Additive Manufacturing and Industry 4.0

Subjects: Ergonomics

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We present a review on Additive Manufacturing and Industry 4.0 from business innovation and sustainability perspective.

Additive manufacturing | industry 4.0 | Sustainability | business innovation | systematic literature review | bibliometric analysis

1. Introduction

The research trend in additive manufacturing (AM)/3D printing/rapid prototyping has evolved over the past 30 years from a rapid prototyping technology to advanced manufacturing. According to Mohsen [1], the third industrial revolution started in 1987 with the commercialization of the first stereolithography (SLA) machine, named SLA-1, developed by 3D Systems. After several commercialized versions of SLA machines in 1991, three new AM-based technologies were commercialized: fused deposition modeling (FDM), solid ground curing, and laminated object manufacturing (LOM). This was followed by several years of sustained development in the AM technology from using resin to metal powder and from non-functional molding applications to fabricating medical implants [2]. At present, the focus is on the implementation of this technology in the manufacturing environment [3], considering business/operations cost implications [1][4][5][6][7], design for manufacturing or design optimization [8], and the sustainable development of this technology considering environmental implications such as the product life cycle, circular economy (CE), and use of recycled materials [9][10][11]. Few studies have reviewed the business innovation (BI) and sustainable development of the AM technology separately [12][13][14][15][16]. Industry 4.0 technologies facilitate decision making using real-time data [17][18], but others give more importance to how effective Industry 4.0 data are for environmentally sustainable implications [19][20]. Therefore, a systematic literature review and a bibliometric analysis of the AM business model and sustainability areas are needed to consider the integration of these developments into Industry 4.0.

2. Additive Manufacturing

As defined by the American Society for Testing and Materials (ASTM) and the ISO/TC 261 Committee for Standardization in Additive Manufacturing, additive manufacturing is a collection of technologies able to join materials to make objects from 3D model data, usually layer upon layer, as opposed to the subtractive manufacturing methodologies [21].

In the existing literature, AM processes have been classified by various parameters: materials used, direct or indirect process technology, and the state of the raw material used (which is one of the most commonly used basis) (See Figure 1).

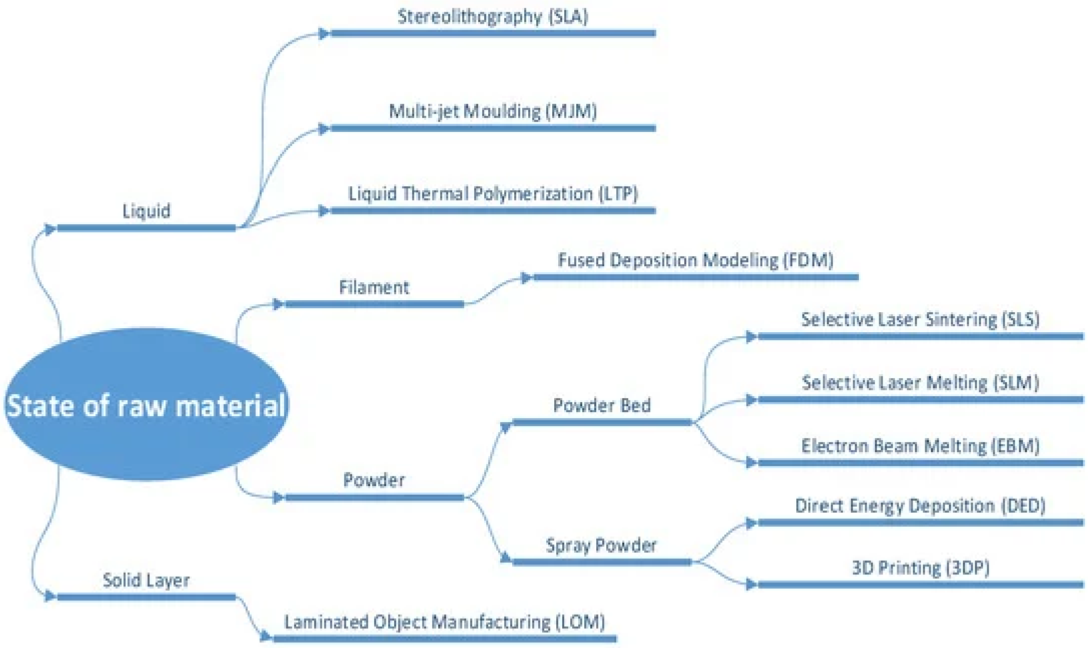

Figure 1. Types of additive manufacturing processes based on state of raw materials.

Past research indicated significant advances in the AM technology in terms of its applications [22][23][24][25][26], economic impact [3][27][28][29], use of raw materials [30][31][32], and design [34][34][35]. To the best of our knowledge, the filament and powder are the most frequently used raw materials for cost characterization, business model proposals, and sustainability processes. Furthermore, the filament and powder are the most common AM technologies implemented for Industry 4.0 integration [36][37], and which are compared with traditional manufacturing methods [6][38][39][40].

3. Industry 4.0

In recent years, Industry 4.0 has seen significant advances in production processes, data management, cybersecurity, and competitiveness based on customization and client relationship (see Figure 2) [37][41][42][43]. Industry 4.0, well known as the fourth industrial revolution, was born in Germany as Industrie 4.0 in 2011 as a proposal to develop the German economy [44][45].

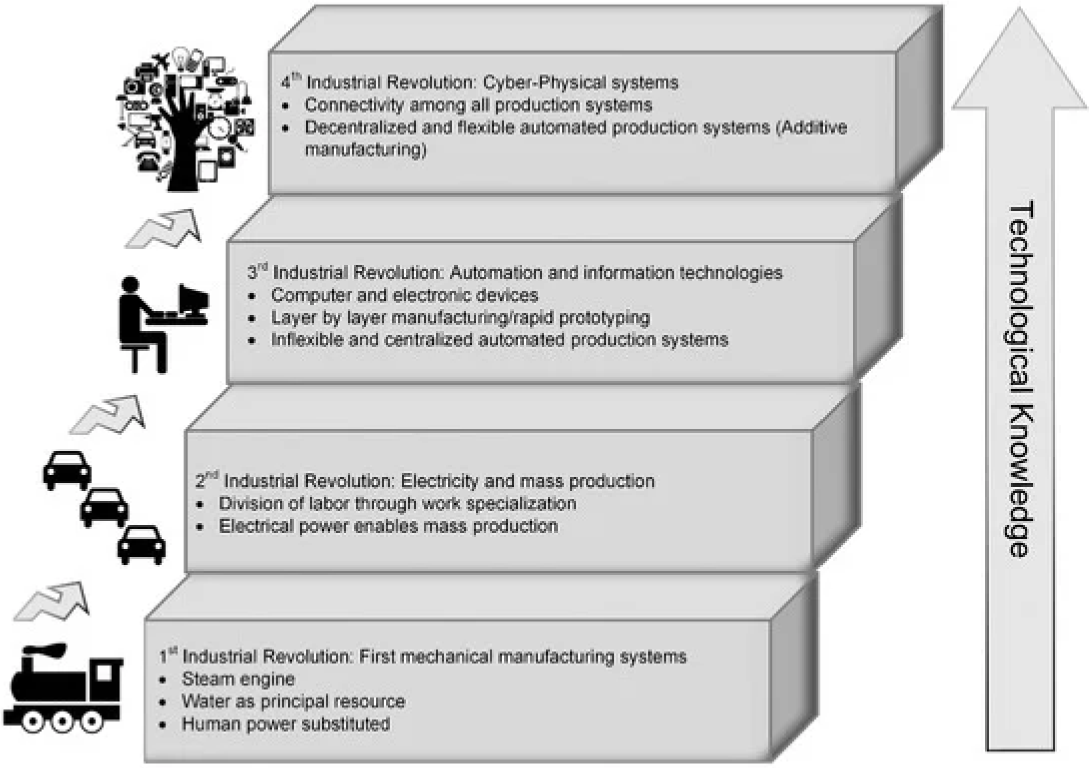

Figure 2. Industrial revolutions (adapted from [46][47]).

Industry 4.0 is characterized by interactions and communication among industrial equipment and cyber-physical systems for managing operations in real time [48] for decision-making, Internet of Things, artificial intelligence, robotics, cybersecurity, and 3D printing [49] (see Figure 3). By means of Industry 4.0, companies can use autonomous fabrication systems, make decentralized decisions, and facilitate interconnectivity among employees, machines, orders, suppliers, and customers [18][50] Technology based on Industry 4.0 enables organizations to create products that meet customers' needs, and facilitates production parameter control such as energy consumption, material flow, and real-time monitoring [18].

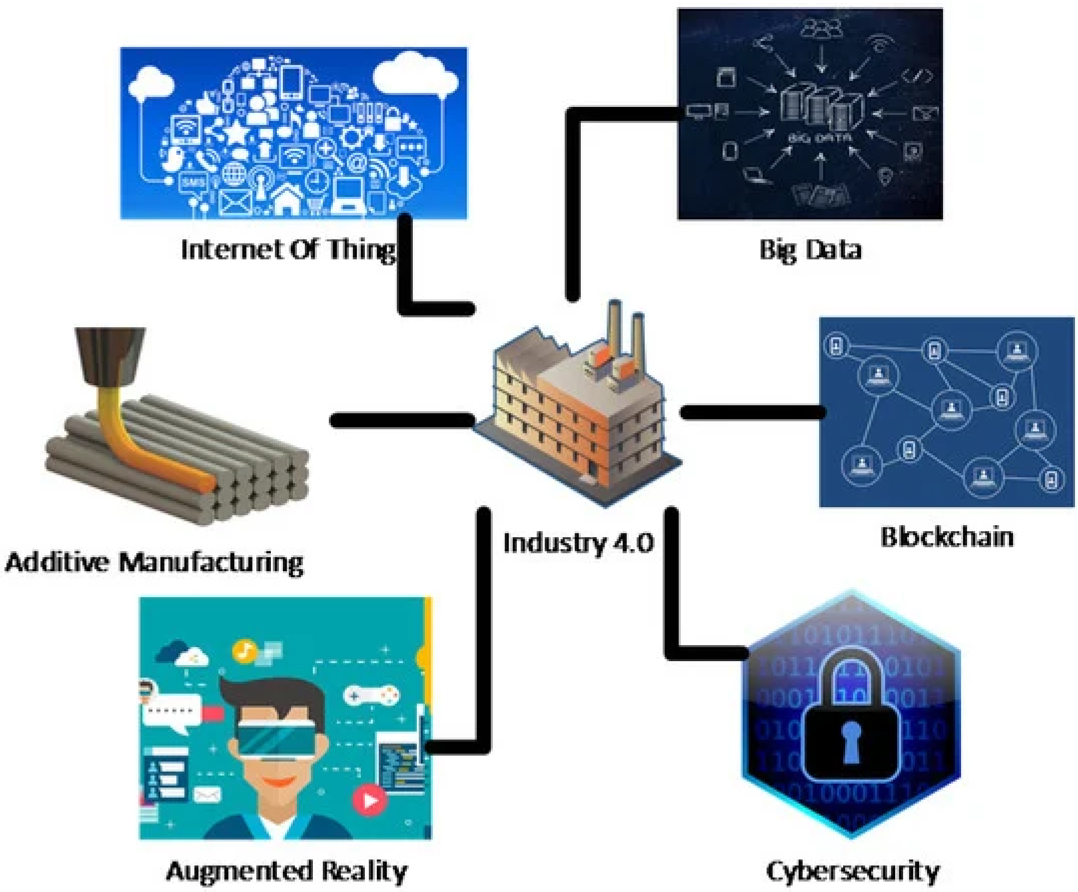

Figure 3. Industry 4.0 technological trends (adapted from [37]).

Recent research established Industry 4.0 as an enabler of recent trends related to CE [36][42][51][52][53], innovation in businesses concerning manufacturing [43][54], new business models [55][56], and supply chain and cost model configuration [57].

The pursuit of increased competitiveness drives research in energy efficiency, resource redistribution, and smart equipment, which are key characteristics of Industry 4.0 [58]. The growth and proliferation of Industry 4.0 are related to the implementation of smart factories, smart products, cyber-physical systems, smart cities, and digital sustainability [45].

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