Adaptability of Additive Manufacturing in Manufacturing Sector: A Review

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Abstract - Technology of additive manufacturing also known as 3D priming is capturing the market in short span of time, owing to fabricate complex components at low cost and efficient behavior. So, the application of additive manufacturing leads to new era of manufacturing where automation or computer creates the design and extrude the product for assembly. In additive manufacturing or 3D printing the components are built through layer-by-layer deposition and geometry was control by computer that ends in high precision product. The researchers dedicated on such systems provide excited results and showed huge potential towards adaptability in manufacturing sector. But there are various limitations that restrict its application in many areas. Hence, this research dedicated to explore the sectors where additive manufacturing technology is efficiently working and chance of adaptability in manufacturing sectors. Furthermore, this article illustrates the challenges that have to encounter during implementation of this technology. At last, a conclusive remark on the application of additive manufacturing has been made.

Keywords - Additive Manufacturing, Manufacturing Sector, Automation.

I. INTRODUCTION

Industry 4.0 stated a new revolution in manufacturing industries that enable the systems towards achievement of high level of precision with accurate dimension. Earlier systems have numerous of deviation in the quality perspective due to technical and human factors that also responsible for high wastage. The minimizations of waste and accurate dimension of product aiguilles the profit of every industry. So, now a day's every industry wants to adopt additive manufacturing systems to fulfill the demand of customers at minimum cost. In additive manufacturing systems 3D object scanners or CAD (computer-aided-design) model is used to deposit the material layer by layer, following the command instructed by additive manufacturing software following the geometry in precise manner [1-3]. The commands are controlled by the computer systems based on specific algorithm i.e. STL format. This technology is also explained under different name such as "3D printing" and "rapid prototyping". The development in advance ceramic [4-5] and arts industries also looking for coloring & fine finishing systems that could be possible by automation resembling to 3D printing techniques [6].

The technology of additive manufacturing was first founded by Dr. Hideo Kodama by filing a patent in 1980. The researcher wants to develop photopolymer prototypes that can be exposed to ultraviolet light, to provide rigidity. Later, the first Stereolithography (SLA) device was showed by Chuck Hull in 1986. Till now numerous of additive manufacturing systems were developed based on Stereolithography technology. After invention of Stereolithography device another system of selective laser sintering (SLS) was developed within a year in which leaser source was used to bind the powder or impart the rigidity, but it was commercialized in year 2006. Then after the system of additive manufacturing are highly acknowledge by the industries due to high reliability, sustainability, reduction of logistics costs, high speed production, energy saving and provision to meet production on demand [7-9]. So, numerous of researches are going on worldwide to make compatible with additive manufacturing systems. The limited information and expose restrict its application in many areas; to fulfill this many researchers illustrated very useful finding that lead to new era of manufacturing. In this regard, Shahrubudin et al [10] complied numerous of researches dedicated on 3D printing for its effective utilization in manufacturing industry alongside the availability of materials for 3D printing technology. Researchers concluded that this technology effectively beneficial for people, company and government to upgrade and improve the infrastructure by implementing this technology. Shahid [11] demonstrated the beneficial effect of computer alongside visualization and creation of almost impossible designs in the manufacturing industries. Researchers illustrated all possible mechanism that exist with 3D printing towards achievement of cost effective components. Mpofu et al. [12] suggested huge application in cellular telephone industry by converting a virtual model in physical product through layer by layer deposition controlling the geometry by software command. Researchers illustrated that additive manufacturing is an exciting technology that

showed its potential in every industries. Siddique et al. [13] presented a tutorial for Rhinoceros 3D towards development of prototype printing in stepwise manner. Researchers demonstrated that low cost products can effectively used in general and specific fields. Furthermore, Rhinoceros 3D modeling software can effectively used for simulation as well as designing of product in effective manner. Furthermore, a mini review on the additive manufacturing was carried out by Crisostomo and Dizon [14] to demonstrate the effectiveness in food processing, agriculture, environment protection and monitoring. Researchers presented various case studies to deliberate the sustainable and efficient manufacturing can be acheied by using additive manufacturing technique. Srinivasan et al. [15] also presented an overview of additive manufacture in perspective of engineering industries. Researchers suggested that there is requirement of more data to improve the reception of additive manufacturing processes. Kidwell [16] carried out informative work to examine the implementation of 3D printing technology in construction industries and the problems yet to encounter for its beast application. Researchers suggested two techniques, the first one was uniform concrete used for prefabrication and plastic wall components adhere with Winsun, or Branch Technology to perform the prefabrication. The second techniques were related with the fabrication of in-house scale mockups for building components. The research explored that the contractors save time and money due to omission of third party involved in fabrication, interior décor etc. Furthermore, Yin et al. [17] also applied the concept of additive manufacturing for construction industries that lead to more safety, saves construction time, and costs also improves quality of the project and tremendously reduce the environmental impact. Researchers also suggested that the limited knowledge of structural properties, safety and economics of the materials restrict the application to some extent. The thixotropic concrete materials or low-viscosity concrete could be possible solution for better application of additive manufacturing, in which the nozzles are used for chemically treatment and layer by layer deposition could be carried out. Furthermore, the system could be synchronies with automation though pouring of concrete whereas, steel bars are manual placed. For effective utilization of additive manufacturing researchers concluded that the selection of process should be follow standards in terms of structural design, testing, materials, specifications and manufacturing.

Hence, the above literature and complied work suggested the potential of additive manufacturing technology lead every industries to a new era of revolution. The idea to implement the systems in the industries growing day by day, but still there are many more concepts and knowledge that are inconclusive and needed in depth exploration. So, in this work an endeavor has been made to explore all the possibilities and technology implemented in manufacturing industries towards development of precise and low cost component. This work also covers the numerous of process that already exist in the market and have potential to apply in every industries. Therefore, this work covers the articles which are published in last decade; special attention is given on the recent valuable work that concentrates on the adoption of additive manufacturing in the industries.

II. REVIEW ON APPLICATION OF ADDITIVE MANUFACTURING TO CAST A COMPONENT

There are numerous of methods that can be used to fabricate the components using additive manufacturing technique. The advanced methods which are cost effective and highly appreciated by the scientific community are discussed in this section to explore its application in the manufacturing industries. Hence, detailed methodologies alongside mechanism, which are still unexplored and used in manufacturing industries, are discussed. As it was acknowledge that the stating of additive manufacturing takes place from 1980 but its real application in manufacturing sectors starts from 2005. The pioneer work towards industrial application of additive manufacturing was carried out by UK based company RepRap, giant producer of self-replicating machines. Company used desktop fused deposition modeling (FDM) 3D printers for fabrication of parts and data induced in it was explore in public domain. The results inspired a company MakerBot to produce DIY kits in 2009. Furthermore, under banner of DIY projects, the company encourages it for hobbyists interested towards 3D printing that provide ideas for implementation. Then after in year 2011 Prusa Research was founded to develop Prusa i3 design based on earlier works of RepRap machine. The developed Prusa i3 design showed an effective result and available in the market later, competed by MakerBot that developed Replicator 2 in year 2012 [18]. Theses inventions not only provide serene pathways towards developed of 3D printing equipment but also change the scenario of current manufacturing technologies. Apart from this, the technology of additive manufacturing was also effective for coloring or to improve the material which already existed but required some modification for functional products and successfully showed by Ramya, and Vanapalli [19] in their review article. Researchers also concluded that 3 D printing technology not only used for production of product but also pay high output towards maintenance of equipments in efficient manner. Kitson et al. [20] used open source 3D printing platform data in order to develop an automated synthesis robot have application in pharmaceutical industries. At first fused deposition modeling technique was used to develop different volumes of 3D print reaction vessels made up of polypropylene, further the technology of 3 D imparted to produce the nonsteroidal anti-inflammatory drug ibuprofen via a consecutive one-pot three-step approach. Researchers successfully demonstrated that the parameters could be changed using robot control software using python programming language. Researchers finally concluded that the fully automated chemical synthesis had potential to encounter the reproducibility issues of synthetic chemistry in pharmaceutical industries, and could lead a new era of digitalization.

A complete overview on the methodologies that were opted in additive manufacturing like powder bed fusion, stereolithography, fused deposition, digital light processing and metal transfer dynamic along with the feasible selection of materials such as advanced epoxy, ABS, hydrogel, silver and steel are thoroughly discussed by Hossain et al. [21]. Researchers showed a successful implementation of 3D printing concepts in industries that grown in very shorter time.

Nyirjesy et al. [22] carried out a case study to develop a system for facial wounds using 3 D printing technology. In this study, researchers used computer assisted design and three-dimensional printing to develop patient-specific wound splint. The process successful implemented for wound stabilization by considering point of-care manufacturing in the setting of hemifacial necrotizing fasciitis also beneficial for the complex wound management in the head and neck. Zhao et al. [23] made an endeavor towards implementation of 3 D printing concept and its feasibility application for ceramics materials. Researchers used both traditional i.e. hand-made techniques as well as digital i.e. computer-designed 3D ceramic shape to complete the product. Furthermore, the developed algorithm was beneficial for the innovation of ceramic art and design and may start new milestone for these industries. An in-depth reviewed work on Fused deposition modeling (FDM) towards its adaptability in manufacturing industries was carried out by Zhang et al. [24]. Researchers encountered the problems associated with FDM materials i.e. accumulation of shrinkage stress after fabrication that lead to warping, distortion and lack of shape stability of final component. Researchers suggested that the advancement in technology incorporated with suitable binder of materials, probably one of the solutions to said problems. Du et al. [25] worked on production of high internal phase emulsions (HIPEs) developed through crosslinked by Transglutaminase (TG). The developed HIPEs showed uniform droplet diameter and a good storage stability alongside good thermal stability when treated through TG-crosslinked gelatin. The developed emulsion of HIPEs materials had huge potential for 3D printing technology due to higher viscosity and lower frequency dependence. Hao and Lin [26] selected molding principle and process flow to demonstrate its successful application in manufacturing Industries. Recently, Sharma et al. [27] selected various MMCs to demonstrate the adaptatbility of 3D printing in Mecdial sector. Researchers suggested that all 3D printing techniques like selective laser sintering, stereolithography, direct metal laser sintering, electron beam melting, and selective laser melting have huge potential towards its application in medical sector. Kumar et al. [28] successful demonstrated the capability of additive manufacturing in extrusion-based system. The review article clearly demonstrated the capability of additive manufacturing in extrusion-based AM systems. **Table 1** shows Adaptability of additive manufacturing in manufacturing sector.

Table 1. Adaptability of Additive Manufacturing in Manufacturing Sector

Methods Opted	Objective	Summary of work
Mann–Whitney test were carried out using 175 research data from small- and medium-sized industries. Kulkarni et al. [29]	To reveal the challenges and potential adoptability of additive manufacturing in small- and medium-sized industries.	Benefits, challenges and business were the three factors that significantly affect the adoptability of the additive manufacturing. The adoption minimizes the wastage in production decreases the inventory cost, and beneficial for customization of products. However, requirement of skilled labor, high investment incurred to run the system and limited dimensions (size) acceptance limits the adoptability.
Fuzzy Bayesian Network. Twenty three potential impact factor based on research and industrial experience were characterized in six parts. Jing et al [30]	Holistic framework were developed using fuzzy Bayesian Network to mitigate the application risk and improve the feasibility and adaptability of AM in industry.	The analysis align with case study successful showed the potential adaptability of fuzzy Bayesian Network (based on AM) to fabricate the composite engine blades, and the critical factors identification with proper solution was possible. Furthermore the decision support tool proposed through fuzzy BN can be used for assessing the risk and uncertainty of AM technology application.
Adaptability of smart materials and useful impact on next generation additive printings (3D and 4D printings) in manufacturing domain. Mondal et al. [31]	Challenges and potential adaptability of special materials with piezoelectric properties and shape-changing characteristics in additive printing.	The industries like medical areas, defense, aerospace, automotive and energy sectors have successfully apply smart materials (piezoelectric and shape-changing materials) through AM technology using manufacture program. Furthermore, the lack of efficient supply chain, need of advance technology, huge investment and restrictions in availability of materials (lack of knowledge on behavior of materials) restrict its application.
Bibliometric analysis based on research articles on additive manufacturing and its applications in Industry 4.0. Haleem & Javaid [32]	Adaptability, challenges and future potential of Additive Manufacturing technology in Industry 4.0 was studied	Research observed 13 important AM applications in Industry 4.0. The challenges that should be encounter were comparable low strength and inferior quality and high cost of the printing machine system. Furthermore the article suggested that disruptive technology may be the successfully encounter the challenges in the future manufacturing system which showed potential to achieve required goals

1004 articles were encompasses among them 141 full-text analysis Kunovjanek et al. [33]	Correlation and benefits was established between Additive manufacturing and supply chains for future adaptability	Research highlighted a huge potential ranging from aerospace to consumer goods industries had provision to adopt the AM technologies For digital value chain. Researchers also revealed that the key industries that were highly benefited with AM technologies are aerospace and industrial goods followed by automotive sector and consumer goods.

So, from above discussion it can be suggested that the feasibility of additive manufacturing has huge opportunity in every sector of industries [34, 35]. The challenge to adopt this system is selection of materials and surface integrity. The inbuilt technology that requires high melting temperature creates sever problems towards its implementation. Furthermore, the surface integrity of product needs further finishing problems that may be encounter through attachment of finishing processes with additive manufacturing system.

III. CONCLUSION

The human's life, economy, and modern society shows high influence of 3-D printing technology in short span of time due to automation and minimization of manual interference. The automation results in high profit, prolong life of components and minimization of complexities as operated by computer that provide larger way of businesses. So, every industries wants to adapt the additive manufacturing in their systems but lack of knowledge on the implementation or real time problem restrict its application in day to day life. So, in this review work it was found that contribution in additive manufacturing process is huge in food medical pharmaceutical as well as core manufacturing sectors. The problems of high temperature melting and surface integrity is achieved by incorporation some new systems that allied with additive manufacturing technique.

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