# Automation and manufacturing of smart materials in additive manufacturing technologies using Internet of Things towards the adoption of industry 4.0

*VorugantiNaresh* Kumar[1*], *Muntather M.* Hassan[2], *Ruby* Pant[3], *V. Hima Bindu*[4], *G.* Sivasankar[5]
[1*]Associate Professor, Department of CSE, CMR Technical Campus, Hyderabad, Telangana, India
[2]Department of Structurals Techniques Engineering, College of technical Engineering, The Islamic University, Najaf, Iraq; Department of Structurals Techniques Engineering, College of Technical Engineering, The Islamic University of Al Diwaniyah, Al Diwaniyah, Iraq; Department of Structurals Techniques engineering, College of Technical Engineering, The Islamic University of Babylon, Babylon, Iraq
[3]Department of Mechanical Engineering, Uttaranchal Institute of Technology, Uttaranchal University, Dehradun, 248007, India
[4]Department of ECE, GRIET, Hyderabad, Telangana
[5]Associate Professor, Department of Artificial Intelligence & Machine Learning, Aditya Engineering College, Surampalem,India

**Abstract.**Business 4.0 emphasizes mass personalization and customisation. Even though additive manufacturing (AM) technologies are capable of producing single items, they are not suitable for 3D printing in large quantities. They are at a disadvantage because they can't finish the industrial process in big volumes. As a result, all activity utilizing additive manufacturing techniques in industrial manufacturing is cautious. Thus, that is the basis of this study. In order to increase the dependability of additive manufacturing procedures and large-scale 3D printing of smart products for global businesses, the research attempts to identify and take advantage of Industry 4.0 technologies. Our study focuses on the requirements of Industry 4.0 technology in data science and additive manufacturing applications. Technologies (ITs) are used in additive manufacturing. Business 4.0 emphasizes mass personalization and customisation. Even though additive manufacturing (AM) technologies are capable of producing single items, they are not suitable for 3D printing in large quantities. They are at a disadvantage because they can't finish the industrial process in big volumes. As a result, all activity utilizing additive manufacturing techniques in industrial manufacturing is cautious. Thus, that is the basis of this study. In order to increase the dependability of additive manufacturing procedures and large-scale 3D printing of smart products for global businesses, the research attempts to identify and take advantage of Industry 4.0 technologies. Our study focuses on the requirements of Industry 4.0 technology in data science and additive manufacturing applications. Technologies (ITs) are used in additive manufacturing.

* Corresponding author:nareshkumar99890@gmail.com

**Keywords:** Global business, Internet, Software Design, wisdom

# 1. Introduction

Business 4.0, or the fourth industrial revolution, brought about a lot of developments. Smart manufacturing, or continuous automation of the production process, is becoming the focus of global trade [1] and is currently one of the most comprehensive courses offered. The foundation of business 4.0 is the integration of cyber-physical and physical systems, information sharing, self-managing production and storage facilities, and process monitoring [2]. Machine-to-machine (M2M) communications, Industry 4.0, 5G, Software Design Network (SDN), and other technologies are being used by the industrial industry [3]. Embedded software, sensors, and computer-like devices 4,444 technologies can communicate to process data transfer and viewing times [4]. Use the ERP cloud to oversee the delivery process. Additionally, the interface has revolutionized a number of items on the market. The production process can be digitized and offers various benefits. This is discussed in the article along with time efficiency and improvement. Production and enhancement of quality. Communication expenses are decreased when equipment can communicate without the need for human involvement. Article 5-10: Harassment one. 2014 saw the Internet of Things start to grow quickly, ushering in Industry 4.0 as global technology started to become a reality and pave the way for the Internet of Things. Achieving the Gartner Hype Cycle "Expected Peak Rise" To mark the organization's 25th anniversary, the Pew Research Center released its 4,444th annual research report in May 2014.

The World Wide Web, which was created by Sir Tim Berners-Lee, will grow and expand in 2025, according to a number of Internet experts on embedded systems, wearable technology, and the Internet of Things. Article experts think that writing, wisdom, and knowledge are important. Article Body art is among the primary methods. The benefits of Chapter include the enhancement of human existence [11]. Old shoes can support unique aspects of many site kinds and are covered. Artificial intelligence, the Internet of Things, and 3D printing are examples of technologies that are employed in Chapter Numerous health issues still exist.

## 1.1 Additive manufacturing

Developed in 1987, layered manufacturing technology is the most advanced layered printing technology in the business. accepts the layering of components concept.This device generates tangible goods that are recyclable. a three-dimensional CAD-created model of an object or three-dimensional model of an object uses a layer computer controlled machine tool to compile component information [20]. Such as the integration of computer-aided design (CAD), materials science, mechanical engineering, laser beam technology, and manufacturing engineering. The most popular materials for use in additive manufacturing methods are as follows: decreases design time, produces more customized goods, produces intricate geometries and components directly, and eliminates waste. A few commonly used additive manufacturing techniques are stereolithography (SLA), laser metal deposition (LMD), lamination targeted manufacturing (LOM), fused deposition modeling (FDM), selective laser sintering (SLS), and 3D printing (3DP). Industrial use and research and development [21–24]. Electro Optical Systems (Germany), Arcam (Sweden), MCP Tooling Technologies Ltd. (UK), Stratasys (Israel), 3D Systems (USA), Optomec Inc. (USA), Z Corporation (USA), and other firms are a few examples of these companies. Numerous sectors employ additive manufacturing due to its versatility. For instance, in the aviation industry Indeed, these are useful for quickly simulating samples of huge aviation areas. These can also be utilized to make auto components. Technology for quick tooling and prototyping. In addition to its application in mechanical engineering, additive

manufacturing has been found useful in the medical sector for producing tangible goods and crafts. DICOM picture data can also be utilized with AM to build 3D printed models [12].

### 1.2 Internet of Things

The Internet of Things had a significant year in 1999 (IoT). Co-founder and MIT AutoID Center director Kevin Ashton invented the phrase "Internet of Things" in 1999 while serving as an assistant brand manager for the US multinational client firm Procter & Gamble (Procter & Gamble). He looked. Equipment with radio frequency identification (RFID) is crucial. The Internet of Things enables computers to control each device independently and uses radio waves for identification. He was therefore interested in employing RFID technology to assist individuals in managing the delivery process of Procter & Gamble. An IoT network is composed of four distinct layers: (a) The network layer, which enables data transfer via wired or wireless networks; (b) the sensing layer, which makes it easier to integrate sensors and actuators. Newly developed IoT protocols that leverage low-power local area networks are Sigfoz, LoraWan, and NB-IoT, among other networking and data IoT protocols. an enormous number of inexpensive, energy-efficient devices. According to Lee and Lee Internet of Things Providers, there are five keys to 2015: RFID is used to identify products; wireless sensor networks are used to track and monitor objects (e.g., Part: Maintenance Product Location); middleware facilitates communication between linked devices; and so on. Chapter [Chapter] Article Setting up an interface to facilitate communication between people and technology They exist in numbers.

IoT is used in large businessesAviation, automotive, telecommunications, medical, pharmaceutical, retail, logistics and supply chain,Manufacturing, industrial processes, transportation sector,Business and Agriculture. Internet of Things refers to technology that can also help people fight the epidemic Chapter:

Hospital Connect: A complete hospitalnetwork will help prevent the spread of the diseaseImmediate response to patient health events.UAV (UAV) Applications: Because it is not recommended to have it.face-to-face interactions, drones fill job gaps such aspackage delivery, remote thermal testing and remote controlVirus and other detection articles.

Benefits of Blockchain: Information is securely stored on paper nodes, and access to it is restricted to two people. This article can help by providing solutions to lessen the burden of the condition on patients. Blockchain is utilized to store patient information.

Chips on patients: Meat Network Patients' bodies can also aid in maintaining their health. provision of quality medication in times of need.

IoT Control Button: The following are the sole ways that hospital patients can make requests for meals, restrooms, and other services: Click the programmable line button to initiate an event. a single. Technologies associated with the Internet of Things, including robots, big data, 3D printing, machine learning, and artificial intelligence, are evolving quickly.

These technological innovations have resulted in significant changes, as the Internet of Things has shown itself to be a useful tool for comprehending gadgets. The world surrounding these gadgets comes to life in part because of their activation. Company Remote job management and control are made possible by decentralized management. IoT, or the Internet of Things, has been developed using new support technologies and is the way of the future of computing since the advent of the Internet.

### 1.3 Business 4.0

The book revolution was the precursor to the business revolution. Up to the point where the production process is almost 18 years old. Around this time, the first wave of industrialization started. The Second Industrial Revolution and the development of electrical devices from 1760 until the middle of the 19th century Where are assembly lines used in large-scale manufacturing?

The emergence of digital technology—currently the most distinctive—has taken place. the late 20th century saw the third industrial revolution. Business 4.0 He put forth the notion of significant changes. Thorough study is being conducted to advance 3D printing technology as the industry grows to understand its significance [13]. Efficiency and Mass Customization: Modern IT Trends have transformed the production of personalized goods. The cloud is now able to develop a customer-based production model thanks to these Business 4.0 technologies. ideas. Table 1 displays the primary Industry 4.0 technologies utilized in production. Production processes are being renewed as a result of Industry 4.0. Smart manufacturing that incorporates multiple technologies Developers look for factory prospects with smart design in order to expand the production process globally. Germany's economic center, the northern region of Rhine-Westphalia, is having difficulty with Internet of Things Development and Improvement. Industry 4.0-related research projects are being implemented by numerous universities and R&D institutions in the area. These projects are finished and ready to be handed to the firm. About 200 million euros are being invested by the German government in Industry 4.0. Productivity is predicted to rise by 30% and boost the economy of the nation by a total of 15.6 billion euros. The fastest broadband Chapter high-speed network, with over 100 megabits per second, is found in North Rhine-Westphalia, making data extremely safe. About a thousand researchers across states are focusing on it.

**Table 1.** Technologies in Business 4.0

| S. No | Technologies | Description | References |
|---|---|---|---|
| 1 | Edge Computing | Article on technology implanted in the human body. The body permits the use of digital communications and wireless networks. Section for everyone worldwide. The ticket can be kept in the car body using these mechanisms. It is a sizable Chapter. instantly keeps an eye on the patient's health. | [22] |
| 2 | Implantable Technology | Supply chain digitization will involve cloud supply chain solutions for better reaction times and overall improvements. Article Quickness and economical efficiency. ideas offers an integrated chain frame framework for IoT cloud design. synchronized sharing of data Capacity for production and sales Kev. | [23] |
| 3 | Digital Supply Chains | Digitalization of the supply chain will take action cloud supply chain solutions improved response and improvements Article Speed and cost effectiveness. thoughts Provides chain frame layout built-in IoT cloud design Synchronous data sharing Production and sales capacity Kev. | [22] |
| 4 | BlockchainIoT | Blockchain Internet of Things Fusion Technology has undergone appropriate market testing. a basic infrastructure for transportation. Materials like cash or data, fraud control, private blockchain network. Chapter transactions will benefit immediately from this blockchain and IoT combination. Blockchain-based initial decentralization of Bitcoin allows cryptocurrencies to be exchanged for cash. Every data flood is in the transport mechanism. | [24] |
| 5 | AI | Deep learning neural networks and machine learning | [21] |

| | | | |
|---|---|---|---|
| | | algorithms offer a wide range of uses. Its artificial intelligence produced data and machine translation. expertise in the medical field and other fields of industry, materials science, and manufacturing that is dependable and efficient. | |

## 2 Need for training

Using additive manufacturing technology, the following restrictions are removed: The following conventional manufacturing techniques enable businesses to produce bespoke goods and designs with improved performance. Worldwide industrial base Production processes for additive manufacturing applications could be more effectively optimized by concentrating on advancing additive manufacturing technology [14]. This demonstrates how easily procedures for additive manufacturing can be modified and adjusted. Production is high. The Scientists Chapter connects disparate technological fields. The popularity of digital manufacturing rises as the economy becomes better. A rise in customized quality and improved output is driving the Business 4.0 wave. The production process's level of automation will be further raised in order to boost output, efficiency, and repeatability of the traditional AM technique. Learning is the primary driving force behind this article. Utilizing 3D printing precision technologies in conjunction with Industry 4.0 technology. This article's primary research goal is to ascertain. Article: The necessity of researching additive manufacturing processes and utilizing the Internet of Things in additive manufacturing Applications of electronic manufacturing processes in Chapter Enterprise 4.0.

## 3 Materials and procedures

Fundamental ideas in data science include automation, artificial intelligence, business 4.0, 3D printing, additive manufacturing, and the internet of things. education essential components integrated in many ways to produce the effect of research articles limiting the literature review's reach Section Objective [5]. It is where most research publications are found. 4,444 Numerous study articles from referees have been added to the well-known search engine Google Scholars. To concentrate on research alternatives, resources like IEEE Xplore, ScienceDirect, ResearchGate, and Taylor & Francis are also utilized. Research goals for each chapter. We also looked at the body of previous research.

## 4 Write smart data using additional devices

Biomedical implants employ a fast prototyping method for printing thermoplastic polymers, like polylactic acid, which is environmentally friendly and can break down in the body over time [46]. For improved flex characteristics and bending strength in 3D printing, optimize the FDM process parameters, such as the original layer thickness. As a result of improved manufacturing techniques, body and part development Numerous industries can use the technique to produce engineered goods with excellent performance and quality. Printing programmable data can also be accomplished with additional production equipment, in addition to conventional production methods. Additionally, many layers of conventional materials can be produced using 3D printers in addition to other materials. Information from intelligence sources is also available [15].
Smart data is slow to make The use of 4D bioprinting has led to the rise of Medicine 4.0. Smart materials such asmemory polymers can be used to make 3D printed organs that can adjust their shape when placed in the human body. These smart dental implants are useful

when traditional dental implants are not enough. ArticleEspecially in emergency situations. Recently, engineers at Rutgers University developed a 3D printed, light-activated smart gel Chapter that changed its body strength in response. Smart gel shrinks in response to light and can be used to create medical productscontracts. Using smart materials to 3D print end productswill help fulfill personal greatness, which is the important characteristic of Industry 4.0.

# 5 Internet of Things as technological support for additive manufacturing

IoT has a significant impact on the rapid prototyping process. IT, in order to establish a dynamic "network collaboration" setting for the development of systems that manage the planning, building, and timely delivery of goods. Faster speed, less equipment, and greater customisation are all made possible by the internet of things. Techniques from additive manufacturing were used in its design. Design and manufacturing section and control can benefit from the application of 3D printing and data physics system integration. Additionally, it gives users design freedom and multidimensional extrusionone. -based CAD software, IoT devices, 3D printers, and human-machine interfaces are examples of embedded IoT components. IoT-enabled additive manufacturing equipment installed. These Internet of Things (IoT) devices send data to both humans and machines for tracking and interface (any platform that can be controlled remotely, like a laptop, tablet, or smartphone). Data is transferred to the cloud platform using these APIs. Cloud searches for pertinent content and analyzes data Part Platforms on the cloud, such as 3D printers, offer event information. contents No matter how far away the user is from the AM machine, they may still access the outcome. commercial procedure Figure 1 depicts the IoT 3D printer.

# 6 Smart IoT 3D printing

### 6.1 Smart tablet case for medical compatibility

Patients with chronic illnesses should be mindful of their health for their own sake as well as for the sake of others. Cut back on medical expenses. 3D-printed pill box A microprocessor designed to save energy is installed in the copy box. real-time sensor, buzzer, and clock. pertinent data 4,444 patients' health statuses are stored on a cloud platform for easy access. When a patient is fasting, doctors can determine when to take medication. Section The server receives a request from the microcontroller. Medication Schedule revised. Patients are advised to schedule their medication using an audio signal (buzzer) and to identify the tablets in the medication box by sending a signal at the same time.

### 6.2 IoT-enabled wearable device detects body temperature

Section Pain can be detected by core body temperature, such as fever, weariness, or insomnia. Conventional thermometer readings on skin temperature, however, can differ

### 6.3 New loop antenna printing for electronic devices

Stretchable loop antenna made of 3D printing for wireless strain alleviation Article Information's intended use. Ninjaflex, a 3D printable product material used as a substrate for loop antennas, was created using an additive manufacturing process based on a fused deposition model. These 3D print antennas are employed in real-time healthcare and can be sent in smart electronics.

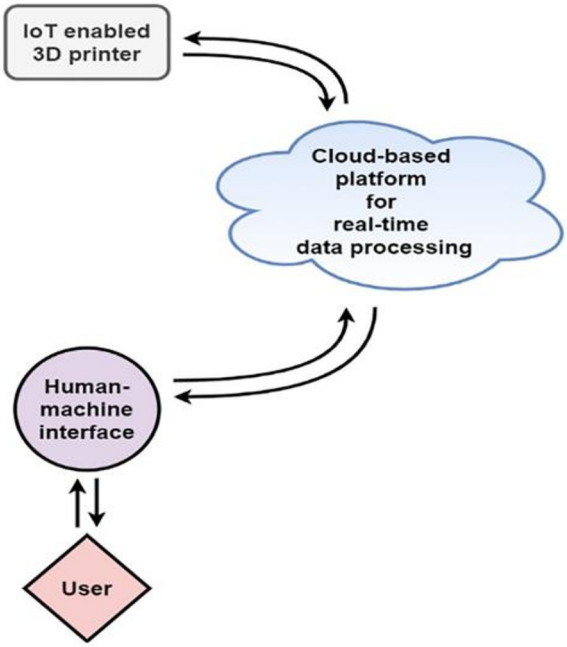


**Fig. 1.** IoT enabled automated additive manufacturing systems

**6.4 3D printing eagle eye**

Small lenses, such as four 3D printed lenses with varying focal lengths and views totaling 70 in length, can also be created using AM technology. can be applied appropriately to Micro Multi-Hole Imaging System and Applications, including security targets, endoscopy, optical metrology, and optical detection.

## 7 Digital manufacturing system using additive manufacturing and the Internet of Things

Patients with chronic illnesses should be mindful of their health for their own sake as well as for the sake of others. Cut back on medical expenses. 3D-printed pill box A microprocessor designed to save energy is installed in the copy box. real-time sensor, buzzer, and clock. pertinent data 4,444 patients' health statuses are stored on a cloud platform for easy access. When a patient is fasting, doctors can determine when to take medication. Section The server receives a request from the microcontroller [16]. Medication Schedule revised. Patients are advised to schedule their medication using an audio signal (buzzer) and to identify the tablets in the medication box by sending a signal at the same time.

## 8 Additive manufacturing must meet the importance of Industry 4.0

The Internet of Things Industry 4.0 is primarily propelled by additive manufacturing techniques. These additive manufacturing techniques, however, lack sufficient flexibility. has been tailored to work settings because of the few connections and low output of the intended product. and the roughness of the working surface, poor production rates, hazardous emissions, and the inability to increase repeatability. Because of these problems,

modeling and simulating additive manufacturing processes are essential requirements for both the present and the future [17].

## 9 Essential automation for Industry 4.0 through additive manufacturing

Making Use of the Internet of Things Jobs are in greater demand as innovation rises. In order to close the gap between customer desire and reality, information processing technology and additive manufacturing are developing quickly. Automation of Additive Manufacturing Technology will assist in resolving some of the issues that have impeded the development of 3D printers by incorporating the most recent IT developments. Scene Gain adaptability. It was discovered that the apps worked well for automating the 3D printing procedure. Table 2 Chapter Section provides a brief description. This technique is used in the process of additive manufacturing. Rapid prototyping methods' capacity to provide appropriate items at a lower cost than the manufacturing process makes something testable available. Actually, self-care programmable interfaces will speed up and improve the efficiency of additive manufacturing operations. Big business is changing quickly in terms of adaptability and efficiency. Section: Additional Need for Generating Power.
More current entries Computer-Based Techniques in 3D Printing Processes Open Up Vast Manufacturing Engineering Opportunities and Provide the Groundwork for Ways to Address Global Market Needs.

**Table 2.** Major automations in Industry 4.0

| S.No | Major Automation | Description | References |
|---|---|---|---|
| 1 | Beacon technology | Beacons are incorporated into 3D printers. Every sign is identified by a unique number (ID). indicate "yes" The portion that deals with Bluetooth applications for mobile devices. These programs send and receive IDs. Through Wi-Fi, it transmits this data to the cloud platform. Details for cloud identification Reply to the user with a message using their ID. | [4] |
| 2 | Artificial Intelligence | In this system, four distinct nozzle components are represented by a real-time camera. Multiple levels are detected and predicted using convolutional neural network methods and elevations. 3D printer printing flaws. | [22] |
| 3 | Visualization of the Internet of Things in Smart Factories | Additive Manufacturing Systems (FAMS) When a consumer uses a mobile device or the internet to request certain information (color, size, shape, or number of pieces), this content is recorded and saved on the cloud platform. Use application programming interfaces (APIs) and Internet of Things devices to access data. three-dimensional as a product prepared to generate workflows using printer cloud data. | [21] |
| 4 | Networked physical systems | Physical systems that are networked generating 3D models for the visual additive manufacturing technologies identification access system using dynamic additive manufacturing technology. In the shortest amount of time, this | [22] |

| | | | |
|---|---|---|---|
| | | technique improves the productivity and capacity of the large-scale production process. | |
| 5 | Blockchain | To achieve tremendous personal achievement, build a digital framework built on blockchain, digital twins, and AM. Section: Production machinery modifications. Every modification is intended to be retained. The process file has undergone changes. Through supply chain centralization, resource pooling, and instant stakeholder involvement, the technology makes on-demand production possible. Partitioning Partnership. | [21] |
| 6 | Cloud | Additive production adopts the intelligent allocation optimization, matching, and cloud interface model (service model, dynamic module) to enhance AM. The system is effective and yields high-quality results. | [24] |
| 7 | Big Data-Based Framework | Big Data-Based Framework This system is intelligent and dependable thanks to information technology. The product life cycle is defined, exported, and stored by sustainable additive manufacturing, real-time and non-real-time information on the beginning of life part (BOL). details that become available later Decision-making involves preprocessing. | [19] |
| 8 | Digital Twins for Additive Manufacturing | Digital Twins for Directed Energy Deposition (DED) AM and Laser Powder Bed Fusion (LPBF) The system is made especially for 3D printing that isn't typical. Studies were conducted based on the utilization of electricity rather than electricity. Model has 90% testing accuracy in predicting errors. DED instances, 87% LPBF<br>Additive manufacturing systems with multi-axis robots can be used to 3D print anything from a variety of sources. Several degrees of freedom prevent limitations on movement tools for extrusion. | [23] |
| 9 | Robot-assisted additive manufacturing | Effective modeling and control techniques are essential for additive manufacturing technologies. -based augmented reality approaches are being assessed for use in metal- and extrusion-based additive manufacturing. Additionally, this method offers a more realistic data prediction generating procedure. We are able to work with 3D printing and create high-quality goods for every product. | [24] |
| 10 | Augmented reality in additive manufacturing | Effective modeling and control techniques are essential for additive manufacturing technologies. -based augmented reality approaches are being assessed for use in metal- | [18] |

| | | | |
|---|---|---|---|
| | | and extrusion-based additive manufacturing. Additionally, this method offers a more realistic data prediction generating procedure. We are able to work with 3D printing and create high-quality goods for every product. by making extrusion optional. | |

## 10 Main benefits of this study

In the additive manufacturing process, the most frequently occurring automation variables are: lower labor costs, lower production errors, and higher-quality products. The global market value of autonomous 3D printers was US$507.8 million in that year, according to data conducted by Mordor Intelligence Market. CAGR attributed to robotics in 2019 The AM process's level of automation is predicted to reach 37.14% in the following year [24]. The use of automated 3D printers is expected to grow in the following sectors: education, food, automotive, manufacturing, medical and dental, aerospace and military, and manufacturing. The IT and fashion industries are two of the sectors.

## 11 Limitations and future work

Section has a future since automated rapid prototyping is a flexible technology. The reason for selecting this research field was Chapter Harassment The research done for this article is purely theoretical; it is not experimental. Become one of 4,444 people[26][27]. Questions about the autonomous 3D printing process are new and updated. The earlier content is still not accessible. education in this sector based on research. Consequently, the topic does not have enough search phrases. arrive on schedule Article The production process will benefit from automation. It is possible to properly coordinate automation technologies and 3D printing to produce a single print. It takes less time to complete highly efficient production systems that satisfy end customers' expectations. Cyber-physical cognitive systems can facilitate rapid prototyping with great customization. Human-machine interfaces will be used extensively, signaling the arrival of Industry 5.0. The technology of 4D and 5D printing machines will be the focus of the fifth industrial revolution. The medical field will make extensive use of this technology for individual growth. As a result, the way the final 4D/5D printing product Section operates improves their capacity for environmental adaptation. When the framework for the 3D-printed smart glasses with lenses is ready, Section tracks user activity using the data returned from the header. Various parameters are obtained from [28-37].

## 12 Conclusion

AM protocol. In Chapter Educational Research, technology is also examined. Because I can make things using a multitude of materials, the product is available in a variety of materials. In addition to offering easy 3D design and modeling, IIoT enables additional technologies for AM processes. Freedom will be the production's primary economic goal. Reduction of waste and personalization and customisation. Pollution will go down by percentage if more production machines are fitted with electronic equipment and produced at a suitable size. 3D mechanization Use of IoT printers in practice Business 4.0. There is also trading that is limitless. Investigate this technology; there are numerous uses for it. A significant shift in the business will occur from the use of smart data as input data for 3D

printers, which will create a vast smart and smart manufacturing market with easily changeable things.

## 13 References

1. R.Y. Zhong Xu, E. Klotz, S.T. *Newman, smart manufacturing Background of Industry 4.0: Overview*. Engineering, **3**, 5, 616-630,(2017).https://doi.org/10.1016/J.ENG.2017.05.015.
2. A.W. Colombo, S. Karnouskos, O. Kaynak, Y. Shi, S. Yin. *Industrial Cyber PhysicsProceedings: Body Front of the Fourth Industry*. IEEE Ind. Electron.Journal, **11**, 1, 6-16, (2017). https://doi.org/10.1109/MIE.2017.2648857.
3. X. Hong, Y. Wei, D.K. Griffith, N. Golmie. *Internet Research onThings: ACyber-physical systems perspective*. IEEE Access, **6**, 78238-78259, (2018).https://doi.org/10.1109/ACCESS.2018.2884906.
4. G.F. Barbosa, R.V. Aroca. An IoT-based control and monitoring solution. J Powder Metall Min., **6**, 158, (2017). https://doi.org/10.4172/2168-9806.1000158
5. A. Haleem, P. Gupta, S. Bahl, M. Javaid, L. Kumar. *3D scan ofcarburetorBody Works using the COMET 3D scanner powered by COLIN 3D software: Questions and ChapterSolution, God*. Today: procedure, **39**, 1, 331-337, (2021), https://doi.org/10.1016/j.matpr.2020.07.427.
6. S. Barr, M. Javaid, A. Bagha, R. Singh, A. Haem, R. Vaishya, R. Suman. *Biosensor Applications in the Prevention of Virus-19 Viruses*, Apollo Medicine, (17), (2020)
7. A. Sharma, S. Barr, A. Bagha, M. Javaid, D. Shukla, A. Haeem. *Multi-AgentApollo Pharmaceuticals' Application Regarding the Use of Chemicals to Prevent the COVID-19 Pandemic*, **17** (2020)
8. S. Kushwaha, S. Bal, A.K. Bagha, K.S. Parmar, M. Javaid, A. Haleem, R.P. Singh. *Important applications of machine learning in the COVID-19 epidemic*. The Journal Mergers and acquisitions, **5**, 4, 453-479,(2020)
9. R.P. Singh, M. Javaid, R. Kataria, M. Tyagi, A. Halem, R. Suman, *ImportantVirtual Reality Applications in COVID-19 Pandemic, Diabetes and MetabolismSyndrome:Research and Analysis*, **14**, 4, 661-664, (2020)
10. R.P. Singh, M. Javaid, A. Haleem, R. Vaishya, S. Bahl. *The Meaning of HealthInformation Technology (HIT) in the context of the COVID-19 pandemic: PotentialResponsibility and Competition*. Business and Management Handbook, **5**(4) (2020).
11. T. Harwood. *History of the Internet of Things (IoT)*. Postscapes, (2019)
12. J. Anderson, L. Rainie,Internet of Things will explode in 2025, Pew Research CenterCentral. (2014)
13. S. Barr, T. Corona warrior Goyal. *Who is at risk during the Covid-19 outbreakCurrent Medical Research and Practice*, **10** (2020)
14. R. Suman, M. Javaid, A. Haleem, R. Vaishya, S. Bahl, D. Nandan. *Sustainability of coronavirus on different surfaces*. J Clin Exp Hepatol., **10**, 4, 386-390, (2020)
15. K.P. Iyengar, R. Vaishya, S. Bahl, A. Vaish. *Impact of the coronavirus pandemic on the supply chain in healthcare*. Br. J. Health Care Manag., **26**, 6, 1-4, (2020)
16. R. Vaishya, S. Bahl, R.P. Singh. Letter to the Editor, Response: TelemedicineProviding diabetes careduring coronavirus outbreak and national lockdown in India Chapter : Physician's Guide, Diabetes and Metabolic Syndrome: TreatmentResearch and Evaluation, **14**, 4, (2020)
17. K.Iyengar, S.Bahl, R.Vaishya, A.Vaish. *Challenges and solutions in meeting up the urgent requirement of ventilators for COVID-19 patients*. Diabetes Metab Syndr: Clin. Res. & Rev., **14**, 4, 499-501, (2020)

18. M.Javaid, A.Haleem, R.Vaishya, S.Bahl, R.Suman, A. Vaish. *Industry 4.0 technologies and their applications in fighting COVID-19 pandemic*. Diabetes Metab Syndr: Clin. Res. & Rev.,, **14**, 4, 419-422, (2020)
19. S.Bahl, R.P. Singh, M. Javaid, I.H. Khan, R. Vaishya, R. Suman. *TelemedicineTechnologies to combat the COVID-19 pandemic: a review*. J. Ind. Integr. Manag., **5**, 4, 547-561,(2020)
20. S.E.P. Koumoulos, A. Bandyopadhyay, S. Bose, L. OÃ¢Donoghue, C.Charitidis. *Additive Manufacturing: Scientific and Technical Challenges, SectionJoint venture and opportunity*. Matt. Today, **21**, 1, 22-37, (2018)
21. A.Haleem, M.Javaid, I.H. Khan. *Holography applications toward medical field: An overview*. Indian J. Radiol. Imaging., **30**, 3, 354-361, (2020)
22. A.Haleem, M.Javaid, R. Vaishya. *3D printing applications for the treatment of cancer*. Clin Epidemiol Glob Health, **8**, 4, 1072-1076, (2020)
23. F.Wahl, R.Zhang, M.Freund, O. Amft. *Personalizing 3D-printed smart eyeglasses to augment daily life*. Computer, **50**, 2, 26-35, (2017)
24. J.Lee,H.C.Kim, J.W.Choi, I.H.Lee. *A review on 3D printed smart devices for 4D printing*. International Journal of Int. J. Precis. Eng. Manuf. - Green Technol., **4**, 373-383, (2017)
25. S.Thiele, K.Arzenbacher, T.Gissibl, H.Giessen, A.M. Herkommer. *3D-printed eagle eye: Compound microlens system for foveated imaging*. Sci. Adv., **3**, 2,(2017)
26. Abdullah, M. I., Raya, L., Norazman, M. A. A., & Suprihadi, U. (2022). Covid-19 Patient Health Monitoring System Using IoT. 2022 IEEE 13th Control and System Graduate Research Colloquium, ICSGRC 2022 - Conference Proceedings, 155–158. https://doi.org/10.1109/ICSGRC55096.2022.9845162
27. Abdullah, M. I., Roobashini, D., & Alkawaz, M. H. (2021). Active monitoring of energy utilization in smart home appliances. ISCAIE 2021 - IEEE 11th Symposium on Computer Applications and Industrial Electronics, 245–249.
28. V M Revathi et al, "A modified invasive weed optimization for MPPT of PV based water pumping system driven by induction motor, IOP: Engineering Research Express, volume 6, number 3, July 2024, 10.1088/2631-8695/ad5cd3.
29. Kandi Bhanu Prakash, Suresh Kakinatla, Sankara Rao Burada and Siva Ganesh Malla, "Hybrid Renewable Energy Sources based Mobile Charging Unit for Public Usage", 1st International Conference on Power and Energy Systems (ICPES 2023), E3S Web of Conf, Volume 540, June 2024, https://doi.org/10.1051/e3sconf/202454001001.
30. Malla, Priyanka, Malla, Siva Ganesh and Calay, Rajnish Kaur. "Voltage control of standalone photovoltaic – electrolyzer- fuel cell-battery energy system" International Journal of Emerging Electric Power Systems, vol. 24, no. 5, 2023, pp. 649-658. https://doi.org/10.1515/ijeeps-2022-0047.
31. M. Panda, O. Al Zaabi, K. Al Jaafari, P. Kumar, K. Al Hosani and U. R. Muduli, "State-of-Charge Droop Control for Efficient Power Sharing and Transient Response in Microgrids," 2023 IEEE IAS Global Conference on Emerging Technologies (GlobConET), London, United Kingdom, 2023, pp. 1-5, doi: 10.1109/GlobConET56651.2023.10149905.
32. R. K. Meena, D. V. Bhaskar, O. Al Zaabi, M. Panda, P. Kumar and U. R. Muduli, "Modeling of Two-Stage Photovoltaic Inverter with Grid Connected and Islanding Operation," 2023 IEEE IAS Global Conference on Renewable Energy and Hydrogen Technologies (GlobConHT), Male, Maldives, 2023, pp. 1-6, doi: 10.1109/GlobConHT56829.2023.10087517.
33. N. Chaudhary, A. Ranjan, D. V. Bhaskar, M. Panda, A. Kumar and P. Kumar, "Harmonic Reduction Strategies for EV Charging in Power Systems Using Shunt Active Power Filter," 2023 3rd International Conference on Emerging Frontiers in

Electrical and Electronic Technologies (ICEFEET), Patna, India, 2023, pp. 1-6, doi: 10.1109/ICEFEET59656.2023.10452228.

34. P. K. Chamarthi, U. R. Muduli, M. S. E. Moursi, A. Al-Durra, A. S. Al-Sumaiti and K. Al Hosani, "Improved PWM Approach for Cascaded Five-Level NPC H-Bridge Configurations in Multilevel Inverter," in IEEE Transactions on Industry Applications, doi: 10.1109/TIA.2024.3409511.
35. M. K. Senapati, O. Al Zaabi, K. Al Hosani, K. Al Jaafari, C. Pradhan and U. R. Muduli, "Advancing Electric Vehicle Charging Ecosystems With Intelligent Control of DC Microgrid Stability," in IEEE Transactions on Industry Applications, doi: 10.1109/TIA.2024.3413052.
36. A. Saxena, R. Shankar, O. A. Zaabi, K. A. Hosani and U. R. Muduli, "Rule-Based Adaptive Frequency Regulation With Real Stochastic Model Intermittency in a Restructured Power System," in IEEE Transactions on Industrial Informatics, vol. 20, no. 2, pp. 2907-2919, Feb. 2024, doi: 10.1109/TII.2023.3299422.
37. Pragathi, B., and P. Ramu. "Authentication Technique for Safeguarding Privacy in Smart Grid Settings." *E3S Web of Conferences*. Vol. 540. EDP Sciences, 2024.