D-printing technologies for electrochemical applications                     | 554      | Ambrosi and Pumera | [209]    |
| Smart structures   | Printing soft matter in three dimensions                                      | 838      | Truby and Lewis | [210]      |
| Food printing      | 3D printing technologies applied for food design: Status and prospects         | 428      | Godoi et al. | [102]      |
| Drug delivery      | 3D printing pharmaceuticals: Drug development to frontline care               | 243      | Trenfield et al. | [211]    |
| Aerospace          | The present and future of additive manufacturing in the aerospace sector: A review of important aspects | 279      | Uriondo et al. | [212]     |

Statistics from Scopus database; access date: October 19, 2022

4. Conclusions

In this work, we conducted a survey on published review papers in AM. Analysis and discussion on reviews in
seven AM techniques are given (i.e., material extrusion, powder bed fusion, material jetting, binder jetting, directed energy deposition, vat photopolymerization, and sheet lamination). As can be seen, most of the review papers are in the categories of powder bed fusion and directed energy deposition. No review papers in sheet lamination were found. In the future, it is necessary to carry out a review on sheet lamination, although it is not a famous AM technique. In addition, typical review papers are categorized into different groups based on the materials these review papers focused on (e.g., metal, ceramic, polymer, biomaterial, concrete, fiber, food, smart material, glass, and wood). The specific objectives of each review paper are listed, as shown in Table 4. For example, He et al.[134] focuses on SiC ceramic in AM, and readers can refer accordingly based on their interests. The aim of this survey paper is to provide a guidance to the development of AM review papers, give a comprehensive analysis on the current available review papers in this field, and hopefully, provide some insights and inspire more ideas. As the review papers published in AM are increasing; nowadays, the selected review papers in this survey are based on the Scopus database, which might have some limitations. In addition, this survey only considers the most cited papers in each category based on the number of citations, while the published time of the review papers is not considered.

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**Conflict of interest**

None.

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