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A Comprehensive Evaluation of Digital Manufacturing Technology

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Abstract - *From Make in India operation to British Factory of the Future in 2050 and Germany's Industry 4.0 undertaking to Made in China 2025, Digital Manufacturing (DM) is stimulating the world's major industrial countries as a technology footing of the upcoming manufacturing. At the same time, in the various divisions of the digital manufacturing realm, distinctive forms of information technologies (IT) are thriving such as the following, robotics command in manufacturing, computer-aided manufacturing and process simulation. In the 21st century, industries are implementing distinctive technologies that form the support of industry 4.0 production of which Digital Manufacturing projects by combining traditional manufacturing technologies with digital techniques. Digital Manufacturing has been appraised as a highly auspicious part of technology for increased quality of the product, reduce in the cost of the product, reducing development time as well as it is leading us towards need of customization and speedy response to the market. This paper highlights the exposure of Digital manufacturing and is completely focused to review the latest inventiveness of Digital Manufacturing in the major industrial countries. Along with, an evaluative review of various distinctives in the area of Digital Manufacturing Technology.*

Key Words: **Digital Manufacturing, Information Technology, Computer-aided Manufacturing, Industry 4.0, Factory of the Future, Digitalization, Additive Manufacturing, Smart Manufacturing.**

1.INTRODUCTION

As we can see, there is an increase in competition world-wide, expansion of customer requirements, and dynamic and unpredictable market trends in the twenty-first century, which challenges the manufacturing market to integrate design, manufacturing, and product support processes in order to decrease the development time and overcome complexity so that there is no compromise in the quality of the products [1]. In this day and age there is a rapid growth in human resources at a very faster rate, so that using traditional manufacturing technologies is not sustainable if we have to compete against industries.

The procedure of digitizing a manufacturing process is called Digital Manufacturing. It includes cross-disciplinary collaboration, integration, and development outcomes of manufacturing technology, computer systems, networking, and management aspects [2]. Digital Manufacturing is a manufacturing process which, with the abutment of technologies such as virtual reality, computer networks, multimedia and rapid prototyping. The simulation and prototype manufacturing of the design and the functions of product can be realized at a faster rate by rapidly analyzing, planning and recombining, coordinating and sharing of all kinds of information which is based on customer demand so as to analyze, organize and recombine the product information, process information and resource information. As digital manufacturing is a new area in science of manufacturing it integrates different manufacturing disciplines and represents the mainstream development direction of Advanced Manufacturing Technology. [3,4].

An emerging area in Product Lifecycle Management (PLM) is Digital Manufacturing. DM helps to connect some stages of product lifecycle which has been developed gradually from manufacturing innovations such as Computer Integrated Manufacturing (CIM), lean manufacturing, flexible manufacturing, design for manufacturability etc. Recent developments in the domain of Artificial Intelligence, robotics, simulation, 3D printing, machine learning and automation caused digital manufacturing to break the wall of traditional manufacturing.[5]

1.1 Digital Manufacturing in Computer-aided ambitious technologies

Computer-Aided Design (CAD) is scrutinized among the technologies that have enhanced productivity, granting faster time to market for the product and substantially decreasing the time needed for product development. The CAD systems have become crucial to state-of-the-art manufacturing firms due to their vigorous integration with ultra-modern manufacturing techniques. In production of the parts, models made from CAD are frequently considered to be sufficient, since they can be utilized for creating the code required to operate the machines for the production of the part. An example for such a technology is Rapid Prototyping. To boost the understanding of the system and during development of a product Computer-aided engineering (CAE) systems are used to decrease the extent of hardware prototyping [6]. A large number of research fields in engineering like computational fluid mechanics, simulations of machines and mechanism (dynamics),

thermodynamics, Finite Element Analysis (FEA) and robotics are supported by CAE systems. To point out, Brinksmeier et al. [7] supervised an extensive view on the advances in the simulation of grinding processes together with a series of models that can be applied in simulation systems. The concept of Computer-Aided Manufacturing (CAM) came into existence following the evolution of the CAD systems. The origination of Computer numerical Control (CNC) was a leap towards implementing CAM systems. Apart from the contrary that this newly developed technology has brought about an insurgence in manufacturing systems by validating greater flexibility in manufacturing and mass production [8], it has also entitled the straight link between the three - dimensional (3D) CAD model and its production. Newman and Nassehi [9] put forward a ubiquitous manufacturing stage for CNC machining, where various implementation of computer-aided systems applications can continuously exchange information. Therefore, CAM and CAD systems have been emerged allowing for simulation of the product and designing of the part. The art of visualizing the part model and the production process has been always present in engineers, to check the quality of the developed product and then physically to execute the process of manufacturing with minimum error probability.

2. BENEFICENCE OF INFORMATION TECHNOLOGY IN DIGITAL MANUFACTURING

For about five decades from now, the use of IT in manufacturing at a large-scale has allowed technologies to grow immensely at a faster rate. New tools with great benefits have been examined thoroughly. Efficiency of these new tools in many applications has been proved. Various applications of these tools' ranges from simple machining applications, to manufacturing planning and control support. The main advantages of IT include the introduction of numerical control and machining centres, manufacturing cells, and flexible systems, costs and increased power [10]. To give an example for introduction of IT in manufacturing area is the concept of Computer Integrated manufacturing (CIM). In late 1980s, the concept of CIM was first introduced which favored the improvement of performance, efficiency, operational flexibility, product quality, responsive behavior to market differentiations, and time to market. During this stage the concept of CIM was not fully understood and could not be exploited to its extent [10]. Over the last 10 years, information systems have been advanced and played a major role in the acquisition of new information technologies in the environment of manufacturing systems.

3. TRADITIONAL MANUFACTURING TO DIGITAL MANUFACTURING

Computer Aided Design (CAD), to design the components based on different criteria, the applications of computer technology come into picture wherein the design is gradually developed along with the demand for Computer-Aided Manufacturing (CAM), with the use of NC machines virtually created models are converted into physical models. Recent developments in Computer Integrated Manufacturing (CIM) to control the process of production by data communication and automation with the help of robots found its application in automotive and aerospace industries. Additionally, the unification of Total quality management (TQM), Just in Time (JIT) manufacturing, Concurrent Engineering (CE), Lean Manufacturing (LM) and engineering science with CIM created a revolution in the manufacturing sector. In addition, developments in science and technology, market trends and demand for customized products at a faster rate transformed computer integrated manufacturing to digital manufacturing [11].

Digital Manufacturing combines modeling, simulation, visualization, data analytics, manufacturing, supply chain and several other processes by a digital link to define, manage and collaborate the overall product life cycle as it is a network driven and technology-based approach. Digital Manufacturing technologies comes with a benefit to reduce cost and decrease the development time. DM technologies increase the efficiency of products and processes by analyzing the data for an optimal design even before it is built. Cloud-based design and manufacturing (CBDM), a customized service oriented networked product development model is also considered as a new emerging technology that will revolutionize digital manufacturing and design innovation with the help of cyber-physical systems (CPS), internet of things (IoT) and big data. CPS is crucial in design and development of future CBDM systems which include system integrity, data security, intellectual property and privacy. Improving manufacturing automation, supply chain management, remote maintenance and diagnostics in future CBDM systems is enabled by IoT. Big data plays an important role in helping designers to derive decisive customer needs from the existing data to improve and develop designs [12].

By the idea of Virtual Factory, which is in fact a fusion-based technology that combines procurement, production, product logistics, service and diverse IT technologies, digital manufacturing enables the simulation of the entire manufacturing process. DM technology helps in predicting, solving and controlling problems in the virtual environment. Figure 1 shows the architecture of the virtual factory ad suggested by Choi, S et al [13]

Fig -1: Architecture of Virtual Factory

4. NEW TRENDS IN DIGITAL MANUFACTURING

Evaluation of key digital manufacturing trends for 2021 and ahead is carried out below.

4.1 Internet of Behavior (IoB)

The Internet of Things (IoT) is no longer a science fiction concept. The Internet of Things (IoT), which connects any electrical gadget to the Internet, is well on its way to becoming a reality in a variety of industries. The Internet of Habits has been coined to describe how IoT collects data and uses it to provide useful insights into users' interests, behaviors, and preferences.

In our daily lives and at work, we will progressively become more aware of the IoB. It combines existing technologies that directly target individuals (e.g., location tracking, facial recognition, and big data) and ties the resulting data to behavioral events like device usage or cash purchases. Organizations exploit this data to sway people's opinions. Organizations could use IoB to detect those with a fever using thermal imaging or computer vision to see if personnel are wearing masks. During the ongoing pandemic, this might be useful in tracking compliance with health protocols.

4.2 Hyperautomation

Despite the fact that hyperautomation has been accelerating at an unstoppable rate for the past few years, the pandemic has raised demand by requiring everything to be "digital-first." To complete tasks, a combination of machine learning (ML), packaged software, and automation technologies are used. To link humans into the process, another level of intelligence is added to accessible automation techniques. Hyperautomation is a technique that goes much beyond traditional automation. The work completion is replicated with the assistance of robotic process automation (RPA), but in hyperautomation, RPA would be merely the first step towards a world of AI technologies. It will make use of the bot's intelligence by combining several forms of automation that will work together to provide a superior result. With technology and humans working together, hyperautomation has the potential to alter the future of industries.

When AI tools are used with RPA, hyperautomation aids in the automation of any routine repetitive operations carried out by business users. It even automates the process using a mix of tools. Adding intelligence to robotic processes creates an intelligent digital workforce that can reduce human workload. These digital workers would be the backbone of a hyperautomation system that would transform the way organizations operate. RPA, AI, iBPMS, and analytics are some of the tools that enable hyperautomation.

4.3 Cybersecurity Mesh Technology

Cybersecurity mesh is a distributed architectural solution to cybersecurity control that is adaptable, scalable, and dependable. Several assets have now been discovered outside of the traditional security perimeter. The cybersecurity mesh enables a security perimeter to be established around a thing/person by spreading policy enforcement and centralizing policy orchestration, it enables a more responsive, modular security strategy. Anyone with access to a computer may secure any digital asset. It makes no difference where the person or asset is. By 2025, the cybersecurity mesh is expected to accommodate more than half of all digital access control requests. The cybersecurity mesh will become the most feasible way to ensuring safe access to and usage of cloud-based apps and dispersed data from uncontrolled services as operations continue to expand.

4.4 Artificial Intelligence (AI) Engineering

Manufacturing is one of the primary sectors that makes full use of Artificial Intelligence and Machine Learning technology. Smart Factories, also known as Smart Factories 4.0, have significantly reduced unplanned downtime and enhanced product design, as well as increased efficiency and transition times, overall product quality, and worker safety. Artificial Intelligence (AI) is at the heart of Industry 4.0, offering increased production while being environmentally conscious. Manufacturing AI is already being significantly invested in by industrial heavyweights such as Siemens, GE, Fanuc, Kuka, Bosch, Microsoft, and NVIDIA, among others. In a span of three years from now Digital Manufacturing (the combination of AI and IoT) will expand immensely as estimated by TrendForce.

A solid artificial intelligence (AI) engineering approach will help AI models scale, perform, be reliable, and interpretable while providing the full benefit of AI investments. AI can improve or automate human choices and tasks, making it critical for digital business transformation. Organizations may use AI to reduce labour costs, enhance customer service or procedures, and create new business models. AI engineering provides a method to integrate AI into the DevOps process as a whole, rather than as a collection of discrete and specialized initiatives. It brings together a variety of disciplines to temper the AI hype while demonstrating a clearer route to value when combining different AI approaches. Responsible AI is evolving as a result of the governance component of AI engineering to deal with concerns of transparency, fairness, trust, ethics, compliance, and interpretability.

4.5 Cloud Technology

By digitizing almost every aspect of contemporary manufacturing operation, information technology is changing the global industrial economy, a phenomenon

known as "smart manufacturing" in the United States and "Industry 4.0" in Europe. Along with other basic technologies including next-generation wireless, sophisticated sensors, high-performance computing, and computer-aided design, engineering, and manufacturing (CAD/CAE/CAM) software, cloud-based computing is a critical component of the smart manufacturing revolution.

Virtually every element of modern manufacturing firm will be impacted by cloud computing technologies. Cloud computing will have an influence on how businesses run their operations at the corporate level, from enterprise resource planning (ERP) and financial management to data analytics and workforce training. Manufacturers' integration with industrial supply chains will also rely heavily on the cloud. Cloud computing will change everything about manufactured products, from how they are studied, planned, and produced to how they are fabricated and manufactured to how they are utilized by customers in the field. In addition, cloud computing will be critical in allowing and democratizing new manufacturing production systems like 3D printing (also known as additive manufacturing), generative design, and the Industrial Internet of Things. In reality, digital services like cloud computing now account for at least 25% of all inputs used to create completed manufacturing goods [14].

4.6 Digital Fabrication Technology (3D Printing)

By successively adding materials to a geometrical representation, digital fabrication technology, also known as 3D printing or additive manufacturing, generates physical items from a geometrical representation. 3D printing is a new technology that is rapidly gaining traction. 3D printing is now widely utilized all around the world. In the fields of agricultural, healthcare, automobile, locomotive, and aviation, 3D printing technology is rapidly being used for mass modification and manufacture of any sort of open-source design. 3D printing uses layer-by-layer deposition of material to create an object directly from a computer-aided design (CAD) model [15].

Surprisingly, the cost of purchasing 3D printers has decreased as technology has advanced. Domestic use of 3D printers is on the rise, with prices ranging from a few hundred dollars to several thousand dollars. However, one significant disadvantage is that printing 3D things necessitates specialized knowledge. In reality, both the digital file and the final printing require the expertise of a skilled individual. In industries like the automobile industry and aerospace engineering, commercial use of 3D printers is on the rise. In the automotive and aerospace industries, for example, spare parts are manufactured, resulting in increased economies of scale [16].

5. MERITS OF USING DIGITAL MANUFACTURING TECHNOLOGY

Digital manufacturing is the use of computer technology in the production of products, services, processes, and supply processes. Digital manufacturing technologies connect systems and processes throughout all production sectors, from virtual design to physical model manufacture and final product maintenance, to create an integrated view of manufacturing. In a nutshell, a firm or an industrial organization employs digital technology to better and gain from its production processes. Manufacturers may create a networked, digitally linked, and completely integrated manufacturing industry, allowing them to take advantage of new technologies. It also allows to utilize real-time data analytics to evaluate the complete manufacturing process and realize productivity gains of 10 to more than 1,000%. Benefits of implementing Digital manufacturing Technology in 21st century includes:

- A reduction in the time and expense of development.
- The incorporation of information from many production processes and divisions.
- The dispersed production of an ever-increasing diversity of parts and products in a number of different locations.
- Manufacturing businesses concentrating on their core competencies and collaborating effectively with other companies and suppliers utilizing effective IT-based cooperative engineering [1].

6. APPLICATIONS OF DIGITAL MANUFACTURING TECHNOLOGY

The four key application areas of Digital manufacturing are evaluated below.

6.1 Automotive Industry

Rapid and disruptive change is nothing new in the automobile business, and digital transformation is the next great disruptor. In the automobile sector, trends such as increasing connection, environmental restrictions, IoT, wireless solutions, and heightened consumer expectations are driving investments in digitalization. The digital revolution has made our lives easier and more convenient, and the automobile sector is no exception. Autonomous cars, production, maintenance, marketing, and sales are all embracing digital technologies.

Examples of Digital Manufacturing in the automotive industry are mentioned below.

1. Tesla has long been a leader in the application of artificial intelligence and big data. They've been collecting data from drivers using onboard sensors since 2014, allowing them to distribute a wireless

upgrade that improved the accuracy of their autopilot software.

2. Polestar, a Volvo brand, has been voted the best-positioned vehicle brand in terms of online sales. Their Polestar 1 and Polestar 2 models, like Tesla's, are exclusively available online. Volvo does, however, retain separate "spaces" at partner dealership sites.
3. BMW's Regensburg factory successfully implemented an IoT platform. They were able to cut the time it took to deploy new apps by 80 percent and cut quality control issues by 5%.
4. Volkswagen collaborated with AR-based software developers to mark vehicle parts with the appropriate tools. This technology, known as MARTA, helps service professionals work more efficiently.
5. Automotive paints and supplies have always been a brick-and-mortar company. With a single eCommerce, CRM, and ERP integration, PBE Jobbers Warehouse, a distributor of car body equipment, has future-proofed its business.

Building prototypes, jigs, and fixtures, tooling, low-volume end-user goods and concept models, and replicating parts are all examples of 3D printing in the automobile sector [17]. Figure 2 illustrates the applications of Additive manufacturing in automotive industry.

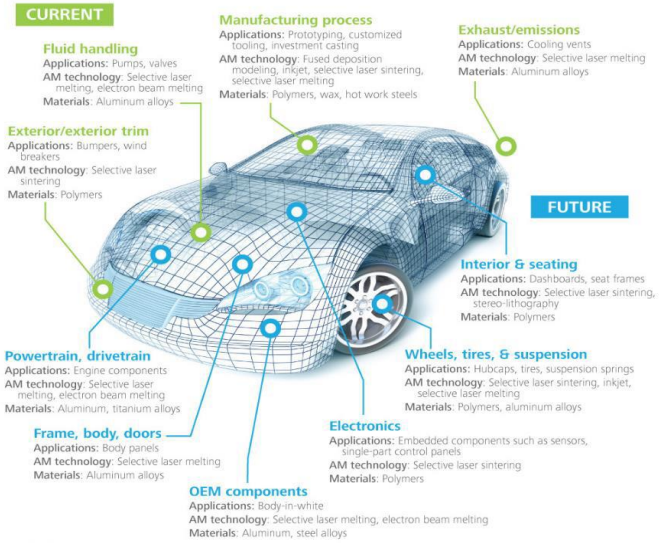

Fig-2 Applications of Additive Manufacturing in Automotive Industry [17]

6.2 Aerospace Industry

Greater digitization and the transition to full-scale digital production are addressing many of the industry's major pain issues in aerospace and military. The trend to increased digitalization is helping creative aerospace and military manufacturers to be more flexible, use their data, create on-demand, reduce discovery and prototype periods, and respond to the growing need for new aircraft.

According to a recent Accenture research, during the next three years, 77 percent of surveyed aircraft manufacturers intend to invest 5 to 10% of total sales in digital technology to support engineering, supply chain management, and production. These three areas are the pillars of digital manufacturing, in which a factory is more connected, responsive, and productive than ever before.

In the aerospace and defense industries, additive manufacturing is used to create lightweight components with geometric and material complexity that are required for safe transit under extreme conditions. Reduced time to market, low-cost design of complicated tools and parts, waste reduction, and part simplification are all advantages of AM in the aerospace and military sector [18].

6.3 Medical Applications

The health-care sector has seen changes in biopharmaceuticals, medical technology, and surgical techniques as we are in the midst of a paradigm transition. Surgical and diagnostic assistance, prosthesis development, tissue engineering, and other applications employ additive manufacturing technology. Recent medical research has improved the capacity to create complex forms in biomedical implants such as craniofacial, dental prostheses, and tissue engineering. Regenerative medicine, drug delivery systems, cancer treatments, and bioprinting have all benefited from digital manufacturing. The latest developments in AM technology have moved the focus of implant manufacture from mass production to individualized pre-operative implant manufacturing based on a digitized 3D model of the patient [19].

6.4 Food Industry

The use of additive manufacturing in the food sector was made possible by the drop in the price of 3D printers and the development of advanced technology. Automation in food manufacturing improves efficiency and quality since food processing is a labor-intensive and repetitive business. Food printing is a digital food production method that allows a cookie to be personalised in terms of colour, shape, flavour, texture, and other factors. Natural Machines' 3D Foodini printer can print sweet and savoury foods such as pizza, spaghetti, tiny burgers, and chocolates in exact calorie quantities that the user must prepare. When opposed to traditionally and centrally made products, the major benefit of edible printing is that food has a shorter shelf life. Managing many components without sacrificing quality, on the other hand, remains a difficulty [20, 21].

Machines are (and will continue to be) used in food processing to assure quality and cost. Costs are reduced,

fresh food quality is preserved, and production is improved by employing automated procedures and machines. In the European food sector, there are well over 30,000 robots. Robotic devices can assist to alleviate safety concerns in more risky tasks in the food industry, such as the automation of a meat cutting process, which might reduce worker injuries. 3D printing has exploded in popularity in recent years across a variety of businesses, including the food industry. From NASA printing a pizza to making soft meals for individuals who can't chew or swallow hard food safely, 3D printed food has been used in a variety of ways. It paves the way for unprecedented food production innovation. With new additive manufacturing 3D printing technologies shaking up the market, there will be no halting down.

7. SCOPES OF DIGITAL MANUFACTURING AFTER COVID-19 PANDEMIC

Businesses have long been interested in technology-led change in various forms. Despite the fact that the COVID-19 epidemic has altered our knowledge of company operations, planning and execution have also created a window for willingness. As businesses slowly but steadily restart operations in the new normal, it is leading to the adoption of Industry 4.0, which leverages the potential of technology-led change. 4.0 was seen as a "Good to Have" capacity in the pre-COVID period because it focused on the business's innovation, sustainability, competitive advantage, productivity, and cost reduction ambitions, but it was also viewed as part of the company's future development and growth plans. The information provided was utilized to increase productivity, offer new goods, simplify supply chains, and develop business models that would allow the company to grow and flourish.

7.1 Transforming to a changing environment in Covid-19

Following COVID-19, it is generally understood that industry flexibility may provide various benefits in terms of customer and market-oriented innovations. Industries, on the other hand, are only a tiny part of the way to adapting to it due to their architecture. Internal and external variables in the industrial industry are evolving at a rapid rate, necessitating a dynamic shift in organizational structure, as well as activities time base transformation is a challenge when altering possession structures, according to COVID-19. Property, personal resources, and well-established procedures are all included in the information system [22].

7.2 Digital Green Manufacturing

Following COVID-19, digital green manufacturing will play a key role, as it has been organically merged for the manufacturing green revolution and manufacturing digitalization, which has provided an opportunity. A breakthrough in circumventing the green manufacturing bottleneck thanks to a very effective, one-of-a-kind methodology for dealing with design and production difficulties in green digital manufacturing. Green digital manufacturing employs the most advanced manufacturing technology, as well as digital technology, management technology, information technology, environmental technology, and control technology, to make efficient use of various resources such as information, material, energy, and capital, and to maintain a smooth flow in the process of achieving global industry optimization [22].

8. CONCLUSION

The way a product is made has changed dramatically over the last several decades as a result of great advances in science and technology. Digital manufacturing is a cutting-edge technology that allows designers to build and construct sustainable goods at breakneck rates! Digital manufacturing becomes increasingly valuable when a product and its production procedures get more sophisticated. Manufacturing technology at its most sophisticated for manufacturers, digital manufacturing is altering the game. Productivity increases, cost reductions, and increased revenue are all possible with smart, linked goods, assets, and processes. The findings of numerous research studies show that digital manufacturing technology in the sectors delivers high production rates, cost optimization, and customer needs, among other things. A variety of technologies have been discovered to be behind the effective adoption and usage of DM technologies, particularly in industrial industries. The combination of digitization technologies and manufacturing systems allowed the manufacturer to quickly respond to a customer's request by gathering information, restructuring it, simulating and prototyping the function and design, and finally committing to the manufacturing mission of the desired product.

Digital manufacturing, which is based on contemporary tools and procedures for engineering, control, supervision, and administration in a network, is critical for adaptability. When factories are viewed as scalable goods, industrial engineering plays a major role in quick adaptability and complexity, taking into account market dynamics and innovation. Engineers and their work are facing new problems such as system optimization, data management, and knowledge. Digital manufacturing is the new era of production.

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