A COMPREHENSIVE REVIEW ON 3D PRINTING TECHNOLOGY

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ABSTRACT
Three-dimensional (3D) printing, or additive manufacturing, has transformed design, prototyping, and production by layering materials like plastics, metals, and ceramics. Various technologies, including FDM, SLA, and SLS, have unique applications and benefits. Industries like aerospace, healthcare, and automotive use 3D printing for rapid production of lightweight components, customized prosthetics, and complex car parts. Benefits include rapid prototyping, increased complexity, reduced waste, and customization. Researchers are addressing challenges like material limitations and cost to unlock the full potential of 3D printing, which is expected to revolutionize industries and aspects of our lives with innovative products, improved efficiency, and reduced costs.
Keywords: 3D printer,Additive manufacturing, 3D printing technology, CAD software, layer by layer.

Introduction
Three-dimensional (3D) printing is a revolutionary technology that creates physical objects from digital designs by layering materials like plastics, metals, and ceramics. This additive manufacturing process enables rapid production of complex geometries and customized products, transforming industries like aerospace, healthcare, and automotive. 3D printing streamlines prototyping, reducing time and costs, and enables the creation of custom prosthetics, implants, and surgical models. Artists and designers use 3D printing to create innovative pieces, while functional parts like gears and robotic components are also made possible. With its sustainability benefits and increasing accessibility, 3D printing is transforming manufacturing, design, and innovation, and its potential to impact everyday life is vast. As the technology advances, we can expect exciting developments and applications across various fields.

Literature
There are different types of methods used in 3D Printing technology with different appllications, advantages and disadvantages. We studied some of the journal papers and mentioned them below:
Chenxing Xin a,et.al., [1] Merging additive manufacturing (AM) with glass manufacturing offers advantages like high resolution, low surface roughness, and optical transparency, enabling the creation of complex glass devices. AM has made progress in fabricating functional glass devices, moving beyond simple geometries. It excels in small-scale structures, offering transparency, precision, and low energy consumption, suitable for applications like color converters, microlenses, and microfluidics. However, traditional methods remain more suitable for large-scale applications like architectural glass and containers due to technical obstacles and high costs. Companies like OXMAN and Nobula3D AB are pioneering 3D printing glass, exploring various AM techniques, printing strategies, and applications.

Aniket Jadhav et.al., [2] 3D printing is a rapidly expanding digital fabrication technique used in mass customization and open-source design manufacturing in various industries. It uses a CAD model to create three-dimensional objects layer by layer. This paper provides an overview of different 3D printing techniques, classifications, materials, and applications. 3D printers are used to create replicas of computer-generated designs in various products and services, including toys, medical implants, maps, and historical artifacts. Materials like plastic, plaster, metal, and fruit can be used for templates, each with its own advantages and disadvantages. Paper is a crucial factor to consider when using 3D-printed items, as it may not be able to handle wear and tear. This paper explores the additive manufacturing process from various angles using programming tools. The study covers the history of 3D printing, materials used, and metal foil laminated object manufacturing principles.Additive manufacturing, also known as 3D printing, involves layering materials in a 3D printer to create products from 3D model data, using various materials like polymers, metals, ceramics, and composites. Technology samples include photopolymers, powder bed fusion, binder jetting, stereolithography, polymers, composites, sheet lamination, material extrusion, and directed energy deposition. Types of additive manufacturing and 3D printing include FDM (fused deposition), modeling, SLS (selective laser sintering), SLA (stereolithography), LOM (laminated object manufacturing), and SDL (selective deposition lamination). And also, this 3D printing technology is used in different sectors, including medical applications, education, architecture, marketing, etc. This review explores 3D printing's role in manufacturing, its benefits, and its applications. It provides an overview of processes, materials, and applications, enabling future research.

Archisman Dasgupta et.al., [3] This paper provides an overview of 3D printing technology, its advantages, and advancements in emerging fields. It discusses its potential in medical, aeronautical, architecture, and defensive structures, and highlights the latest developments in materials like alloys, polymer composites, ceramics, and concrete.3D printing (3DP) is a technology that creates shapes and intricate patterns using 3D data modelling. Invented by Charles Hull in 1986, it has evolved over the years, using various procedures, equipment, and materials. Additive manufacturing (AM) is widely used in construction, prototype manufacturing, and biomechanics. 3DP has reduced waste, increased design freedom, and mechanization, but its implementation in architectural projects is limited. Additive manufacturing techniques, including SLA, FDM, PBF, IJP, LOM, and DED. SLA produces high-quality components at a resolution of 10 μm, but is slower and costly. FDM uses a thermoplastic filament to print 3D layers of different materials, with the filament warmed up before being dispensed onto the base or over previously produced layers. Applications of 3DP in various fields Including Biomaterials and bio-fabrications,Aviation and aerospace ,Buildings and structures3D printing (3DP) technology offers design freedom, mass customization, and the ability to build complex shapes with minimal wastage. FDM is widely used due to its cheap cost, accessibility, and fast processing speed. Polymers are commonly used for rapid prototyping, and 3DP methods for metals and alloys include SLS, SLM . 3DP faces challenges like resource scarcity and regulatory concerns, but with continued research and advancement, it has the potential to revolutionize manufacturing.

Antonio Bacciaglia et.al., [4] his research addresses the limitations of additive manufacturing (AM) in producing large-scale components in one piece, highlighting the need for more efficient internal logistics. The limited printing volume of available AM machines and the time required for the manufacturing process limit the development of AM technologies for large-scale components. To address this, the research proposes a methodology to handle large-scale 3D models before the slicing process by subdividing the model into subparts using a collaborative AM machine with extrusion heads. This method reduces production time by over 50% in a case study of a UAV fixed-wing, which is appealing for the AM industry to increase production volumes and decrease manufacturing time. However, limitations in the developed methodology, such as the need for control system software and proper hardware, limit its applicability to the industrial engineering field. Additionally, the component subdivision into smaller parts produces structural spots that need further analysis. Future work will focus on guidelines and a preliminary design of a compatible AM framework, as well as addressing design guidelines for all AM processes, as done in this work for FDM technology.

Pengwen Wang Huo a. et.al., [5] The use of reverse engineering, product innovation design, and 3D-printing technology has been used to design and develop helmet products quickly and efficiently. The 3D scanner collects point cloud data from the physical model, which is then processed using software like Geomagic Studio for surface reconstruction and fitting. The extracted information is then sent to forward design software like SolidWorks for the helmet's forward design. This approach solves traditional design issues such as complex surface modeling, time-consuming manufacturing, and long production cycles. It also accelerates enterprise product development, shortens the cycle, and reduces costs. The adoption of 3D printing technology also shortens the product development cycle. This research uses reverse engineering, design-related product innovation, and rapid prototyping to create a flow chart for rapid technological innovation. It uses Geomagic Studio's reverse-engineering software and data processing technology to create a frontal model of the human head, which is then printed using 3D-printing technology. The optimized helmet design ensures better comfort and safety for the wearer. Although material limitations during the 3D printing process may limit safety performance, the method can significantly shorten the product development cycle and meet market demand.

Yahya Bozkurt et.al., [6] This study introduces 3D printer technology, a rapidly developing innovation in the industrial age, and its use in various sectors such as aviation and defense. It discusses the various methods of 3D printing and their application in biomedical applications, including surgery, pharmaceuticals, disease modeling, custom implants, organ printing, vet medicine, and tissue engineering. The study compares 3D printing with traditional methods in the biomedical field and highlights future opportunities that are expected to become widespread and developed in the future.3D printer technology offers the ability to produce complex parts faster and cheaper than traditional methods, making it increasingly popular in various sectors. It is particularly useful in the biomedical field, where it is used for various applications such as surgical modeling, disease understanding, manufacturing medical devices, patient-specific implants and prostheses, vet medicine, tissue engineering, the pharmaceutical industry, and organ bioprinting. The use of 3D models in cancer diagnosis and monitoring has significantly improved the accuracy of operations compared to radiographic and clinical examinations. This technology is also preferred for the production of personalized prostheses and implants, which can be produced in desired sizes and colors based on the patient's anatomy.As it becomes widespread, it will bring revolutionary innovations to the medical field, potentially saving many lives. In all areas of medicine, 3D printing-powered inventions aim to provide patients with a high quality of life and a longer life.

Anketa Jandyal et.al., [7] 3D printing is a sustainable technology for producing engineering components due to its reduced material waste, ease of manufacturing, and energy efficiency. The paper discusses various 3D printing processes, their advantages and disadvantages, and the compatibility of materials for each type. It also highlights the various application areas of each process and focuses on Industry 4.0. However, the field still faces issues like material incompatibility and material costs. Future research should focus on developing and modifying processes to suit a wider range of materials and developing cost-effective printer technologies and materials compatible with these printers. This will broaden the range of applications for 3D-printed parts. 3D printing is a sustainable and cost-effective technology that has the potential to replace conventional methods. It is also environmentally friendly, helping to mitigate the negative effects of industrialization. Various 3D printing technologies have evolved, each with its own advantages and disadvantages. FDM is the most common technology, but it is more suitable for polymeric materials. Powder-based technologies like SLS face challenges in transportation and storage. Future research should focus on improving the 3D printing process, making it more efficient and compatible with various materials. The effect of process parameters on the mechanical properties of developed parts can also be studied. This could broaden the applications of 3D printing by making it more user-friendly, efficient, and cost-effective.

Mohd Shuaiba et.al., [8] Additive Manufacturing (AM) technologies enable quick production of physical parts using a three-dimensional computer-aided design system. 3D printing is a key component of AM, allowing layer-by-layer deposition of material until entire segments are created. This technology offers numerous advantages over conventional manufacturing methods, including reduced manufacturing time, creative liberty, and compatibility with advanced and conventional materials. However, conventional manufacturing has a negative environmental impact, making it essential to switch to alternatives like AM. This study aims to understand the sustainability of switching to AM technologies by comparing 3D printing's impact on the environment with existing manufacturing methods. Key parameters considered include energy consumption, global warming, freshwater, marine water, terrestrial toxicity, and acidification. The study aims to help researchers identify the sustainability of AM printing technologies and their potential benefits. The study reveals that 3D printing methods have limited material options, but 3DP is a viable, sustainable alternative for manufacturing complex parts and superficial geometric structures. However, 3DP reduces environmental degradation and material wastage, while SM is better for superficial structures due to less material wastage, quicker build time, and similar environmental footprints. Further research is needed to compare subtractive and additive methods based on their environmental impacts.

Elif Karayel et.al., [9] Additive manufacturing (AM) technology, also known as layered manufacturing or 3D printer technology, has gained popularity due to its advantages such as material savings, lower costs, and design flexibility in complex shapes. However, AM has dimensional limitations. To overcome this, metal materials produced with AM can be combined with commonly used welding methods to obtain large parts. This study introduces AM technology, methods, usage areas, and their effects on mechanical properties and microstructures. It also examines the effects of these new methods on the mechanical properties and microstructures of the metal materials.AM technology is widely used in the medical, automotive, and aerospace industries, offering advantages like complex geometry production, lower costs, and high-strength parts. However, it has limitations in serial and large-part production. Recent studies have investigated AM technology with common welding methods like GMAW, GTAW, FSW, and EBW. Successful connections can be achieved with optimum parameters and suitable welding methods. The use of AM technology and welding methods together is expected to become more common in the future.

Basav Raj Gadagi et.al., [10] This review paper discusses the advancements in 3D metal printing, which involves manufacturing 3D parts directly from 3D virtual parts drawn in software like Catalyst, Solidworks, and UGNX. The manufacturing process is similar to all types of machines, which build up material layer by layer. However, the melting process used in metal is difficult and different from plastic. Additive manufacturing offers freedom for part consolidation, complexity, design, and lightweighting and is suitable for applications in the automobile, aerospace, marine, oil, and gas industries. The paper also discusses the limitations of 3D manufacturing compared to conventional machining, as parts are a week in strength in the Z-direction. Factors affecting 3D part strength include surface finish and porosity, and a case study is prepared to address these issues. The study concludes that 3D printed parts' strength depends on factors like raw material quality, machine environment, and power supply. The available materials range from nickel alloys to high-grade stainless steels. Additive manufacturing technologies offer free product development but require custom designs. Metal 3D printing reduces trial-and-error tests, reduces design-production time, and makes printing more metallic products more cost-effective.

Nurhalida Shahrubin et.al., [11] 3D printing, also known as additive manufacturing, is a versatile technology used in mass customization, open source designs, agriculture, healthcare, automotive, locomotive, and aviation industries. It creates physical objects from geometrical representations by adding materials successively. 3D printing has applications in various industries, such as artificial heart pumps, jewelry collections, 3D-printed corneas, PGA rocket engines, and steel bridges. It can be used for conventional thermoplastics, ceramics, graphene-based materials, and metal. However, it has disadvantages, such as reducing manufacturing labor and printing dangerous items like knives and guns. To prevent terrorism and counterfeiting, it is essential to limit the use of 3D printing to specific individuals. 3D printing technology can produce unique materials like food, lunar dust, and textiles, allowing for customization and nutrient-rich food. In the textile industry, 3D printing offers short processing times, reduced packaging costs, and reduced supply chain costs. In the automotive industry, 3D printing has revolutionized the design, development, and manufacturing of new structures, such as the first 3D-printed electric car in 2014 and the 3D-printed bus called OLLI. In the food industry, 3D-food printing allows for customized food for specialized dietary needs, reducing unnecessary ingredients and enhancing healthy ingredients.

Tadeusz Mikolajczyk et.al., [12] The article explores the use of additive manufacturing, also known as 3D printing, for producing prototypes of innovative solutions. It highlights the advantages of 3D printing, which can produce directly based on a CAD model, which serves as the source of information for generating incremental control files. The article presents an example of 3D printing using the FDM method to create a hybrid structure using ready-made metal elements. The specific features of 3D printing are developed using CAM software based on a CAD model, such as Geomagic and SH3R.3D printing is a crucial step in manufacturing techniques, particularly for building prototypes and unique solutions. It allows for the production of G-code control files for machining directly from CAD models, generating subsequent detail sections. Hybrid manufacturing (HM) combines additive and subtractive processes. An innovative robot gripper solution has been created using ready-made elements from a universal metal construction system and a 3D printing manufactured part. The element is deliberately divided into two parts for high elemental strength. In hybrid construction, dimensional accuracy is crucial, and the article uses a modification of the CAD model to ensure sufficient accuracy of cooperating elements for a functional device.

Chao Wei et.al., [13] This paper investigates the 3D printing of multiple metallic materials using selective laser melting (SLM), a powder bed layer-by-layer fusion technique. The technology is limited to printing a single material across each layer but is desirable for applications like aeroengine components, medical implants, and functional gradient structures. The study combines powder-bed with point-by-point powder dispensing and selective material removal, describing material delivery system design, multiple material interactions, and component characteristics. This paper presents a multiple-material SLM technology that combines conventional powder-bed spreading with point-by-point multiple-material selective powder removal and dry powder delivery for the first time. The research used proprietary experimental SLM equipment and a special CAD data preparation procedure to produce 316L/In718 and 316L/Cu10Sn samples. The study confirmed the feasibility of depositing multiple materials on the same building layer and across different layers. However, defects like porosity and cracks were found in the ultrasonically deposited powder region.

Benjamin Kading et.al., [14] This paper presents a manned Mars mission using in-situ resources for structure fabrication. It outlines a two-phase mission, with robotic construction units preparing a functional base for human habitation. The paper discusses potential structures created using additive manufacturing techniques and in situ materials. The approach is compared to previous missions before concluding.This paper presents a prospective approach to Martian exploration using in-situ resources to reduce launch and deep space transit mass and volume requirements. It describes mission design and structures constructed using 3D printing of common Martian basalt. The paper identifies two technical concerns: basalt 3D printing and maintaining the base's pressure environment. It presents several solutions based on the characterization of Martian basalt composition and discusses strategies for base construction. Future work will focus on the refinement of the basalt 3D printer and the characterization of various basalt compositions to understand its utility as a pressurized structure.

D. King et.al., [15] This technology accelerates time to market by focusing on the tool rather than the part. The selective laser sintering (SLS) process has been adapted to produce metal-based prototypes for rapid tooling applications. Modular injection mould tool inserts are being developed to reduce time to market by using alternative tool materials like Rapid Steel , copper polyamide, and CNC machined Ureol and Araldite. These tools undergo rigorous testing to confirm design accuracy and ensure turnaround times. This paper discusses the selection of the most appropriate mould material for time to market.

Matthew N. O. Sadiku et.al., [16] 3D printing, or additive manufacturing, is a process that creates three-dimensional parts layer by layer, revolutionizing industries like transportation, communication, and exploration. It is highly valued in the aerospace industry, where it is used to design, build, and maintain commercial and military aircraft. This paper examines the use of 3D printing technology in the aerospace industry, highlighting its groundbreaking development in the aerospace and defense industries. The aerospace sector has been using 3D printing for over a decade, revolutionizing design and production processes. Advancements in technology and aerospace-grade materials have reshaped the way aircraft are built and maintained. 3D printing is transforming plane landing and takeoff and engines' efficiency. As the technology spreads, more companies are expected to develop on-site 3D printing operations and invest in them. The aerospace sector is set to soar to new heights, as without 3D printing, future aircraft will never be able to land.

Qian Liu et.al., [17] The paper examines the impact of 3D printing technology on industrial production efficiency and economic growth in China's automotive sector. It examines its applications, including complex geometric parts production, rapid prototyping, and customization. The paper also addresses technological and market challenges, such as material limitations, printing speed, quality control, regulatory compliance, and market readiness. It discusses emerging technologies and future research directions, and provides strategic recommendations for maximizing 3D printing's potential in the industry. The findings suggest that addressing existing challenges and leveraging future innovations are crucial for successful adoption and economic growth.The paper emphasizes the importance of strategic investments in research and development, workforce training, and partnerships to maximize the potential of 3D printing technology in the automotive industry. It also highlights the need for agile manufacturing practices, intellectual property protection, and supply chain optimization. The paper provides a roadmap for manufacturers to navigate the complexities of adopting 3D printing technology for future growth and development.

Abhishek Sharma et.al., [18] This study evaluates the combustion performance of 3D-printed injector elements through hot testing under lab-scale operating conditions. It compares the performance between 3D-printed and conventionally machined injectors, highlighting the hot testing methodology and its utility for future engine development. The study highlights the potential of 3D-printed injector elements in reducing complexities and lead times in next-generation launch vehicle development. The study successfully evaluated the combustion performance of conventional and 3D-printed injector elements in a multielement combustor. Twelve hot tests were conducted on both types of elements at a 5-bar chamber pressure condition. The results showed similar C* efficiency for both sets of injectors. The lab-scale combustion qualification showed the adequacy of 3D-printed elements, but further investigation at higher chamber pressure conditions is needed. The study provides firsthand experience in designing and hot-testing a multi-element lab-scale combustor, which can be used for 3D printed element qualification. The study concludes that 3D-printed injectors can be confidently implemented in LOx-methane engine development.

Matthew N. O.Sadiku et.al., [19] 3D printing technology is revolutionizing car design and manufacturing, leading to widespread production of car parts and nearly complete car manufacturing.

This shift from clay to CAD has significantly influenced the design philosophy. Affordable 3D printing services are crucial for consumer vehicle development and maintenance, with the possibilities offered by 3D printing technologies having a significant impact on the automotive industry. This paper explores the significant impact of 3D printing on the automotive industry. The automotive industry is on the brink of a manufacturing revolution due to the emergence of 3D printing technology. As the value of 3D printing spreads, it will reshape the way we design, build, and maintain vehicles worldwide. Government initiatives and consumer demand for new innovations and lower prices are propelling the automotive 3D printing market forward. Automakers are increasingly integrating 3D printing into their production lines, aiming to produce complete cars, from utility concept cars to sporty electric cars.

Syed Fouzan Iftekar et.al., [20] This paper critically reviews recent trends in 3D printing technology, focusing on materials and their applications in the manufacturing industry. It highlights the need for further development to overcome its limitations, including high costs, low printing speeds, limited part sizes, and strength. The review also summarizes research conducted by experts in the field, including their focuses, techniques, and limitations. The review provides valuable insights into the technology's prospects. Multi Material SLM research has made significant progress, with numerous published articles and numerous research papers showcasing their machines. Future developments should focus on investigating material properties and process parameters, as well as identifying defects automatically. Multi Material 3D printing's future relies heavily on dedicated research studies and industrial partnerships. Numerical simulations for multi material PBF processes are still in their infancy, but lagrangian particle methods offer a more efficient approach. Further research is needed to validate these models and improve their accuracy.

Pradeep Kumar Mishra et.al., [21] 3D printing is a promising additive manufacturing technique for engineering components, offering reduced material waste, easy manufacturing, and energy efficiency. It outperforms traditional polymer composite fabrication in terms of complexity, time, and prototyping flexibility. Composites have been used since the 1900s, with fiberglass used in military aircraft, boats, pipes, medical devices, tool handlers, and train floors. Carbon fiber and Kevlar fiber were introduced in the 1970s for defense and aerospace applications. 3D printing fabricates physical objects layer by layer from CAD models, with the target shape modelled using CAD software and saved in STL file format. The process begins in the machine, and the part is removed after the last layer is completed. Composite 3D printing in aerospace and automotive is gaining popularity due to its potential to reduce carbon emissions and fuel consumption. It has been used to print parts like drones, unmanned aerial vehicle wings, and gas turbine engine components, reducing structural weight without compromising properties. 3D printing is replacing conventional manufacturing methods for automotive components due to the reduced time and ease of fabrication.

Mehrshad Mehrpouya et.al., [22] This study provides a comprehensive overview of the current state of powder bed fusion (PBF) techniques for additive manufacturing of multiple materials. It reviews emerging technologies in PBF multimaterial printing and summarizes the latest simulation approaches for modeling them. The topic of multimaterial PBF techniques is still new and undeveloped, but it is of interest to academia and industry on many levels. The study aims to cross-compare current methodologies and their advantages and disadvantages through a systematic review. Findings show that the development of multimaterial PBF techniques is still in its infancy, with many fundamental research questions not addressed before production. Experimentation has limitations and is costly, so modeling and simulation can be helpful but are heavily dependent on material data and computational power. The study investigates multimaterial PBF techniques and discusses novel printing methods with practical examples.

Matthew S. Thompso et.al., [23] 3D printing, also known as additive manufacturing (AM), has grown from rapid prototyping to mass production, attracting global interest in various fields such as science, engineering, production, education, and politics. AM is suitable for mass customization, such as in the production of hearing aids and dental straighteners, and high-value medical applications, such as chitosan 3Dp for tissue scaffolds, antioxidant bioresorbable vascular stents, and hydrogel-based materials for implantable medical devices. As AM matures, the role of additives in polymeric systems will continue to grow, with the industry's future directions focusing on additives in polymeric systems.AM technologies are based on building up a part layer by layer, with machine development initially outpacing material development. Unique and high-performance materials have been identified and implemented for various AM platforms, such as rigid engineering polymers for SLA-based technologies, nylons and polyetherketoneketone (PEKK) for SLS, and fiber-reinforced grades for FFF. Additives and functional fillers can help address challenges in speed, mechanical properties, environmental interaction, and manufacturing readiness. AM is poised for growth in manufacturing settings, particularly in aerospace, automotive, and defense applications.

Pankaj Kumar et.al., [24] 3D printing is an emerging technique for fabricating biomedical components, with researchers exploring various methods such as fused deposition modeling, inkjet printing, stereolithography, and selective laser sintering. This technology is used for designing bones, prosthetics, intervertebral disks, medical equipment, heart valves, and tissue building using blood vessels and drugs. The review article aims to explore different additive manufacturing processes, challenges, and future developments in 3D printing for biomedical components. This review explores the use of 3D printing techniques for creating biomedical components. It highlights the potential of 3D printing in producing prosthetics, relocating intervertebral disks, and developing bone-like structures for scaffolding, orthopedics, and dental work. The technology has sparked interest among medical professionals due to its ability to match patients' anatomy and complex internal structures. 3D printing also allows for the creation of functioning heart valves made of human tissue, blood vessel fabrication using living cells for vascular disease removal, and the production of drugs using purified metals, polished polymers, purified ceramics, and hydrogels. Additionally, 3D-printed skin could provide temperature, pressure, and pain sensations to robots, prostheses, and humans. The study also explores the potential of 3D-printed skin for enhancing the functionality of medical devices.

Sofia Pessoa et.al., [25] Building Information Modeling (BIM) has revolutionized the construction sector, allowing better information management and communication among stakeholders. 3D printing (3DP) has proven to be an interesting technology for architecture, engineering, and construction (AEC), offering economic, environmental, and constructability advantages like reduced building time and waste, mass customization, and complex architectural shapes. Universities and companies worldwide are developing and applying 3DP to building construction. However, new challenges arise, such as ensuring building performance. A literature review reveals that the focus has been on printability, structural soundness, safety, and durability, but still requires fire resistance and adequate hygrothermal and acoustic behavior. Civil engineering faces fragmentation and low productivity due to fragmentation and a lack of innovation. Additive manufacturing (AM) can help automate processes and improve efficiency. However, the adoption of AM remains slow due to its undeveloped nature. Current studies focus on printability, structural soundness, safety, and durability. Advancements in building physics are crucial for optimal performance and the introduction of AM in the construction market.

Purushottam Sharma et.al., [26] Rapid prototyping (RP) is a rapid and flexible fabrication process that involves layer-by-layer fabrication of three-dimensional physical models directly from computer-aided design (CAD). It involves creating a CAD model, converting it to STL file format, slicing the STL file, layer-by-layer fabrication, cleaning, and finishing the part. The use of computers in CAD, CAM, and CNC machine tools has increased. RP techniques include stereolithography (SL), selective laser sintering (SLS), fused deposition modeling (FDM), and laminated object manufacturing (LOM). SL uses photopolymerization, SLS uses powder material and CO2 lasers for scanning and sintering, FDM works on melting and solidification, and LOM observes layer-by-layer lamination of paper material sheets. RP has applications in various industries, including aerospace, automotive, biomedical, and electronic. This paper discusses rapid production (RP) technology for manufacturing industrial and domestic products using layer-by-layer material addition or deposit. It highlights various RP techniques and their applications, providing a platform for researchers and practitioners to compare trends and challenges. The paper also highlights the importance of considering product application, commercial viability, budget availability, and control over process parameters when choosing a RP technique.

N. Shahrubudin et.al., [27] Additive manufacturing is gaining attention in various industries, including healthcare, biomedical, aerospace, and construction. However, in Malaysia, there is a lack of acceptance of this technology, leading to calls for its development in biomedical products. A study using qualitative methods, particularly in-depth interviews, identified twelve key challenges faced by biomedical firms when using 3D printing technology. These include issues with binder selection, poor mechanical properties, low-dimensional accuracy, powder agglomeration, nozzle size, material choice, texture, lifespan, customization, layer height, and build-failure. Six challenges in managing 3D printing management include staff re-education, product pricing, limited guidelines, cyber-security issues, marketing, and patents and copyright.This study is crucial for the biomedical manufacturing sector, particularly in developing countries like Malaysia, as it provides insights into the use of 3D printing technology for manufacturing biomedical products. It serves as a guideline for new manufacturers, human resources, and management sectors, offering early insights into the challenges faced by companies adopting this technology. The findings aim to assist Malaysians in obtaining concise information about 3D printing technology's utilization in the manufacturing industry, emphasizing its safety and effectiveness in manufacturing medical products.

Andrea Zocca et.al., [28] As humanity plans manned missions to Mars, strategies for designing and operating safe environments for long-term work in space are needed. In-space manufacturing is crucial for timely spare parts supply. Additive manufacturing (AM) technologies, such as laser-beam melting, are attractive for manufacturing metal parts. However, handling metal powders without gravity is crucial for successful application in space. Gas-flow-assisted powder deposition, a method that compensates for missing gravitational forces in microgravity experiments, is used to fix metal particles in a gas flow driven by a vacuum pump.A stainless steel metal powder has been successfully processed in the LBM process at microgravity (µ-g) conditions in a parabolic flight campaign. A gas flow was established to compensate for gravitational forces, showing drag forces comparable to or even exceeding those on particles with a diameter of 38 µm. The study produced the world's first metallic tool, a 12 mm wrench, using LBM at µ-g conditions. Other parts were manufactured at hypergravity, µ-g, and 1 g, with no significant deviations found in the microstructure.

Nurhalida Shahrubudin et.al., [29] Additive manufacturing, also known as 3D printing or digital fabrication, is a rapidly emerging technology that forms solid 3D objects from 3D models in digital files. It is used in shaping the globe and producing various products, from plastics to advanced ceramics and metallics. This paper provides an overview of the Critical Success Factors (CSFs) for 3D printing technology in manufacturing firms, focusing on nine major factors: cost, technology, business and support, management and organization, materials, quality and accuracy, demand, the environment, and research and development.This review identifies Critical Success Factors (CSFs) that influence the successful adoption of 3D printing technology in the manufacturing industry. Management, organization, and technology are major issues influencing the implementation of 3D printing technology. Understanding these CSFs can help businesses and governments upgrade and improve 3D printing technology infrastructure in Malaysia. Future studies should use field observations and document reviews using qualitative and quantitative methods, with triangulation being the best method for enhancing validity and reliability. Focusing on specific industries like automotive, architecture, biomedical, education, and military, a more thorough study can provide more detailed information on 3D printing technology.

Kubilay Bayramoglua et.al., [30] Additive manufacturing (AM), also known as 3D printers, is a transformative technology in the precision manufacturing industry. It is versatile, flexible, and customizable, suitable for various sectors. The maritime sector is also increasingly using 3D printing technologies to meet various needs. This study examines the marine applications of 3D printers, their latest technologies, projects, and applications in the maritime industry, highlighting their wide range of working fields and the potential for innovation in the industry.Fused Deposition Modelling (FDM) or Fused Filament Fabrication (FFF) is a 3D printing technology that has reduced equipment prices and increased the variety of models. This technology is used for various purposes, from hobby to commercial production. This study reviews the application of 3D modelling and printing in the maritime context, highlighting the potential for future innovations. 3D printing models are more effective than traditional models in terms of time and cost. Additive manufacturing technologies are expected to increase the use of less materials and robots with integrated large-volume 3D printers. 3D printers offer significant benefits in the maritime sector.

Shiwpursad Jasveer et.al., [31] 3D printing is a non-traditional machining method that creates objects by laying successive layers of material. It is a tool-less process that reduces costs and lead times by stacking layers of material on each other, resulting in a more cost-effective and efficient production process. Current 3D printing technologies include Stereolithography (SLA), Fused Deposition Modelling (FDM), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM), and Digital Light Processing (DLP). The first step is to create a model using CAD software, which describes the object's geometrical properties. The model is then converted to STL file format, defining the external closed surfaces. 3D printing has revolutionized manufacturing by improving design, reducing lead time, and tooling costs. Stereolithography is popular due to its accuracy and surface finish, while Digital Light Processing offers a different light source. Fused Deposition Modelling is less expensive but suitable for home use, offering high accuracy and surface finish. Selected Laser Sintering is suitable for complex shapes and geometries but may not provide high accuracy or surface finish. Laminated Object Manufacturing is ideal for non-functional prototypes but requires post-processing.

Medhavi Kamran et.al., [32] 3D printing has revolutionized manufacturing by layering building parts using an additive approach. This article compares 3D printing with traditional methods for producing components and complex objects for various applications. 3D printing is versatile, rapid, and accelerates innovation. It reduces energy usage, minimizes material waste, and compresses supply chains. The paper covers feed mechanisms, process information, supporting materials, software, and recent developments in 3D printing technology. This paper presents the concept of 3D printing technology, comparing its cost and build time with traditional manufacturing methods. It provides an introduction, a brief history of 3D printing, and a detailed description of additive technology, feed mechanisms, wire filaments, and firmware classification. The paper concludes that 3D printing technology has the potential to revolutionize and reshape the world, encompassing various technologies at once, with economic benefits and social impacts. It has improved manufacturing industries and the way of life in various fields, such as medical, manufacturing, aerospace, biotechnology, and space research. 3D printing produces objects and complex structures according to need, enhancing the status of manufacturing industries and the way of life in the universe.

CH. Venu Madhav et.al., [33] 3D printing is a significant technological advancement in additive manufacturing, offering numerous advantages over conventional methods. It involves fused deposition modeling and layer-by-layer deposition of materials, which are processed using CAD software. 3D printing is particularly useful in the field of mechanical engineering for researching and developing various components, from everyday structures to aerospace components. Its advantages include simplicity, reliability, and precision, making it a popular choice for creating components that can be used as concepts. This paper provides an overview of additive manufacturing and its various applications in the engineering industry, not just engineering. The process is primarily used for creating components that can be used as concepts. 3D printing is a rapidly growing field in additive manufacturing, used in various disciplines like medical, civil, and electrical. It allows for quick prototype creation, verification, and reduced lead times. This paper reviews the importance of 3D printing in various applications in mechanical engineering, highlighting its potential for creating prototypes quickly and reducing lead times.

Onder Ayyildiz et.al., [34] This study aimed to develop a novel method for manufacturing customised spectacles using 3-D printing technology for a child with facial deformities due to Goldenhar syndrome. The process involved five steps: patient selection, using surface topography, 3-D printing of the phantom model, 3-D designing of the spectacles, and 3-D printing of the spectacles. The effective time required for 3-D printing of the spectacles was 14 hours, and the spectacles weighed 7 g and cost AUD$160.00 to manufacture.The 3-D-printed spectacles fitted precisely onto the face and were considered to provide a superior outcome compared to conventional spectacles. Optical alignment, good comfort, and acceptable cosmesis were achieved. One month after fitting, the 3-D-printed spectacles did not require further changes.Customised 3-D-printed spectacles can be created and applied to patients with facial deformities, as a significant number of children with facial deformities require spectacle correction. The 3D printing technique described herein may offer a novel and accurate option, allowing for the creation of customised spectacles to maximize optical alignment and comfort in special conditions. In conclusion, the 3-D printing technique described in this study may offer a novel and accurate option for producing customised spectacles for patients with facial deformities, providing a more suitable and comfortable solution for these children.

Vinod G. Cokhare et.al., [35] This research paper explores 3D printing, also known as additive manufacturing (AM), and its history, process, materials, and advantages compared to additive manufacturing. 3D printing, or additive manufacturing, is a process that creates 3D objects from electronic data sources through additive processes. The first 3D printer was designed by Charles Hull in 1984, who pioneered stereolithography and the STL file format. 3D printing has evolved into more useful, affordable, and applicable in various fields such as research, engineering, medical, military, construction, architecture, fashion, education, and the computer industry.3D printable models can be created using CAD design packages or 3D scanners, which can be challenging for average consumers. Additive manufacturing systems can reduce construction time to a few hours. However, 3D printing technology has disadvantages such as intellectual property issues, size constraints, and limitations in raw materials. Large objects are not feasible with 3D printers, and the cost of purchasing a 3D printer is high.The aerospace and aerospace industries are increasingly using 3D printing for design optimization, as smaller vessels require more efficient and accurate parts. The medical and dental industries use 3D printing for dental crowns and tools, while the jewelry sector offers new design freedoms and improves traditional processes. Architectural models are also being produced using 3D printing, offering a fast and economical method.

Jay Wilhelm Timothy et.al., [36] The market is focusing on delivering various goods for commercial, government/military, and scientific exploration. The retirement of NASA's space shuttle fleet and increasing demand have created a gap in space goods delivery. Private companies and space agencies are now using sounding rockets for delivery and research. Orbital ATK, a company capable of such delivery, uses Solid Rocket Boosters (SRBs) in their launch configuration. SRB systems provide added thrust to launch vehicles, making them less complicated and cost-effective compared to liquid propulsion systems. The nozzle, responsible for channeling thrust, is subjected to intense heating due to interaction with combustion flow. An investigation into nozzles that can withstand solid rocket motor firing conditions and maintain acceptable performance was conducted using graphite and 3D-printed titanium nozzles. The focus is on the precision of manufacturing methods, the survivability of parts during operation, and the thrust and pressure profiles of different nozzle types.

S. Soller et.al., [37] Airbus Safran Launchers is developing injectors for its current and future liquid rocket engines using additive manufacturing. The company has taken a stepwise approach to developing all capabilities to design, manufacture, and operate injectors made by additive manufacturing without compromising existing engines. This includes material characterization, updating design tools, single element screening tests, and designing, manufacturing, and hot-fire testing different injector configurations. The research activities aim to fully capitalize on the possibilities offered by additive manufacturing for future liquid rocket engines, whose design is not yet fixed. The company has matured the technology to the point where further qualification and application into flightworthy components for use on the Ariane 6 can be performed. The technology is further investigated within research and technology programs to fully exploit its capabilities. In conclusion, Airbus Safran Launchers is pursuing a comprehensive approach to applying additive manufacturing to liquid rocket engine injectors, demonstrating the maturity of the processes and allowing for further qualification and application into flightworthy components.

Mohsen Attaran et.al., [38] 3D printing has revolutionized manufacturing by enabling the production of moderate-to-mass quantities of products that can be individually customized. This technology reduces manufacturing lead times, shortens the time to market for new designs, and meets customer demand more quickly. This study discusses 3D printing's evolving technologies and trends, identifies implementation challenges, explores its transformative potential for different industries, and surveys its impact on various industry segments. 3D printing facilitates easy on- demand manufacturing of replacement parts, allowing parts to be printed in remote locations by local distributors and service providers. The need for large bulk inventories is outdated. 3D printing technology is still in its infancy and requires further advancements in technology, including reducing costs of printers and printer material and increasing printer capabilities to be faster, more accurate, and work autonomously. There are tremendous opportunities in various industries, from industrial to retail, for 3D printing to significantly impact product manufacturing and business operations. Almost every sector, including automotive, aerospace, and medical, is riding on the 3D opportunity, bringing innovations to reality. However, 3D printing should be seen as a complement to traditional factories, allowing for better product quality and the ability to manufacture entirely new ones that were previously impossible.

Azhar Equbal et.al., [39] Rapid tooling (RT) is a progression of rapid prototyping (RP), which aims to reduce lead time and improve tool quality by producing tooling directly from CAD models. This technology plays a significant role in increasing the pace of tooling development. Rapid tooling has already had a dynamic impact on the engineering environment, with international competition driving quick and economic product development and market introduction. Rapid tooling techniques have significantly reduced the cost and time required for the preparation of molds and dies, which account for the majority of overall manufacturing costs and cycle time. The rapid manufacturing of prototype components assesses aesthetics, ergonomics, and fitment, playing a positive role in achieving these goals. Existing techniques, particularly in casting and injection molding, have been successful in developing direct methods of making tools on RP machines. Major companies and universities are involved in the expansion and applications of RT, and this new trend in manufacturing has had a major influence on many related engineering activities. However, rapid technologies are still slower than traditional manufacturing technologies, and the number of available materials is limited. More research is needed to overcome these limitations and develop rapid manufacturing techniques to change the future of the manufacturing sector.

Stefan Junk et.al., [40] The application of additive manufacturing technologies is becoming increasingly prevalent in various product development sectors, allowing for quick and inexpensive use of prototypes and small series. 3D-Printing (3DP) is one of the highly cost-efficient technologies, but its use is currently limited to presentation models with fixed and rigid structures. This paper introduces two new developments that offer new applications for 3DP: a new design method for creating moveable functional models and a new application of 3D printing with plaster powder for the rapid manufacture of thermoforming tools.The paper emphasizes the importance of considering the special requirements for 3D printed prototypes and components, as well as the operating principle of these new technologies, which typically build materials in layers. The paper also presents two case studies that demonstrate the advantages and disadvantages of these developments compared to conventional technologies.The paper also discusses the economic advantages and disadvantages of 3D printing in the field of Rapid Tooling, highlighting its potential as an economic alternative to slow conventional technologies and expensive laser-based additive manufacturing technologies. It also discusses plans for tests in metal forming, where printed tools are used to form metal sheets, requiring new post-processing methods to increase infiltration depth and tool strength.

III. Conclusion

3D printing, or additive manufacturing, is a transformative technology that builds objects layer by layer from digital models, offering a range of methods and applications. Key methods include Fused Deposition Modeling (FDM), which is cost-effective and popular for prototyping; Stereo lithography (SLA), known for high precision using UV-cured resin; Selective Laser Sintering (SLS), which creates durable parts from powdered materials; Digital Light Processing (DLP), which provides high speed and resolution; and Binder Jetting, suitable for large-scale and full-color prototypes. The technology finds applications across various sectors, including rapid prototyping in product development, custom prosthetics and implants in healthcare, lightweight components in aerospace and automotive industries, construction of buildings with reduced labor and waste, and the creation of customizable consumer goods. Overall, 3D printing is reshaping manufacturing by enhancing efficiency, enabling personalization, and fostering innovation, though challenges such as material limitations and cost for large-scale production persist. Ongoing advancements continue to expand its potential and applicability across diverse fields.

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