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A Review Paper on 3D Printing Technology: Processes, Materials, Applications and its Potential Application Opportunities and Challenges Faced in Pakistan

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Abstract- 3D printing or additive manufacturing process is known as part of the digital manufacturing process, involves gradually adding materials to a geometric representation to manufacture physical objects. A quickly developing technology is 3D printing. The world now uses 3D printing extensively in the many fields such as automotive, locomotive, healthcare, agriculture mass customization, aviation sectors and manufacture of any form of open source designs using 3D printing technology are becoming more common. 3D printing process produce an object directly from a computer-aided design model by depositing material layer by layer. In this world mostly many countries are quickly advancing and heavily investing in 3D printing. The advancement of 3D printing technology in Pakistan will be accelerated by strong government assistance, both in the form of laws that are welcoming to investors and subsidies during the early stages of growth. The use of this technology will bear fruit with a few years. Economy will boost as a result of strong manufacturing base. Pakistan will be able to contribute to the international market with skilled professionals and complex products, thus paving way for a sustainable future. The varieties of 3D printing technologies, the materials utilised in 3D printing, the applications for 3D printing technology, and the difficulties associated with adopting 3D printing technologies in Pakistan are all covered in this article.

Keywords- Additive Manufacturing, 3D Printing, Manufacturing Industry, Fused Deposition Modeling, Computer Aided Design (CAD)

I. INTRODUCTION

From a geometrical representation, 3D printing may produce physical objects by adding material in stages [1]. Recently the use of this 3D technology has multiplied phenomenally. Charles Hull first made 3D printing technologies available for purchase in 1980 [2]. At the moment, 3D printing is mostly employed to create prosthetic heart pumps. [3], steel bridge in Amsterdam [4] 3D printed cornea [5], jewelry collections [6], PGA rocket engine [7], and other items connected to the food sector and the aviation industry. 3D printing technology was first used as the layer-by-layer manufacturing of 3D structures precisely from Computer aided design models [8]. Technology that uses 3D printing has become very inventive and adaptable. It provides promise for numerous potential outcomes for businesses wanting to increase industrial efficiency and opens up new prospects, ceramics, Conventional thermoplastics, graphene-based materials, employing 3D printing technology it is now possible to produce materials such as metal. [9].

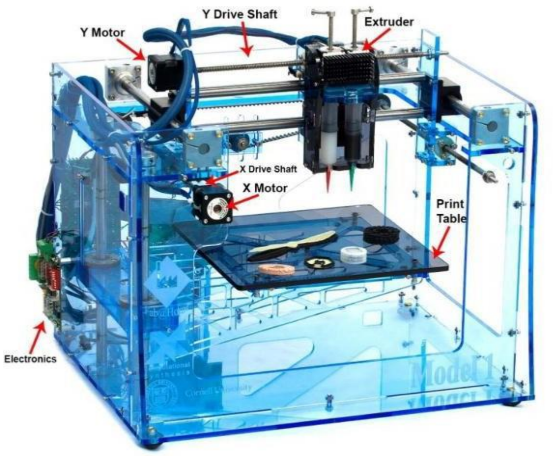

Fig 1: 3D Printer

Industry revolution and production line changes could result from 3D printing technology. Utilizing of 3D printing technology in manufacturing sector decreasing costs. Additionally, the production will be more affected by consumer demand simultaneously. Customers have further control over the finished product and can request that it be created in accordance with their specifications. Nowadays 3D printing machinery located closer to customers, providing a much flexible and rapid manufacturing process also increased quality control [10].

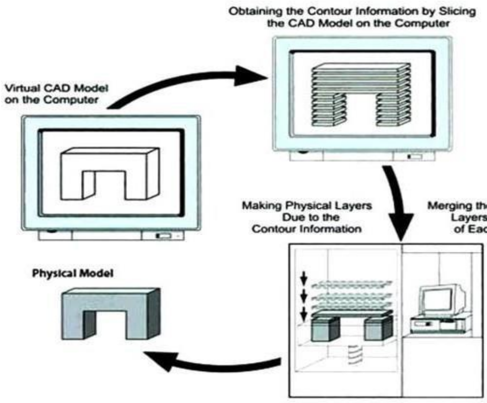

Fig 02: 3D Printing Procedure

3D printing is widely utilized today around the globe in the different sectors such as automobile sector, aerospace industries, healthcare and agriculture industries, 3D printing technology is being utilized widely for mass customization and manufacturing of any types of open source designs. [11]. However, there are many drawbacks to 3D printing in the manufacturing sector. For instance, the utilization of 3D printing technology leads to a decrease in the need for manufacturing labor, which has an immediate and significant impact on the economies of countries that mainly rely on low-skill occupations. Additionally, 3D printing users can create a vast array of components, including weapons, knives, and other dangerous things. In order to prevent criminals and terrorists from bringing guns without being seen, the utilization of 3D printing should be restricted to a select group of people. At the same time, someone who obtains a blueprint will be capable to manufacture fake items with ease. Because 3D printing technology is easy to use and only needs a drawing and data to be entered into the printer to produce 3D objects [12].

In conclusion, 3D printing technology has developed recently as an adaptable and effective tool in the advanced manufacturing sector. Many nations have adopted this technology widely, especially in the manufacturing sector. As a result, this paper gives a detail introduction of the many 3D printing processes, their uses, and finally the materials that are applied in the different manufacturing industries.

II. DIFFERENT 3D PRINTING TYPES

Different 3D printing technologies with various functions have been developed. As per ASTM Standard F2792 [13] According to ASTM there are different seven categories of 3D printing technologies: material extrusion, material jetting, sheet lamination, powder bed fusion, directed energy deposition, binding jetting, and vat photo polymerization. There is no variance over which devices or technologies work well because each one has a specific purpose. Modern 3D printing technologies are increasingly employed to create a different many types of items rather than just prototypes [14].

2.1. Directed Energy Deposition

A further challenging printing method called directed energy deposition is routinely employed for replacement or add extra material to already manufactured parts. [8]. Directed energy deposition can manufacture finest objects and has a tremendous degree of control over the grain structure. Although the nozzle isn't locked to one axis and can travel in several directions, the mechanism of focused energy deposition and material extrusion are comparable. Additionally, the method can be applied to polymers and ceramics, but it is usually employed with metals and metal-based composites, either as powder or wire. Two examples of this technology are laser-engineered net shaping (LENS) and laser deposition [8]. The latest innovation known as laser deposition can be employed to manufacture or repair objects with sizes ranging from metres to milimeters. Considering that it can provide scalability and a wide range of abilities in a single system. LDT is gaining popularity in the oil and gas, aerospace, transportation and manufacturing sectors [15].

2.2. Materials Extrusion

Using 3D printing technology based on material extrusion, it is possible to print food, living cells, and plastics in a variety of materials and colours. [17]. This technique is frequently used and has a fair price. It is also possible to create fully working product components using this technique [8]. The very earliest system for material extrusion is fused deposition modelling (FDM). Early in 1990, FDM was invented, and its primary material is polymer. [18]. FDM creates parts layer by layer, from top to bottom, by extruding hot thermoplastic filament.

2.3. Materials Jetting

Material jetting, which is a type of 3D printing that deposits build material drop by carefully chosen drop, is in accordance with ASTM Standards. Using ultraviolet light, a printer discharges droplets of a photosensitive substance that solidifies and constructs a part layer by layer [20]. Additionally, material jetting manufacture objects with excellent dimensional accuracy and a very smooth surface finish. Composites, ceramics, polymers, biologicals, and hybrids are only a few of the numerous materials available through material jetting, which also provides multi-material printing [8].

Table 1: 3D Printing Technologies ASTM Standard

Categories	Technologies	Key Source	Material Used
Directed Energy Deposition	Laser Engineering Net Shaping (LENS), Electronic Beam welding (EBM)	Laser Beam	Molten metal powder
Materials Extrusion	Fused Deposition Modeling (FDM)	Thermal Energy	Thermoplastics
Materials Jetting	Ployjet or Inkjet Printing	Thermal Energy Photocuring	Wax, photopolymer

III. MATERIALS FOR 3D PRINTING TECHNOLOGY

Such as any manufacturing process, 3D printing requires premium components that consistently meet requirements in order to produce premium products. To ensure this the Suppliers, purchasers and end users of the material develop policies, specifications, and agreements regarding material controls. 3D printing technology can produce fully functioning parts using a number of materials, including polymers, metals, ceramics, and their combine to form hybrid, composite [8].

3.1. Metals

Due to many advantages, metal 3D printing has attracted much attention in the manufacturing, medical, automotive and aerospace fields [26]. Metals are great physical materials that can be employed in a different manufacturing processes, from the printing of human organs to the manufacturing of aircraft parts. There are many examples of these materials include and titanium alloys [27-28], nickel-based alloys [29], alloys of aluminum. [30], stainless steels [31], cobalt-based alloys [32]. A cobalt-based alloy is best for employed in dental applications for 3D printing, because it has high specific stiffness, robustness, elongation heat-treated conditions and high recovery capacity. [28]. Additionally, 3D printing technology can be employed to manufacture aerospace components using nickel base alloys. [29]. Nickel base alloy-based 3D-printed parts can be employed in hazardous environments. This is due to its ability to withstand temperatures of up to 1200 °C and great corrosion resistance. [26]. Finally, titanium alloys can also be used to print the objects utilizing 3D printing technology. Due to its flexibility, strong corrosion resistance, oxidation resistance, and low density, titanium alloy has several very unique properties [31]

3.2. Polymeric Material

The manufacture of polymer parts, from prototypes to functional structures with demanding geometries, makes extensive employ of 3D printing technologies [33]. With the use of Fused deposition modeling it can form to produce 3D printed objects by layering extruded thermoplastic filaments like Acrylonitrile Butadiene Styrene, Polypropylene, or Polyethylene, polylactic acid. [33]. Recently, thermoplastic filaments with elevated melting temperatures, such as polyetheretherketone and Polymethyl methacrylate, can earlier be employed as materials for 3D printing technology. [34]. Because of their economical cost, processing flexibility and low weight., In industry, polymer materials in a liquid state or with a low melting point are frequently employed [35]. Mostly, the use of polymers in medical device and biomaterial products, frequently as inert materials, played a significant part in the effective operation of the devices moreover in the providing of mechanical support in numerous orthopedic implants. [28].

3.3. Ceramic Material

Ceramic is tough, long-lasting, and fire-resistant. Ceramics may be used in most of any required shape and designed geometry because of their fluid state before setting, making them ideal for the design of future construction and building [37]. It is reported that ceramic materials were advantageous for usage in aerospace and dentistry [38]. The examples of ceramic materials are zirconia [39], bioactive glasses [40], alumina [41] and Alumina powder for instance has the ability to be processes by 3D Printing technology. Excellent ceramic oxide alumina has several uses, such as in in microelectronics, chemicals, adsorbents, aerospace sector, catalyst and other high-tech industries. [42]. Alumina has high curing complexity [38]. Complex-shaped alumina parts can be manufactured using 3D printing technology and can have high green density and sintering density [39].

IV. 3D PRINTING APPLICATION IN DIFFERENT MANUFACTURING INDUSTRIES

4.1. Aerospace Industry

The design freedom in part and manufacturing that 3D printing technology offers is unparalleled.3D printing technology has the capability to manufacture lightweight components with enhanced and complex geometry in the aerospace industry, which can lower energy and resource requirements [52]. By adopting 3D printing technology, it is also possible to reduce the amount of material needed to make the components for aerospace, which can result in fuel savings. Furthermore, 3D printing technology is mostly employed in the manufacturing of replacement parts for certain aviation parts such as engines. The engine's parts are readily damaged and regularly need to be replaced. In order to obtain such spare parts, 3D printing technology is a good alternative. [53]. Nickel-based alloys are increasingly favored in the aerospace industry because of their corrosion resistance/ oxidation, tensile qualities and damage tolerance [54].

4.2. Automobile Industry

The ability to design, develop, and produce cutting-edge items thanks to 3D printing technology is currently revolutionizing the industry. By enabling faster, lighter structures with greater complexity, the use of 3D printing in the automotive industry has spawned new phenomena. For example, Local Motor created the first three-dimensionally printed electric vehicle in 2014.Local Motors expanded the variety of uses for 3D printing technology beyond just the automotive industry by manufacturing the OLLI, a 3D-printed bus. A 3D printed, electric, driverless, and incredibly smart bus is called OLLI. Additionally, Ford is a leader in the usage of 3D printing technology and produces prototypes and engine parts using it [55].

4.3. Electronic and Electric Industry

As 3D printing becomes more widely used in the sciences, technology, and manufacturing sectors, producers are starting to see its potential realized in a number of exciting ways. Nowadays, Electronic devices have so far made extensive use of a number of 3D printing technologies, including electrodes, electronic materials, and tools with mass customization and adaptable sketching [74]. An affordable and speedy method of mass generating electrode materials is offered by the manufacturing process for the 3D electrode using the FDM of 3D printing technique. The drawing and surface area of the 3D electrode can be comfortably modified to suit a specific application, in contrast to commercial electrodes like aluminum, carbon and copper electrodes. Additionally, the completely automated, highly precise 3D printing procedure for the 3D electrode allowed for the quick completion of the manufacturing process for 08 electrodes in just 30 minutes [75].

V. Applications Of 3D Printing In Pakistan

Although Pakistan's technological culture does not yet use 3D printing, the benefits it can bring to the nation's numerous industries are mentioned below.

5.1 Education System

The foundation of any nation's progress and the source of many remarkable innovations are its educational institutions. However, 3D printing will develop the educational system and give teachers help through 3D prototypes. The current educational system in Pakistan uses antiquated, conventional teaching methods that lack collective learning. Students studying engineering, architecture, and medicine will be capable to easily understand latest concepts through hands-on instruction using miniature models. [76]. Projects for research and development in Pakistan will be revitalized by 3D printing.

5.2 Manufacturing Industries

Manufacturing companies in Pakistan import refurbished equipment that has now become outdated. Because of this, we are no longer able to replace any damaged or missing parts from older items. In this case, the manufacture of such items will see the prestigious use of 3D printing. The only production activity in Pakistan's aerospace and automation sectors is the assembly of components. However, because to the development of 3D printing, Pakistan will be capable to produce the majority of the components. Due to its lack of significant manufacturing sectors, Pakistan struggles to draw significant foreign investment. A paradigm shift will be brought about by 3D printing, which will democratize production and enable people to launch small businesses. Additionally, the rising need for this technology will entice investors to build up business in Pakistan. This will make it possible to manufacture intricate and customized products at a very low cost [83]

5.3 Jewelry Industry:

Millions of dollars' worth of jewelry are traded in the Pakistani jewelry market every year, however there is an issue with this because traditional jewelry designs are still the mainstay of the sector and can only meet local customer demand [77]. Intricate designs are either not made in our country or require a great deal of time and effort to made. To solve this issue, additive manufacturing offers a quick and inexpensive alternative [78].

5.4 Medical Field

The patient's quality of life is improved, and the price of medical equipment is decreased because to 3D printing. Prosthetics, dental implants, braces, and hip and knee implants are all readily available and individually available for each patient. Medical students will benefit from 3D printing since it will make it easier for them to practice on working models, reducing the frequency of medical failures in Pakistan. It will be very helpful to surgeons as well because they may examine the damaged area with 3D printed models [84]

5.5 Agricultural Tools

Nearly half of Pakistan's labour force is employed directly or indirectly by the country's large agricultural population. The major economic sector in Pakistan is agriculture, which contributes 24% of the country's GDP and is the main origin of export revenue. [79]. Farmers use machinery and tools outside of cities, making it challenging for them to repair these items when they break. They will be capable to produce and maintain agricultural products using 3D printing. Additionally, they will be also capable to design and create agricultural labour hand equipment, such as ones for planting, weeding, harvesting, and food processing. [80].

VI. Problems Faced To Implement 3D Printing Technology In Pakistan

There is no doubt that 3D printing has a definite potential to aid in the growth of the nation, but there are several problems that tend to hinder the use of the technology.

6.1 Lack of Availability of 3D Printing Specialists

Currently, there is a lack of specialists in Pakistan who are capable of utilizing 3D printing technology to model, create, and manufacture various products. The implementation of 3D printing in curriculum and the workforce is especially challenging because our antiquated educational system will resist change. Consequently, the change will not be a simple operation. So, it is important to educate the public about 3D printing and material advancement through training, courses, exhibitions, and seminars. [81].

6.2 Materials Challenges

Due to the development of new materials, producers and researchers are expanding the capabilities of 3D printing in several ways. However, Pakistan's capabilities for the creation and study of advanced materials are still not up to mark with the required standards. Our country also lacks significant plastic and chemical manufacturing industry. consumable materials for 3D printing, include metal, ceramic, resin, and plastic [86].

6.3 Hardware and Software Challenges

An operating system is necessary for the 3D printing ecosystem and must be updated over time in order to run the new hardware. Motion components (Stepper motors, Belts, threaded rods, End stops), Print bed, Filament, Controller board, Frame, Power Supply Unit (PSU), Print bed surface, Print head, Feeder system, User interface, Connectivity, and File transfer options are the main physical components of a 3D printer. Our country lacks the desired manufacturing industries for both hardware and software [89]

6.4 Decrease in Manufacturing Jobs

In Pakistan a large number of workers are attached to traditional manufacturing techniques, specially manufacturing industries in Sialkot, Gujarat and Gujranwala. Pakistan is a nation of traditions and customs, and as a people, we have always tried to resist the change. A significant number of machinery used in operations and by operators are eliminated by 3D printing, which is a disruptive factor. This indicates that there will be fewer high-skilled occupations overall as opposed to a large number of low-skilled ones [82].

VII. Conclusion

This review paper presents a complete picture of 3D printing's use to the manufacturing sector. Currently, 3D printing technology is in startup phase to be utilized in the manufacturing sectors; it has many advantages for individuals, government and the businesses. To advance in finding strategies to increase the usage of 3D printing technology, more information is therefore required. The industry and government will be capable to enhance and develop the infrastructure of 3D printing technology with the aid of additional information about the technology. The aim of this paper is to provide a general review of the different techniques of 3D printing technologies, the materials utilized in manufacturing for 3D printing, and finally, the applications of 3D printing technology. In this world mostly many countries are quickly advancing and heavily investing in 3D printing. Pakistan is still in the early stages of development, but with its high proportion of young people and sixth-place global ranking in terms of population, Pakistan has the capacity to alter itself. As of 2018, there were 62 million 3G/4G customers, and internet penetration climbed from 10% in 2012 to 29.55%. Pakistan had highest rise in research output in 2018, having topped the list in percentage terms with the rise of 21%. The advancement of 3D printing technology in our country will be accelerated by strong government assistance, both in the form of laws that are welcoming to investors and subsidies during the early stages of growth. The use of this technology will bear fruit with a few years. Economy will boost as a result of strong manufacturing base. Pakistan will be able to contribute to the international market with skilled professionals and complex products, thus paving way for a sustainable future.

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