An Overview on Digital Manufacturing

[1]Mr. Jitendra Kumar Singh Jadon, [2]Mr. Rajkishor Singh, [3]Dr. Yogesh Kumar, [4]Mr. Shoyab Hussain
[1,2,3,4]Shobhit Institute of Engineering and Technology (Deemed to be University), Meerut
Email Id- [1]jitendra@shobhituniversity.ac.in, [2]rajkishore@shobhituniversity.ac.in
[3]yogesh.sharma@shobhituniversity.ac.in, [4]shoyab.hussain@shobhituniversity.ac.in

ABSTRACT: In today's highly competitive worldwide market, product businesses are always looking for new ways to cut lead times and handle customized new product innovations that satisfy all consumer requirements, such as product quality, cost, and aesthetics. In general, product companies have adopted a variety of new technologies such as Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Engineering (CAE), Rapid Prototyping (RP), Digital Manufacturing (DM), Additive Manufacturing (AM), and others that offer business benefits by shortening the product development cycle. This technical note aims to describe the evolution of Information Communication Technology (ICT) in manufacturing, outlining their characteristics as well as digital manufacturing concepts. The technologies discussed in this paper include CAD, CAM, CAE, RP, DM, Product Lifecycle Management (PLM), Collaborative Engineering (CE), Reverse Engineering (RE), simulation, and ecommerce (Web Technology) systems. These technologies are discussed in relation to digital manufacturing ideas.

KEYWORDS: CAD, CAE, CAM, DM, ICT, PL, Reverse Engineering (RE), Simulation.

INTRODUCTION

Former US Vice-President Al Gore first proposed the concept of a "digital earth" in his report "The Digital Earth: Understanding Our Planet in the Twenty-First Century" in 1998. Following that, the word "digital" was used to coin a slew of new notions and ideas, like "digital city," "digital agriculture," "digital war," and so on. The use of digitalized technologies in industry, living, education, research and technology, national security, and other fields has increased quickly, with significant advantages. Humanity is entering the "Digital Age."

One of the most important aspects of the digital age is digital manufacturing (DM). The information is represented in 2D drawings in traditional manufacturing, but it is represented in 3D digital models in DM to validate the information transfer. Digital manufacturing technologies are created by combining ICT with traditional manufacturing technologies. This approach has improved the design, manufacturing, and management automation and digitalization. As a consequence, product function, structure, quality, performance, price ratio, development time, customization, benefits, and soon have all altered qualitatively as the demand for customer-based goods has grown. As a result, DM technology has become the most important instrument for businesses to improve their product's competitiveness [1]–[4].

ICT in Manufacturing:

The necessity for faster product development times, as well as the growing need for more customer-centric goods, has led to the creation of the next generation of industrial ICT systems. Manufacturing sectors are attempting to combine their business activities and divisions into a corporate database using modern technologies. These systems are based on digital manufacturing principles, which combine the use of production data management systems and simulation technologies to optimize manufacturing parameters prior to the start of production and to assist subsequent stages. These industrial goals have made it possible to utilize ICT extensively in production. The term "Computer Integrated Manufacturing" (CIM) refers to the use of information and communication technology (ICT) in the manufacturing industry. The improvement of performance, efficiency, operational feasibility, product quality, responsive behavior to market distinctiveness, and speed to market were all impacted by this idea.

Inventory management and Material Requirement Planning (MRP) were both established using this idea. Apart from traditional engineering data and drawing information, a large amount of non-geometry data, such as experience and knowledge, must be handled in digital manufacturing. The discretization and digitization process involves a number of theory issues, such as digital models of physical quantities such as heat, sound, force, vibration, speed, error, and so on, which appear in the manufacturing process alongside geometry quantities such as displacement, multi-coordinates, and coordinated displacement. The next step is to combine digital representations of physical and geometric quantities, as well as their connections, in a computer. Information is a major and active element in digital production. The emergence of the internet, the standardization of software interfaces, and the widespread adoption of formal software design and development methods. The maturity of some software products, such as RDBMS and CAD, has made it easier to integrate various software applications [5].

CAD/CAM/CAE Technologies:

CAD technology has increased productivity, allowing for a quicker time to market for the product and a shorter time to create it. In today's market, there are affordable options with a contemporary photorealistic graphical user interface. Finite element analysis (FEA), kinematics analysis, dynamic analysis, and complete simulation of geometrical characteristics, including texture and mechanical properties of materials, are all features of such systems. CAD models are evaluated for component manufacturing because they can be used to generate code that can be utilized to control the machines that produce the part. One example of such a technique is rapid prototyping. With the advancement of computer technology and the blending of computer graphics and mechanical design, the computer-aided design (CAD) system, which uses a database as its core, an interactive graphics system as its method, and analysis and calculation as its main body, has found widespread use in digital manufacturing. The idea of computer-aided manufacturing (CAM) emerged as a result of the advancement of CAD technologies. The advent of computer numerical control was a significant step toward the adoption of CAM systems (CNC). This new technology has revolutionized the manufacturing industry by allowing for mass production and more flexibility, as well as a direct connection between the three-dimensional (3D) CAD model and its production. Newman and Nassehi suggested a global production platform for CNC machining, where different computer-aided systems (CAS) applications may share information in real time. The platform suggested is based on the STEP-NC standard. Furthermore, the standardization of programming languages for these computers has prompted solution makers to include automated code creation in their applications [6]–[9].

Simulation:

PC reproduction has become one of the most widely used procedures in assembling frameworks configuration, allowing chiefs and architects to investigate the multifaceted nature of their frameworks and the impact that changes in the framework's design or operational arrangements may have on the framework's or association's exhibition. Static, dynamic, persistent, discrete, deterministic, and stochastic re-enactment models are classified. Re-enactment software packages have provided representation capabilities, including liveliness and graphical client connection features, since the late 1980s. PC recreation gives you a lot of freedom when it comes to analyzing and realistically dissecting scenarios, which cuts down on the amount of time and money it takes to make decisions based on the framework's behavior. Other IT frameworks, such as CAx, FEA, creation planning, and advancement frameworks, are often integrated with re-enactment frameworks.

Rapid Prototyping Technology:

Rapid prototyping (RP) is the layer-by-layer deposition of a physical model using computer-aided design (CAD) data without the use of tools. 3D Systems initially marketed RP in 1987, making it a relatively young technology. Automobiles, electric household appliances, and aircraft are just a few of the sectors that have utilized RP systems. The stereolithography (STL) file, which represents a model produced by a CAD surface or solid modeller, is the starting point for most RP procedures. The RP models may be used to illustrate or validate ideas, as well as to test for form fit and function and to create a tooling (or master) pattern for casting or molding.

Every year, there is a high need for implants or endoprostheses in surgery. Standard implants and customized implants are the two types of implants available. One significant disadvantage of the traditional approach for creating personalized implants is that the design process occurs before to surgical interventions, making it almost difficult to determine the implant's optimal shape [10].

Reverse Engineering:

RE stands for "reengineering" and refers to the process of generating a CAD model from an existing physical item that may be used as a design tool for making a duplicate of an object, extracting the design idea from an existing model, or reengineering an existing component.

i. *Introduction:*

In today's competitive global market, product companies are always looking for innovative methods to reduce the time it takes to create new products that satisfy all consumer requirements. Product firm has invested in CADCAM, fast prototyping, and a variety of other innovative technologies that help the company. Reverse engineering is currently recognized as one of the technologies that may help businesses reduce the time it takes to create a product. The process of developing, producing, assembling, and sustaining goods and systems is known as engineering. Forward engineering and reverse engineering are the two kinds of engineering. The conventional method of going from high-level abstractions and logical concepts to the actual implementation of a system is known as forward engineering. There may be a physical component without any technical information, such as drawings, bill-of-materials, or engineering data, in certain circumstances. Reverse engineering is the process of replicating an existing component, subassembly, or product without the use of drawings, documentation, or a computer model. Reverse engineering has been defined in a variety of ways by various academics, depending on the job at hand.

ii. *Need for Reverse Engineering:*

Reverse engineering is used for a variety of reasons, including: the original manufacturer no longer exists, yet a client need the product, and The product's original maker is no longer producing it, or the product has become outdated. The original product design documentation is either missing or non-existent. Creating data to repair or produce a component for which no CAD data exists, or where the data has been outdated or lost. Comparing a manufactured component to its CAD description or to a reference item, inspection and/or quality control Some negative aspects of a product must be removed, such as excessive wear, which may suggest that the product should be enhanced, as well as reinforcing positive aspects of a product based on long-term use. Analyzing the positive and negative aspects of competitors' goods, exploring innovative ways to enhance the performance and functionality of products, Making 3D data from a model or sculpture for use in games and films To construct, scale, or replicate artwork, 3D is created from a person, model, or sculpture. Measurement and documentation for architectural and construction projects Individualizing clothes or footwear and assessing a population's anthropometry To produce dental or surgical prostheses, tissue created body parts, or surgical planning, data is generated. Documenting and reproducing criminal scenes, for example.

Product Life Cycle Management:

Product Lifecycle Management (PLM) is a business approach that helps manufacturers increase the profitability of their goods. There are a variety of tools in PLM that may help with this, with the design of the product receiving a lot of attention in the past. Digital Manufacturing, a strategic approach to designing and implementing optimum manufacturing processes, is a new and rapidly expanding field within PLM. The use of technologies that contribute to increased efficiency has a beneficial impact on the creation of contemporary products. Products are becoming into sophisticated, highly-integrated systems with inherent technical intelligence that allow customers to use them reliably, cheaply, and effectively even at the technological frontier. As a consequence, corporate strategies are increasingly focusing on improving technical systems, optimizing product use, and maximizing value addition throughout a product's life cycle.

i. *The New Method of Life Cycle Management:*

D The ecosystem is increasingly threatened as a result of limited natural resources, more emissions, and more severe technical general circumstances. As a result, a shift in strategy has occurred, with the design and use of technological goods now taking into consideration both economic and environmental goals. Manufacturers are taking on an increasing amount of responsibility for the use and cost of their technological goods. However, in order to avoid losing market share, many businesses simply meet statutory basic requirements in pre-sales and after-sales. There is a widespread belief that the cost-benefit ratio is inadequate, particularly in the after-sales industry. However, there is a future vision in life cycle management for maximizing overall product use while minimizing environmental effect. Series goods with a restricted number of variations fall into the second category. Services and maintenance, as well as industrial recycling and partial reuse of parts and components, are all part of the life cycle management for these goods. The third category has been given to high-quality capital items. The primary emphasis here is on making the most of strategy, sustaining performance, and adding value to the after-sales process. In this category of goods, industrial recycling has a small economic significance.

ii. *Partnerships for Sustainable Product Life Cycles:*

Traditional manufacturing paradigms have concentrated on elements of profit through producing and selling goods to end-users up until now. The new paradigm considers the life cycle of technological goods as well as value and benefit optimization in areas like as engineering, assembly, service, maintenance, and disassembly. The goal is to minimize ecological losses while still meeting public or governmental mental constraints throughout the life cycle.

- *Manufacturer's View:*

The stages of design and engineering, manufacture, assembly, use, servicing, disassembly, and recycling are all included in the product life cycle. Additional dimensions are specified and are dependent on the product and manufacturing system. The primary goal is to meet the demands of markets and consumers for the most effective use of production resources. As a consequence of customer-near services such as maintenance and disassembly for reconfiguration, reuse, or recycling, the new vision adds value in the use and recycling phases.

- *Customer’s View:*

Customers often want to achieve high utilization in the use phase at the lowest cost, even if it means changing procedures. Flexible production systems with minimum set-up times and costs are required, as well as process performance assurance. In industrial production, the economic efficiency of capital-intensive goods is determined by product needs and profiles, as well as technical requirements and capabilities. These needs are continuously changing, necessitating continuous adaptation of production methods.

Benefits:

Manufacturing firms may benefit from digital manufacturing by increasing productivity in both manufacturing planning and production processes.

- With an uniform and complete approach to production design, digital manufacturing allows product, process, plant, and resource information to be related, examined, and taken through change processes.
- Part production processes may be improved in a controlled environment thanks to digital manufacturing. It may generate flexible work instructions that include 2D/3D component information as well as machining and tooling instructions.
- By digitally verifying robotics and automation programs, digital manufacturing's simulation capabilities assist minimize commissioning costs.
- It is feasible to build factory models quicker and verify that they are functioning under optimum architecture, material flow, and throughput before ramping up production using digital manufacturing.
- By providing a graphical platform for analyzing dimensional variation and other metrics, digital manufacturing may help support sixsigma and lean efforts.

DISCUSSION

Digital manufacturing encompasses advancements in the virtual representation of industrial facilities, structures, assets, machine frameworks, equipment, work crew, and their skills, as well as the tighter integration of product and procedure development via re-enactment. Closing the gap between item definition and actual assembly generation exercises within the endeavor, completely transforming implied manufacturing information into unmistakable, and, finally, computerized data, streamlining information across the board, and developing standard models are some key requirements.

CONCLUSION

Digital manufacturing is emerging as a new manufacturing technology and paradigm in the development of sophisticated manufacturing technologies. The following are the main characteristics and functions of digital manufacturing: no ambiguity and reusability of digital product descriptions, prediction of product development process and performance, and manufacturing activities that are independent of distance, time, and location through a networked environment. This study shows that digital manufacturing uses a variety of technologies such as CAD, CAM, CAE, RP, (PLM), CE, and others to create virtual representations of factories, buildings, resources, and machine systems. The features and ideas of digital manufacturing are revealed in this review article. Customized manufacture of any product, particularly clinical production of dental implants, has a lot of potential for product optimization. DM assists in reducing lead times while maintaining quality, affordability, and aesthetics in order to fulfill client requirements.

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