Digital Manufacturing: A Review

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Abstract:- **In today's intensely competitive global market, product companies are constantly searching new ideas to reduce lead time as well as addressing customization new product developments that meet all customer expectations viz. product quality, cost, aesthetic etc. In general, product company has adopted variety of new technologies like Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Engineering (CAE), Rapid Prototyping (RP), Digital Manufacturing (DM), Additive Manufacturing (AM) and so on that provide business benefits in reducing the product development cycle.**

This technical note aims to describe the evolution of Information Communication Technology (ICT) in manufacturing, outlining their characteristics together with digital manufacturing concepts, the technologies considered in this paper include CAD, CAM, CAE, RP, DM, Product Lifecycle Management (PLM), Collaborative Engineering(CE),Reverse Engineering(RE), simulation, e-commerce(Web Technology) systems. These technologies are presented in the context of digital manufacturing concepts.

Keywords—ICT, CAD, CAM, CAE,simulation, DM, RP, Reverse Engineering (RE), PLM

I. INTRODUCTION

In 1998, the concept of 'digital earth', was first presented by former Vice-President of United States Al Gore, in his report entitled "the Digital Earth" understanding our planet in the 21st century [1]. There after many new concepts and ideas have emerged with the term "digital" like digital city, digital agriculture, digital war etc.The application of digitalized technologies in the field of manufacturing, life, education, science and technology, the national defense, etc have elevated rapidly with considerable benefits. The mankind is moving towards "Digital Age".

Digital Manufacturing (DM) is one of the most vital components in this digital world. In conventional manufacturing, the information represented as 2D drawing where as in DM it is represented in 3D digital models to confirm the information transmission. The integration of ICT with conventional manufacturing technologies forms the digital manufacturing technologies. This concept has upgraded the automation and digitalization of the design, production and management. As a result the products function, structure, quality, performance, price ratio, development time, customization, benefits and so on have changed qualitatively together with the growing demand for customer based products. Hence DM technology has become the most vital tool for the companies to enhance the competitiveness of their products [2].

II. ICT IN MANUFACTURING

The need for shorter product development time together with the increasing demand for more customer based products have led to the next generation of ICT sytems in manufacturing. Manufacturing industries striving to integrate their business functions and departments with new systems in a company database. [3]. These systems are based on the digital manufacturing concepts according to which production data management systems and simulation technologies are jointly used for optimizing manufacturing parameters before beginning the production and supporting the further phases [4]. These industrial objectives have given room for the extensive use of ICT in manufacturing. The concept of Computer Integrated Manufacturing (CIM) indicates the introduction of ICT in the manufacturing world. This concept was influenced the enhancement of performance, efficiency, operational feasibility, product quality, responsive behavior to market differentiation and time to market [5]

This concept was introduced into inventory control and Material Requirement Planning (MRP) respectively.[6]. In digital manufacturing apart from conventional engineering data and drawing information but also a lot of non-geometry information like experience and knowledge should be processed. The discretization and digitization process contains a series of theory problems, like digital model of physical quantities that is heat, sound, force, vibration, speed, error and so on that appear with the geometry quantities like displacement, multi-coordinates, coordinated displacement in the manufacturing process. Next is fusing the digital models of both physical and geometric quantity and their relationships in computer.[7]. In digital manufacturing information is dominant and active factor. The advancement in internet, standardization of software interfaces, the wide acceptance of formal techniques for the software design and development. The maturity of certain software products like RDBMS, CAD has given way for facilitating the integration among different software applications [3].

A.CAD/CAM/CAE Technologies

CAD technology has boosted the productivity, allowing faster time to market for the product and reducing the time required for product development. Affordable solutions, offering a modern photorealistic graphical user interface, are nowadays available in the market. Functionalities of such systems integrate finite element analysis (FEA), kinematics analysis, dynamic analysis and full simulation of geometrical properties including texture and mechanical properties of materials. CAD models are considered for the production of the parts, since they can be used for generating the code which can drive the machines for the production of the part. Rapid prototyping is an example of such a technology.[8] With the evolution of computer technology and the combination of computer graphics and mechanical design, the computer-aided design (CAD) system which takes the database as a core, the interactive graphics system as the method and takes the analysis and calculation as the main body, and this system also has widespread application in digital manufacturing [9]. Following the development of the CAD systems, the concept of computer-aided manufacturing (CAM) was born. The great step towards the implementation of CAM systems was the introduction of computer numerical control (CNC).This new technology has brought a revolution in the field of manufacturing by enabling mass production and greater flexibility [10], it has also enabled the direct link between the three-dimensional (3D) CAD model and its production. Newman and Nassehi [11] proposed a universal manufacturing platform for CNC machining, where the applications of various computer-aided systems (CAx) applications can seamlessly exchange information. The proposed platform is based on the standard STEP-NC. In addition, standardization of programming languages for these machines lead solution developers to integrate an automatic code generation in their applications.

According to Chang TC, Wysk RA, Wang HP Computer-aided manufacturing (CAM) is the sum of all direct and indirect activities from the blank to the finished product completed in product manufacturing process using computer-aided technology [12].It transforms programming which includes manufacturing, detecting, assembling, dispatching as well as all related digital information facing product design, manufacture, management, accounting and so on., into data which may be interpreted and understood by computer and shared fully in the manufacturing process, which formed the CAx integration, causing the computer-aided technology to rise to a greater level [13, 14]. Computer-aided engineering (CAE) is an extension of CAD technology, which is used for engineering analysis, calculation, verification and simulation for part models in the process of manufacturing by using computer system, thus carrying out effective evaluation and giving results for the function, performance and various index of product design.

B.Rapid Prototyping Technology

Rapid prototyping (RP) refers to the fabrication of a physical model from computer-aided design (CAD) data by layer-by-layer deposition without using tools. RP is a relatively new technology that was first commercialized by 3D Systems in 1987. RP systems have been mainly used in manufacturing industries such as automobiles, electric home appliances and aerospace. Generally, RP processes begin with an stereolithography (STL) file that describes a model created by a CAD surface or a solid modeller. The RP models can be used to visualize or verify designs, to check for form fit and function or to produce a tooling (or master) pattern for casting or molding [15].

There is a great demand for implants or endoprostheses in surgery every year. Implants could be generally divided into two categories: standard and customized implants. One major drawback of the conventional method for designing customized implants is that the design process is prior to surgical interventions so that it is virtually impossible to know the optimum geometry of the implant [16]. The design and manufacturing of custom-made implants is a multistage process. The conventional process begins with image processing to extract geometric contour curves form computed tomography (CT) data and enter them into a CAD system. Then, the Nurbs surfaces geometric model of defected bone is created from the contour curves and an implant is designed to t conform to the created model. Later, implant construction is verified through consultation between the designer and the surgeon. The final stage is the fabrication of the implant on a CNC machine tool [17, 18]. The weak points of this method are long design cycle, difficulty in consultation between the designer and surgeon and experience dependence for designer. Geometric model building based on sectional medical images is the foundation of the design of medical implants, mechanical analysis of bone, computer-aided surgery and so on. Sectional images of CT or magnetic resonance imaging (MRI) are the main processing objects. CT revolutionized medical imaging in 1972. Traditional CT systems assemble a series of cross-sectional images by incrementing the patient across the plane of acquisition a few millimeters between each slice. In this manner, a series of equally spaced two-dimensional images can describe three-dimensional anatomic structures to sub millimeter detail. [19]. The computer-aided implant design is carried out on screen, but a solid RP model is required on hand is for easier collaboration between designer and surgeon. The bone model made by RP technology based on sectional medical images is helpful for researchers to know about configuration, position and anatomic structure of surgical location, to measure geometric parameters of pathological bones, to confer about prostheses design and to simulate assembly before operation. RP operates on the principle of depositing material in layers or slices to build up a model, rather than forming a model from a solid block. The space between the layers is typically 0.05 to 0.10 mm. Stereo lithography apparatus (SLA), laminated object manufacturing (LOM) and fused deposition modeling (FDM) are typical RP systems. [20].With a RP model in a surgeon's hands and a visual model on screen, the design process is straight forward and fast. The surgeon makes cuts in the defected side of the RP model, in this case, and the designer responds with cuts made in the healthy side of the visual model. Surgeon and engineer make cuts in different sides because the cutout part from the healthy side would be used as a design template for the implant to maintain aesthetic facial symmetry after operation.

C. Reverse Engineering

RE refers to creating a CAD model form an existing physical object, which can be used as a design tool for producing a copy of an object, extracting the design concept of an existing model, or reengineering an existing part.

1) *Introduction*

In today's competitive global market, product enterprises are constantly seeking new ways to shorten lead times for new product developments that meet all customer expectations. Product enterprise has invested in CADCAM, rapid prototyping, and a range of new technologies that provide business benefits. Reverse engineering is now considered one of the technologies that provide business benefits in reducing the product development cycle. Engineering is the process of designing, manufacturing, assembling, and maintaining products and system. There are two types of engineering, forward engineering and reverse engineering. Forward engineering is the traditional process of moving from high-level abstractions and logical designs to the physical implementation of a system. In some situations, there may be a physical part without any technical details, such as drawings, bill-of-materials, or without engineering data. The process of duplicating an existing part, subassembly, or product, without drawings, documentation, or a computer model is known as reverse engineering. Different researchers have given different definition for Reverse engineering based on their specific task. The different definitions are: According to Motavalli & Shamsaasef Reverse engineering is defined as the process of obtaining a geometric CAD model from 3D points acquired by scanning/digitizing existing part. The process of digitally capturing the physical entities of component, referred to as reverse engineering (RE) [21]. Abella et al described RE as, "the basic concept of producing a part based on an original or physical model without the use of an engineering drawing".[22] Yau et al defined RE, as the "process of retrieving new geometry from a manufactured part by digitizing and modifying an existing CAD model"[23]. Reverse engineering is now widely used in numerous applications, such as manufacturing, industrial design, and jewellary design and reproduction. In some situations, such as automotive styling, designers give shape to their ideas by using clay, plaster, wood, or foam rubber, but a CAD model is needed to manufacture the part. As products become more organic in shape, designing in CAD becomes more challenging and there is no guarantee that the CAD representation will replicate the sculpted model exactly.Reverse engineering provides solution to this problem because the physical model is the source of information for the CAD model. This is also referred to as the physical-to-digital process.

2) Need for Reverse Engineering

Some of the reasons for using reverse engineering are: The original manufacturer no longer exists, but a customer needs the product, The original manufacturer of a product no longer produces the product or the original product has become obsolete, The original product design documentation has been lost or never existed, Creating data to refurbish or manufacture a part for which there are no CAD data, or for which the data have become obsolete or lost, Inspection and/or Quality control- comparing a fabricated part to its CAD description or to a standard item, Some bad features of a product need to be eliminated i.e excessive wear might indicate where a product should be improved, strengthening good features of a product based on long-term usage, Analyzing the good and bad features of competitor's products, Exploring new avenues to improve product performance and features, Creating 3D data from a model or sculpture for animation in games and movies, Creating 3D from an individual, model or sculpture to create, scale, or reproduce artwork, Architectural and construction documentation and measurement, Fitting clothing or footwear to individuals and determining the anthropometry of a population, Generating data to create dental or surgical prosthetics, tissue engineered body parts, or for surgical planning, Documentation and reproduction of crime scenes, and so on.[24].

D. Product Life Cycle Management

Product Lifecycle Management (PLM) is a business strategy that enables manufacturing companies to achieve greater profitability from their products. Within PLM, there are a number of tools designed to accomplish this, with a lot of attention historically placed on the design of the product itself. A new and fast growing discipline within PLM is Digital Manufacturing, a strategic approach to developing and deploying optimal manufacturing processes. The development of modern products is being positively influenced by the application of technologies contributing towards increasing efficiency. Products are becoming complex highly-integrated systems with internal technical intelligence enabling the customer to utilize them reliably, economically and successfully even in the fringe ranges of technology. As a result, business strategies are aiming more and more towards perfecting technical systems, optimizing product usage and maximizing value addition over the entire life time of a product. [25, 26]. When manufacturing technical products, industrial corporations normally their strategies will be towards economic targets. Their main business lies in developing, producing and operating products either for individual customers or for complete sectors of the market. Service and maintenance are considered by many companies to be necessary to achieve long-term business relationships with customers. [25, 27]. The manufacturing of parts and components is performed by suppliers or specialized companies. More and more often, the ultimate result is to make profit out of business operations in design, engineering, final assembly and service. These phases of production are the core competencies of companies which produce strong market or customer-oriented products and add value during a product's life cycle. [28]

Behind these tendencies, there is a new paradigm: in order to add value and maximize utilization, products are linked in the manufacturer's network from beginning to end. Here in this paper under the heading of PLM out of many factors only two important points, i.e. new method of life cycle management and Partnerships for sustainable product life cycles are discussed.

1) The New Method Of Life Cycle Management:

Due to limited natural resources, the environment is becoming endangered due to emissions and more severe technical general conditions. Thus a change in strategies has taken place considering economical objectives and ecological aspects into account in the design and utilization of technical products. Manufacturers have to shoulder more and more responsibility for the usability of their technical products and for their cost of usage. However, many companies only follow statutory general conditions in pre-sales and after-sales in order to prevent them from losing their markets. There is a general notion that the cost-benefit ratio, especially in after-sales business, is insufficient. [27, 29, 30].But there is a future vision in life cycle management for optimizing the total utilization of each product and to reduce environmental impact to a minimum. The second category is assigned to series products with limited numbers of variants. Life cycle management for these products includes services and maintenance as well as industrial recycling and the partial re-use of parts and components. High-quality capital goods have been assigned to the third category. The main focus here is on maximum utilization of strategies, maintaining performance and additional added value in the field of after-sales. Industrial recycling only plays a minor economic role in this category of products. [31]. From the technical point of view, the modular design of a product's construction is of particular importance. The increasing substitution of mechanical components with software also supports the short term usage of a product for variable task assignments; retrofitting times can be shortened due to the fact that modified software can be loaded in a much shorter space of time than hardware components can be exchanged.[32].

2) Partnerships For Sustainable Product Life Cycles

Until now, traditional manufacturing paradigms have focused on aspects of profit by manufacturing and selling products to the end-user. The new paradigm takes into account the life cycle of technical products and the optimization of value and benefits such as engineering, assembly, service, maintenance and disassembly. The objective is to reduce ecological losses and to fulfill public or govern mental restrictions over the life cycle [26, 33, 34, 35, 36,37].

a. *Manufacturer's View*

In general, the life cycle of products can be defined as the phases of design and engineering, manufacturing, assembly, usage, service, disassembly and recycling. Further dimensions are defined and depend on the specific structure of products and production. The main objective is to fulfill the requirements of markets and customers for the efficient utilization of manufacturing resources. The new vision is adding value in the usage and recycling phases as a result of customer-near services including maintenance and disassembly for reconfiguration, reuse or recycling. [25, 27,33, 34, 38, 39, 40, 41].

b.Customer's View

Normally, customers are interested in achieving a high utilization in the usage phase at the lowest cost, even if processes need to be changed. The requirement is for flexible manufacturing systems with minimal set-up times and costs which provide a assured process performance. The economic efficiency of capital-intensive products in industrial manufacturing depends on the requirements and profiles of products, technical requirements and capacities. These requirements are changing constantly with the result that manufacturing systems need to be permanently adapted. [42,43,44,45].

c.Life Cycle Objectives

A common understanding between manufacturers and users is a pre requisite in order to be able to activate potentials, to obtain the maximum benefit from each technical product during its life cycle and to fulfill economic and environmental objectives. Common sense and active optimization demand technical solutions to link products at any point in time throughout their entire life cycle to the information networks of manufacturers and users. This can be achieved by implementing technical products in global IT networks and electronic services. [31].

E. Collaborative Engineering

Collaborative engineering is a discipline that "studies the interactive process of engineering collaboration, whereby multiple interested stakeholders resolve conflicts, bargain for individual or collective advantages, agree upon courses of action, and/or attempt to craft joint outcomes which serve their mutual interests."[102].

1) Introduction

Collaboration is an important business practice, which has significant implications on the product development process. One implication of a collaborative Engineering/manufacturing environment is that the design and manufacturing resources, although perhaps physically distributed across a wide area are networked, well-integrated and collaborated within an enterprise. Another implication of a collaborative manufacturing environment is that multi-disciplinary team members geographically distributed are organized collaboratively to achieve a common goal through the internet [46, 47]. The flow of the information technology, especially the Internet, provides the infrastructure necessary for an integrated and distributed engineering environment. In this environment, teams of engineers from different parts of organizations could collaborate together toward design, development, and integration. The virtual product design and integration environment would require the collaboration from different teams and functions involved throughout the product life cycle. This environment provides the means necessary to share tools that are co located and geographically dispersed.

The distributed environment is highly heterogeneous, where designers, engineers, resources, and models are distributed and not centralized in one location, and groups within the company work together across the computer network. In this environment, many interrelated design decisions are being made in order to meet the objectives. Collaborative engineering (CE) is the systematic approach to the integrated, concurrent design of products and related processes, including manufacturing, product service, and support. This approach is intended to cause developers to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements. The objective of CE is to reduce the development cycle time through a better integration of resources, activities, and processes.[48].

2) Design and Development of A Product- A Collaborative Approach

This topic presents an integrated framework for distributed and collaborative environment, which could assist organizations to achieve integrated design goals. This system focuses the integration of the software tools and the resources involved in the design process to collaborate the geographically dispersed design teams and vendors. The progress in IT have enabled designers to more effectively communicate, collaborate, obtain, and exchange a wide range of design resources during development [49]. Key to the analysis of any problem is the identification of what functions are performed and the relationships between them [50]. A collaborative engineering development process includes a set of activities and functions arranged in a specific order with clearly defined inputs and outputs. Each activity in the process will take a set of inputs and transforms it into an output of some value. The process is considered efficient, when the output of the process satisfies the general customer and product requirements and meets management objectives and cost [51, 52]. Software vendors may provide "custom" software packages for individual firms. Different industries have different product development strategies, which demand a generic framework that will help them, collaborate efficiently irrespective of their product, organizational structure, and/or geographical location. The two important elements in this changing environment are increased product sophistication and variation. Minimizing the total costs and being quick to develop and market new products is the key for survival. [53].

3) Collaborative Design and Development

Design refers to the activities involved in creating the product structure, deciding on the product's mechanical architecture, selecting materials and processes, and engineering the various components necessary to make the product work [54]. Development refers to the entire process of identifying a market opportunity, functional requirements, and finally testing, modifying, and refining the product until it is ready to manufacture. The development of a product is time-consuming, lengthy, and expensive. In product development process the design occurs before final full-scale manufacturing. In most of the cases this design is refined for the manufacturing difficulties, which leads to increased cost and time. The manufacturing department is responsible for estimating the feasibility, cost of building the prospective new product, and modifications, if necessary. If the decision has been taken to outsource some of the components in the final product, the *vendors* come into direct consideration. The vendors become a part of the design team, as they will be contributing toward the development of the final product. Hence, it is very important to consider the vendors' involvement in the design process beginning from the initial stages of the design and development of the product. Thus, in any product design and development scenario the interaction among marketing, engineering, manufacturing, and, in most cases, the vendors is very important. This requirement is met by the application of collaborative product development (CPD) [55, 56, 57, 58].The early involvement will result in a complete understanding of all the requirements and agreement approach to the design of both the product and its manufacturing and support processes. Product development teams promote open discussion and innovative thinking resulting in superior products, more efficient processes, and, ultimately, a more satisfied customer [59]. For an efficient distribution of activities among the design teams, the structured approach is very important. The distribution process should start with the product definition and end with manufacturing of the product. The product definition and the structure should be based on the well-understood customer requirements. These requirements should be evaluated and refined considering the expected time-to-market and quality of the product. The utilization of this expertise could help in improving product quality, optimize the product at the system level, and reduce the cycle time [60]. The integration of different CAD/ CAM/CAE tools could shorten the development process and optimizes the design. The use of common electronic product model reduces the chances of redundancy and errors. The feature-based solids modeling, *parametric modeling,* and electronic design frameworks facilitate the analysis and use of product data among participating teams. It is possible to electronically simulate product performance, interface checking, and manufacturing feasibility.[61]. This overall development process should not be set as standard and needs to be improved as it progresses [62, 63]. Research is going on in developing the technologies or infrastructure to support the distributed design environment. Some are working on providing a platform for sharing or coordinating the product information via the World Wide Web [64, 65]. Others are developing the framework that enables the designers to build integrated models and to collaborate by exchanging services [66, 67, 68, 69, 70, 71, and 62].

F. The role of web in manufacturing.

Global competition and rapidly changing customer requirements are forcing major changes in the production styles and configuration of manufacturing enterprises. Traditional centralized manufacturing systems are not able to meet these requirements. In recent years, the internet has become the world wide information platform for the sharing of information and data. Information processing is an important challenge in an internet-based manufacturing environment, and must facilitate distribution, heterogeneity, autonomy and cooperation. In the field of manufacturing, a number of concepts such as agile manufacturing, virtual manufacturing, next generation manufacturing, etc have emerged. [72, 73]. Virtual manufacturing is considered as the most advanced and efficient form of modern networked organization, and is supported by extensive use of information and communication technologies. This is essentially internet-based manufacturing and its main characteristics are the exploitation of distributed information, integration of processes and remote manufacturing. The internet, incorporating multimedia and distributed information processing technology, has provided considerable potential for remote integration and cooperation in global manufacturing applications because it has become the world wide information platform for the sharing of all kinds of information [74]. Today manufacturing enterprises, software developers and networking companies are all exploring the usage of the internet/intranet and web technology to support distributed manufacturing facilities around the world [75]. At the beginning manufacturing enterprises were in the process of creating a distributed design and manufacturing environment that are able to integrate marketing analysis, product design, product development and manufacturing process together. [76] Advanced manufacturing strategies such as lean manufacturing, agile manufacturing, and globalization of manufacturing using different concepts like computer integrated design and manufacturing(CADCAM), Computer Integrated Manufacturing (CIM), Concurrent Engineering in order to design, develop and manufacture the products in a distributed environment it follows the concept of internet/web based technology. [77, 78].

III.DEVEOPMENTS IN DIGITAL MANUFACTURING

In recent years developments in Digital manufacturing is covering all the areas like academics, industry, medical science, digital shops, digital city and so on to solve the problems of modern world.

A. Background

Manufacturing is the backbone of our economy. Millions of people are employed in different companies. Huge amount of money invested in manufacturing industries across the globe. Manufacturing has a long tradition and its role is adding value for the economies and their prosperity. But now there is a strong change caused by globalization and internal changes of technologies. More than 90 years ago Taylor formulated the paradigms of scientific based manufacturing: "Analysing the manufacturing work on elementary processes with scientific based methodologies gives benefits to the economic efficiency of companies and their workers" (Taylor, 1983). Till Today the so called "Taylorism" is the dominant paradigm of manufacturing in practice. The methodologies have changed and computers are used in nearly all processes. Manufacturing is on the way to a knowledge-based and digital era.[79].

B. Necessity of Digital Manufacturing

The necessity of digital manufacturing is to speed up the manufacturing process which includes two aspects: (1) To speed up the product development that is to reduce development lead-time. (2) To reduce production lead time. The extension of global production realizes universal production; anywhere anybody makes the same products swiftly and inexpensively using the same procedure.[80]

C. Definition

Based on the necessity, "Digital Manufacturing "Can be defined. Digital manufacturing is a methodology for manufacturing which uses tangible knowledge (digital values) and information technology (IT). In digital manufacturing, the ambiguity of tacit knowledge in manufacturing should be eliminated thoroughly, and the tacit knowledge should be transformed into tangible knowledge, such as numerical values and/or equations and finally into digital values[80]. Digital manufacturing is a key point of integration between PLM and various shop floor applications and equipment, enabling the exchange of product-related information between design and manufacturing groups. This alignment allows manufacturing companies to achieve their time-to-market and volume goals, as well as realize cost savings by reducing expensive downstream changes.[81]

D. Mode of Application

The modes of digital manufacturing for application of digital technology to manufacturing.

- Transforming technical and technological knowledge into numerical data.
- Virtual design and manufacturing.
- Extracting the meaning from data, processing and utilizing it.
- Consistent and collective use of data.
- Remote management.

E. The Motivation

Global networks of communication and the diffusion process of electronics and information systems characterize the environment, in which peoples live, business and manufacturing is done. The world of manufacturing of this century is a networking information world – inside and outside of enterprises and linked to all participants of markets.[82].

F.Objectives

New technologies and the adaptability of the manufacturing structures are challenges for our future. The manufacturing demands as objectives of future development towards 2020:

Competitiveness of manufacturing industries:

- to survive in the turbulent economic environment
- to compensate migration and consumption of technologies
- to have more and better jobs
- to stabilize economic growth
- to ensure welfare and social standards of living

Leadership in manufacturing technologies:

- to support innovative products and platforms
- to lead manufacturing with global standards
- to guarantee human and social standards of work

Environment friendly products and manufacturing:

- to reduce the environmental losses
- to change the consumption of limited resources
- to maximize the benefits of each product during its life cycle.

All of these objectives are focused on the innovation of the manufacturing industries. [82]

G. Benefits

Digital manufacturing can help manufacturing companies improve their productivity in both manufacturing planning and production processes.[81].

- Digital manufacturing enables product, process, plant and resource information to be associated, viewed and taken through change processes, with a consistent and comprehensive approach to production design.
- Digital manufacturing allows part manufacturing processes to be optimized within a managed environment. It can produce flexible work instructions capable of displaying 2D/3D part information, along with the machining and tooling instructions.
- The simulation capabilities of digital manufacturing help reduce commissioning costs by validating robotics and automation programs virtually.

- Using digital manufacturing, it is possible to create factory models faster and ensure that they are operating under optimal layout, material flow and throughput before production ramp-up.
- Digital manufacturing can be used to support six-sigma and lean initiatives, by providing a graphical environment to analyze dimensional variation and so on.

H.Academic Research

The developments in digital manufacturing may be categorized into two major groups. The developments of the first group have followed a bottom-up approach considering digital manufacturing, and extending its concepts, within a wider framework, e.g. the digital factory or enterprise. The developments of the second group have followed a top down approach considering the technologies in support of individual aspects of digital manufacturing, e.g. e-collaboration and simulation. The Verein Deutscher Ingenieure, has addressed that the digital factory includes models, methods, and tools for the sustainable support of factory planning and factory operations. [83]. At a theoretical level, several researchers have contributed to the definition of the digital factory vision and suggested how this vision could be implemented in reality [84]. Data and models integration has been a core research activity to support implementation. The introduction of consistent data structures for improving the integration of digital product design and assembly planning and consequently supporting a continuous data exchange has been investigated. [85]. Similar activities have focused on the definition of semantic correlations between the models distributed as well as the associated databases and the introduction of appropriate modeling conventions [83]. On top of these developments, a number of methodologies for computer-supported co-operative development engineering, within a digital factory framework, have been published. [86].

The new concept of digital enterprise technology (DET) has also been introduced as the collection of systems and methods for the digital modeling of the global product development and realization process in the context of life-cycle management [87]. On the basis of the DET framework, a new methodology has been suggested that focuses on developing novel methods and tools for aggregate modeling, knowledge management, and test on validation planning to ‘bridge’ the gap that exists between conceptual product design and the organization of the corresponding manufacturing and business operations . [88]. From a technological point of view, new frameworks for distributed digital manufacturing have come into picture. Recent developments focus on a new generation of decentralized factory control algorithms called as ‘agent based’. A software agent, first, is a self-directed object, second, has its own value systems and a means of communicating with other such objects, and, third, continuously acts on its own initiative [89].The decision making capabilities of agent based systems on real-time and decentralized manufacturing have been reported. [90]. In such a system, each agent, for example a software application , is responsible for monitoring a specific set of resources, namely machines, buffers, or labor that belong to a production system, and for generating local alternatives upon the occurrence of an event, such as a machine breakdown. Web-based multi-agent system frameworks have also been proposed to facilitate collaborative product development and production among geographically distributed functional agents using digitalized information [91]. The developments in digital mockup (DMU) simulation technologies during the 1990s were the root cause for the emergence of Virtual Reality (VR) and human simulation in digital manufacturing. These developments have led to new paradigm that integrates product, process, resource, knowledge, and simulation models within the DMU environment [92]. The VR technology has gained major attention and has been applied to several fields related to digital manufacturing research and development. Virtual manufacturing is one of the first fields that attracted researchers’ attention. A number of VR-based environments have been demonstrated, providing desktop and/or immersive functionality for process analysis and training in such processes as machining, assembly, and welding [93, 96]. Virtual assembly simulation systems focusing on digital shipbuilding and marine industries, incorporating advanced simulation functionalities have also been introduced by Kim et al. [97]. Human motion simulation for integrating human aspects in simulation environments has been another key field of interest. [94, 95, 98]. Collaborative design in digital environments is another emerging research and development field. The development of shared virtual environments has enabled dispersed people to share and visualize data, to interact realistically, as well as to make decisions in the context of product and process design activities over the web [99]. Research activities have been also launched for the definition and implementation of VR- and augmented-reality-based collaborative manufacturing environments, which are applicable to human-oriented production systems [100, 101].

IV.CONCLUSIONS

As a new manufacturing technology and paradigm, digital manufacturing is becoming the mainstream in the development of advanced manufacturing technology. The main features and functions of digital manufacturing include: no ambiguity and reusability of digital description of products, prediction of product development process and product’s performance, and manufacturing activities’ independence of distance, time and location through networked environment.

This review presents that Digital manufacturing incorporates different technologies like CAD, CAM, CAE, RP, (PLM), CE, and so on, for the virtual representation of factories, buildings, resources, machine systems equipment, for the closer integration of product and process development through modeling and simulation.

It realizes from this review paper, the characteristics and concepts of digital manufacturing. There is vast scope to achieve in customized manufacturing of any products especially in clinical manufacturing of dental implants that helps in product optimization. DM helps in reduction of lead time, to maintain quality, cost, aesthetic etc to meet the customer expectations.

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