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Additive Manufacturing and Advancement in Prototyping Development: A Review

HARUNA MOHAMMED SHEHU[1], OKPANACHI GEORGE ECHIYE[2], ALAPA FREDERICK[3], AHMED EL- MANSUR[4], ADIKANKWU HENRY[5], MUSA DIKA[6]
[1, 2, 3, 4, 5, 6]*National Space Research and Development Agency, Abuja*

***Abstract-* Additive manufacturing (AM) has revolutionized the field of prototyping, enabling rapid, flexible, and cost-effective production of complex components and products. This paper explores the advancements in AM technologies and their impact on prototyping, highlighting the benefits of reduced lead times, increased design freedom, and improved product quality. We discuss the current state of AM in Nigeria, its applications in various industries, and the opportunities for innovation and growth. The paper also identifies challenges and future directions for AM adoption in Nigeria, including the need for infrastructure development, skills training, and industry-academia collaboration.**

Keywords: Additive manufacturing, 3D printing, prototyping, rapid prototyping, Nigeria.

I. INTRODUCTION

Additive manufacturing (AM), also known as 3D printing, has transformed the field of prototyping by enabling rapid, flexible, and cost-effective production of complex components and products. Additive manufacturing is not only limited to prototypes but also used as a small-scale manufacturing because it offers cost effective products, strong and lightweight parts, flexible designs, minimizing wastage of materials, ease of access, fast design and productions and many more advantages. Now a days additive manufacturing technology offers wide range of applications also in various industrial sectors such as in aerospace, defense, medical science, electronics, civil engineering, automotive industries, ocean engineering and aviation industries etc. As the advancement occurs around additive manufacturing various number of materials also developed for 3D printing, materials like metals, polymers, composites, ceramics, wood, powder, glass and building materials, biodegradable materials, smart materials etc. The technology has been increasingly adopted in various industries, including aerospace, automotive, healthcare, and consumer goods, due to its ability to reduce lead times, increase design freedom, and improve product quality (Gibson et al., 2015).

II. REVIEW OF ADDITIVE MANUFACTURING TECHNOLOGY

The term ‘additive manufacturing’ covers a broad range of production technologies that fabricate products layer-by-layer, enabling three-dimensional objects to be ‘printed’ on demand. The ASTM F42 Technical Committee that is responsible for overseeing the development of AM standards defines the technology as “a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies” (ASTM, 2012). Some of the most widely adopted AM technologies are fused deposition modelling (FDM), stereolithography (SLA), selective laser melting (SLM), selective laser sintering (SLS) and digital light processing (DLP), but there are a variety of other AM processes too, including polyjet, electron beam melting (EBM) and laminated object manufacture (LOM) (Petrovic et al., 2011). In terms of materials, a variety of polymers, metals, ceramics and composites can be used for AM. The use of these materials is dependent on the type of AM process used (Guo and Leu, 2013). The first applications of AM were in rapid prototyping and then tooling. These application areas continue to be exploited to the present day but performance improvements to AM technologies mean that they are increasingly being used for direct manufacturing. Certain industries such as aerospace, where the need to produce a small number of highly complex aircraft components makes the application of AM technologies ideal, are already fully aware of their potential and are investing in research to improve their reliability and applicability (Guo and Leu, 2013; Lyons, 2012). In the medical sector highly, personalized one-off products are needed. The capabilities of AM make it the ideal technique to address this need. This is exemplified by the manufacturing process for in-ear hearing aids which has almost entirely shifted to AM (Sandstrom, 2015), while other applications in orthodontics, prosthetics, orthotics, implants and replacement organs are at various stages of maturity and adoption. The pattern of industrial emergence, technology adoption and diffusion can be seen to follow the niche development and speciation that has been observed in previous emerging industries (Ford et al., 2014; Phaal et al., 2011). In addition to these technical and commercial developments there have been a range of other advances made in cold spraybased AM processes that have not been used as prototyping methods (Sova et al., 2013). Although these have not traditionally been considered as AM, they are being promoted as such and fit within the ASTM definitions of AM. Alongside the advances that have been made in AM in the industrial market, a variety of consumer grade '3D printers' have proliferated on the market. The majority of these home 3D printers (e.g. RepRap, Makerbot, Ultimaker) are based on the fused deposition modelling (FDM) technology originally developed by the US firm Stratasys. Their commercialization was made possible following the expiry of the first patents protecting this technology, an open source movement that saw hobbyist activity around the technology, and crowdfunding through platforms such as Kickstarter and Indiegogo. These machines offer the promise that individual consumers will be able to design and produce personalized products at their convenience (Lipson and Kerman, 2010).

III. ADVANCEMENTS IN ADDITIVE MANUFACTURING

AM technologies have evolved significantly over the years, with improvements in printing speed, accuracy, and material properties. Some of the most common AM techniques include:

Fused Deposition Modelling (FDM): A widely used technique that involves extruding molten plastic to create complex shapes (Ahmadi et al., 2018).

Stereolithography (SLA): A technique that uses a laser to cure liquid resin, producing high-resolution parts (Lima et al., 2017).

Selective Laser Sintering (SLS): A technique that uses a laser to fuse powder particles, creating complex geometries (Kumar et al., 2019).

IV. APPLICATIONS OF ADDITIVE MANUFACTURING IN PROTOTYPING

AM has been extensively used in prototyping due to its ability to rapidly produce complex components and products. Some of the key applications of AM in prototyping include:

Aerospace Industry: AM is used to produce lightweight components, such as aircraft parts and satellite components (Khalil et al., 2020).

Automotive Industry: AM is used to produce car parts, such as engine components and dashboard parts (Wang et al., 2019).

Healthcare Industry: AM is used to produce customized implants, prosthetics, and surgical models (Ahmadi et al., 2020).

V. BENEFITS OF ADDITIVE MANUFACTURING IN PROTOTYPING

The use of AM in prototyping offers several benefits, including:

Reduced Lead Times: AM enables rapid production of complex components and products, reducing lead times and accelerating product development (Gibson et al., 2015).

Increased Design Freedom: AM allows for the creation of complex geometries and structures that cannot be produced using traditional manufacturing techniques (Lima et al., 2017).

Improved Product Quality: AM enables the production of high-quality components and products with improved surface finish and accuracy (Kumar et al., 2019).

VI. CHALLENGES AND FUTURE DIRECTIONS

Despite the benefits of AM in prototyping, there are several challenges that need to be addressed, including:

Infrastructure Development: The lack of adequate infrastructure, including 3D printing facilities and skilled personnel, hinders the adoption of AM in Nigeria (Ahmadi et al., 2018).

Skills Training: There is a need for training programs to develop skills in AM and prototyping (Khalil et al., 2020).

Industry-Academia Collaboration: Collaboration between industry and academia is essential to develop AM technologies and promote innovation (Wang et al., 2019).

VII. CONCLUSION

Additive manufacturing has revolutionized the field of prototyping, enabling rapid, flexible, and cost-effective production of complex components and products. The technology has been increasingly adopted in various industries, including aerospace, automotive, and healthcare. However, there are several challenges that need to be addressed, including infrastructure development, skills training, and industry-academia collaboration.

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