DIGITAL MANUFACTURING FOR COMPETITIVE ADVANTAGES

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ABSTRACT

Digital manufacturing has been considered in competitive advantages in integrated as well as advance manufacturing process, over the last decade, as a highly promising set of technologies for reducing product development times and cost as well as for addressing the need for customization, increased product quality, and faster response to the market. This paper describes the evolution of information technology systems in manufacturing, outlining their characteristics and the challenges to be addressed in the future. Together with the digital manufacturing and factory concepts, the technologies considered in this paper include computer-aided design, engineering, process planning and manufacturing, product data and life-cycle management, simulation and virtual reality, automation, process control, shop floor scheduling, decision support, decision making, manufacturing resource planning, enterprise resource planning, logistics, supply chain management, and e-commerce systems. These technologies are discussed in the context of the digital factory and manufacturing concepts. Digital simulation tools are jointly employed for the design of an existing aircraft engine components manufacturing cell to be enhanced through automated robotic Deburring. The application of 3D Motion Simulation is illustrated for layout and material handling system design. Discrete Event Simulation is applied to analyses different scenarios and improve the cell performance with regards to two key objectives: (a) optimization of the batch throughput time for the part number fabricated in the manufacturing cell; (b) utilization increase of the automated Deburring station by processing additional part numbers coming from other manufacturing cells in the same production department

Keyword: - *History, Reviews ,factory & cell layout, DM Software, Case study, Merits, Future Scope of DM*

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1. Introduction

1.1 History:

More than 80 years ago Taylor formulated the paradigms of scientific based manufacturing: “Analyzing the manufacturing work on elementary processes with scientific based methodologies gives benefits to the economic efficiency of companies and their workers”. The so called “Taylors” is still today the dominant paradigm of manufacturing in practice. The methodologies changed and computers are used in nearly all processes. Manufacturing is on the way to a knowledge-based and digital era [21].

Digital manufacturing is the use of an integrated, computer-based system comprised of simulation, three-dimensional (3D) visualization, analytics and various collaboration tools to create product and manufacturing process definitions simultaneously. Digital manufacturing evolved from manufacturing initiatives such as design for manufacturability (DFM), computer-integrated manufacturing (CIM), flexible manufacturing, lean manufacturing and others that highlight the need for more collaborative product and process design. The need for reduced development time together with the growing demand for more customer-oriented product variants have led to the next generation of information technology (IT) systems in manufacturing. Manufacturing organizations strive to integrate their business functions and departments with new systems in an enterprise database, following a unified enterprise view [22]. These systems are based on the digital factory/manufacturing concept, according to which production data management systems and simulation technologies are jointly used for optimizing manufacturing before starting the production and supporting the ramp-up phases [21]. Digital manufacturing would allow for, first, the shortening of development time and cost, second, the integration of knowledge coming from different manufacturing processes and departments, third, the decentralized manufacturing of the increasing variety of parts and products in numerous production sites, and, fourth, the focusing of manufacturing organizations on their core competences, working efficiently with other companies and suppliers, on the basis of effective IT-based cooperative engineering.

Digital manufacturing systems allow manufacturing engineers to create the complete definition of a manufacturing process in a virtual environment, including:

- Tooling
- Assembly Lines
- Work Centers
- Facility Layout
- Ergonomics
- Resources

Digital manufacturing in industry based the stand up the bridging pillars, and these pillar are the shown in fig such as Product design, engineering and production. The evolution of IT in manufacturing is described in the next section. Recent developments and the digital manufacturing concept are then discussed, followed by the conclusions regarding the perspectives and the outlook of digital manufacturing in the future.

Modern manufacturing systems should be capable to meet several challenges and satisfy requirements and constraints that rapidly vary over time. Following the concept of product life cycle, the concept of manufacturing systems life cycle has emerged in the last years. This approach considers the manufacturing system, and the entire factory, as a product characterized by several stages. These stages start from the initial system design, and proceed through the implementation, operation, and subsequent re-design/reconfiguration of the manufacturing system[22].

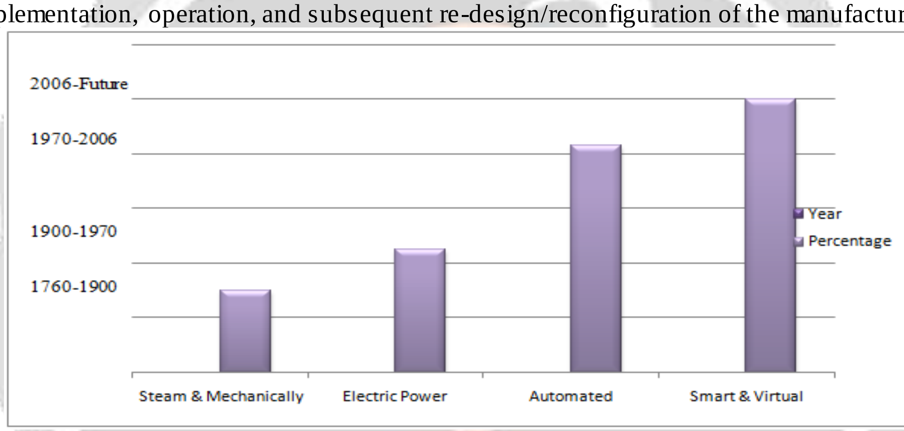

Chart 1.1: Revolution of DM system in Industry

1.2 DM in Computer-aided competitive technologies

CAD is considered among the technologies that have boosted productivity, allowing faster time to market for the product and dramatically reducing the time required for product development. Although the first CAD applications were inherently difficult to use owing to the text-based input systems and the extremely slow computational equipment, their successors have become more than necessary in today's manufacturing companies, regardless of their size. 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. The CAD systems have become indispensable to today's manufacturing firms, because of their strong integration with advanced manufacturing techniques. CAD models are often considered sufficient for the production of the parts, since they can be used for generating the code required to drive the machines for the production of the part. Rapid prototyping is an example of such a technology. Computer-aided engineering (CAE) systems are used to reduce the level of hardware prototyping during product development and to improve the understanding of the system [4]. The CAE systems support a large number of engineering research fields, including fluid mechanics (computational fluid mechanics), dynamics (simulation of machines and mechanisms), and mechanics of materials (FEA), thermodynamics, and robotics. For instance, Brinksmeier et al. [5] conducted an extensive survey on the advances in the simulation of grinding processes together with a series of models that can be implemented in simulation systems.

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). Apart from the fact that this new technology has brought about a revolution in manufacturing systems by enabling mass production and greater flexibility [6], it has also enabled the direct link between the three-dimensional (3D) CAD model and its production. Newman and Nassehi [7] 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 (G&M code and APT) leads solution developers to integrate an automatic code generation in their applications. From that point on, CAD and CAM systems have been developed allowing for part design and production simulation. Engineers have the ability to visualize both th e part and the production process, to verify the quality of the product and then physically to perform the manufacturing process with minimum error probability.

1.3 DM: Outlook

The speed-up of a manufacturing process consists of two aspects: one is the sp eed-up of product development to reduce development lead time and the other is that of production to reduce production lead time [9]. In parallel, the quality and manufacturing cost of the final product are determined again in both the design and productio n phases. This demonstrates that there is a significant need for a bridge to be built between the production of development and the real production; digital manufacturing aims to play this part. Years ago, both FEA and computer-aided machining were the true 'black arts' of manufacturing. With products that devolved out of high-end academic research, these software products often needed highly trained, highly scientific minds, and a deep and healthy bank account. In the 1990s, both FEA and computer-aided machining suddenly became affordable and usable, even on the shop floor. FEA integrated with mainstream design products has meant that most testing and analysis can be conducted quickly and with reliable results. Now, an engineer can find out much earlier in the process if a design has any flaws and then can eradicate them quickly. The recent technology improvements are making digital manufacturing real to many, and many companies are using pieces of digital manufacturing without realizing it [10].

In digital manufacturing, the ambiguity of tacit knowledge in manufacturing should be eliminated thoroughly, and the tacit knowledge should be transformed into tangible knowledge, namely numerical values and/or equations and finally into digital values [9]. This is expected to minimize the production performance diversities frequently observed between globally distributed production sites of extended enterprises. Modern information technology can support the communication among the various nodes of the extended produ ction network, but then systematic data management becomes critical. Optimized data management is required through all the stages of digital manufacturing for its efficient exercise. 3D design data can result in huge data files. Gigabytes of information in one or two files mean massive wait times, the inability actually to send them anywhere, and a huge barrier to digital manufacturing. However, the acceptance of XML as communication format and the development of additional formats (such as XVL, JT, and U3D) provide very high compression without a loss of information [10].

Digital manufacturing is one of the core strategies of the European Manufacture vision, that uses a wide range of engineering, software and ICT tools that are mutually networked by a central data management to integrate new technologies into manufacturing processes as quickly and efficiently as possible. In a wider context, digital manufacturing embraces 3D product lifecycle management (PLM) tools to allow for digital prototyping, adequa te process standards, multiscale simulation, and overall factory data management. In digital manufacturing, the digital model of a product is the essence of this concept that could be used to simulate and analyses the related production activities flow or to verify different production planning, machining/tool path, inspection and resource utilization scenarios[6].

2. Literature Review:

(1) Alessandra Caggianoa,b, Luigi Nelea, Emanuele Sarnoa, Roberto Tetia,b - In the last years, efforts have been focused towards new approaches for the automation of gas metal arc welding process parameters. In this framework, an innovative welding system based on a 3-axis motion device and a vision system consisting of a video camera, a laser head and a band-pass filter has been developed and implemented to recognize the desired features of weld joints, such as geometry and dimensions, and automatically adapt the welding process parameters according to these features. This papers focuses on a real case study of the railway manufacturing industry related to the welding process of a bogie frame. Through the employment of 3D Motion Simulation, the identification of a suitable reconfiguration of the system through the substitution of the 3-axis motion device by means of an industrial robot is studied in a totally digital framework. Simulation of the welding process allows calculation of robot kinematics, collision detection and motion planning. In this paper, an innovative Gas Metal Arc Welding system equipped with a vision system consisting of a video camera, a laser head and a band-pass filter was illustrated and implemented with reference to a real industrial case of the railway manufacturing industry. The developed system is able to perform automatic welding process parameters adjustment through a dedicated software procedure according to the information gathered by the vision system.

(2) G Chryssolouris, D Mavrikios, N Papakostas, D Mourtzis, G Michalos, and K Georgoulias -Digital manufacturing has been considered, over the last decade, as a highly promising set of technologies for reducing product development times and cost as well as for addressing the need for customization, increased product quality, and faster response to the market. This paper describes the evolution of information technology systems in manufacturing, outlining their characteristics and the challenges to be addressed in the future. Together with the digital manufacturing and factory concepts, the technologies considered in this paper include computer-aided design, engineering, process planning and manufacturing, product data and life-cycle management, simulation and virtual reality, automation, process control, shop floor scheduling, decision support, decision making, manufacturing resource planning, enterprise resource planning, logistics, supply chain management, and e-commerce systems. These technologies are discussed in the context of the digital factory and manufacturing concepts

3. Methodology

3.1 Advance & Digital Manufacturing

Alteration processes to manufacturing systems are planned on an elementary basis. For example, alterations carried out on a construction lead directly to alterations in processes and documents. For the employee executing operations or for the machines, this leads to alterations in such elementary processes as movement, position or function. This also affects digital tools and the fitting and ergonomic design of individual work stations. The corresponding superior level has the function of management and optimization. Digital manufacturing uses a wide range of engineering and planning tools, software, and information and communication technologies to integrate new technologies into manufacturing processes as quickly and efficiently as possible /5,12,13/.

Main area of research is the development of integrated tools for industrial engineering and adaptation of manufacturing taking into account the configurability of systems.[1] Digital manufacturing is the most important technology of the future. Digital Manufacturing needs:

- distributed data management
- Tools for process engineering
- Tools for presentation and graphic interfaces
- Participative, collaborative and networked engineering
- Interfaces to the reality

Starting with the digital picture of the factory/manufacturing and by deploying the virtual manufacturing technologies consisting of simulation tools and specific applications/ systems, components of the a IE as well, the planners deal with the factory and manufacturing processes in their dynamicity, by having the reflection of the "as is" and state in the future "to be", the so named in our approach the virtual factory/manufacturing. Engineering is a key technology. In the German manufacturing industry about 16% of the employees are engineers [1]. They need tools for efficient work, which allows the fastening of the engineering processes and simultaneous work. Digital and virtual manufacturing is able to support manufacturer's work, when this tools are near reality and linked to manufacturing as it is. R&D is driven by the vision of fully digital engineering and multi-scale modeling the dynamic behavior of products in the whole life cycle. By this way it seems to be possible to activate potentials in the utilization to optimize the life time and to reduce the environmental pollution.

At present, the developmental activities associated with the digital factory/manufacturing focuses on the planning of factories, production plants, new logistic systems, and of the manufacturing processes. Two advanced digital factory/manufacturing concepts are currently offered by Delmia and Tecnomatix: a few solutions from other companies are also available on the market. These are based on a similar concept: the various software tools are mutually networked by a central data management system which constitutes the core of the integrated solutions incorporated in the product spectrum of the respective software supplier. The object of the endeavor is to ensure that all planning results are always completely up to-date and are available to the authorized users at all times. With these concepts and by using a large spectrum of simulation application/systems a virtual and scalable system constitutes the platform for high-end visualization of the planning results and thus facilitates interdisciplinary communication among various experts despite differences

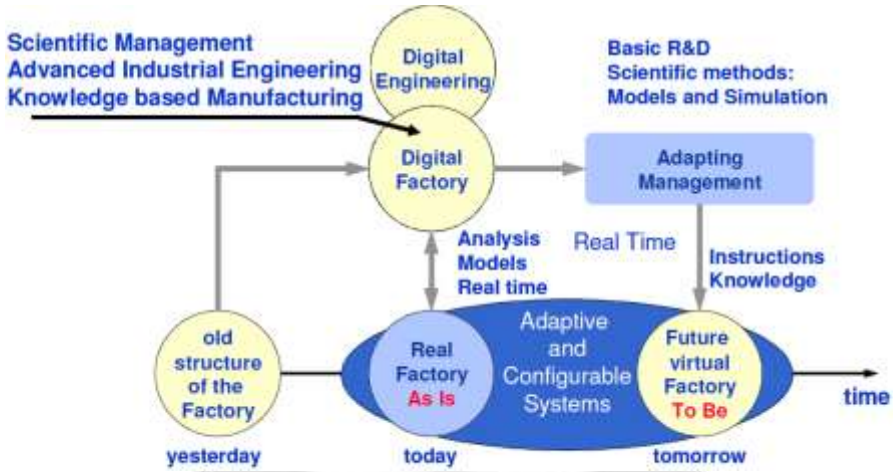

Fig 3.1: Digital Manufacturing

3.2. Factory Layout

In manufacturing company is utilizing a PLM basis factory layout software packages. Which is based on the company criteria such some sophisticated criteria are?

- Analyze for clashes and space restraints
  - Perform an analysis before you install any equipment.
  - Minimize risks with clash detection tools.
  - Simulate the installation sequence of equipment.
- Streamline factory layouts
  - Streamline manufacturing operations.
  - Analyze material flow and energy consumption.
- Maximize production lines
  - Find the most efficient footprint possible.
  - Use modern workflows and point clouds.

3.3 Cell Design

Modern manufacturing systems should be capable to meet several challenges and satisfy requirements and constraints that rapidly vary over time. Following the concept of product life cycle, the concept of manufacturing systems life cycle has emerged in the last years. This approach considers the manufacturing system, and the entire factory, as a product characterized by several stages. These stages start from the initial system design, and proceed through the implementation, operation, and subsequent re-design/reconfiguration of the manufacturing system [10-12]. New market requirements and technology improvements impose very short time for manufacturing system design and reconfiguration in order to win the competition at global scale. This requires the critical examination of several alternative solutions to support optimal design decision making. In the literature, several analytical methods have been proposed over time and are currently employed [13-14]. However, as up-to-date manufacturing systems tend to be very complex, these methods can be notably demanding in terms of computing time and resources.

3.3.1 Manufacturing cell new configuration

In the new manufacturing cell configuration, the grinding machine and the CMM are associated to an automated deburring station provided with a robot that performs deburring, inspection and transfer of components. The deburring station is composed of a rotating table for components input/output, an inspection post provided with a touch probe to verify component positioning with respect to the robot, a deburring device with several tools for different component features, and a tool changer for the robot gripper. Furthermore, a human labor is employed in the manufacturing cell to carry out assembly and disassembly of components and fixtures on the grinding machine input/output buffers and to transfer parts between grinding machine, CMM and automated deburring station. The new manufacturing cell elements are listed and the general layout is shown in Fig. 1.

Manufacturing Cell Elements:-

a) I/O Component Storage b) Component and Fixture Assembly Station

c) Handling Robot d) Grinding Machine
e) Rotating Table f) Handling/Deburring Robot
g) Inspection Post h) Deburring Device
i) Tooling Storage j) CMM – Coordinate Measuring Machine

3.4 Digital Manufacturing Software

Here are examples of digital manufacturing software applications: Tecnomatix is a comprehensive portfolio of digital manufacturing solutions that link all manufacturing disciplines together with product engineering – from process layout and design, process simulation and validation, to manufacturing execution. Built upon the open PLM foundation called the Team center manufacturing platform, Tecnomatix provides a versatile set of manufacturing solutions.NX CAM and CAM Express allow NC programmers to maximize the value of their investments in the latest, most efficient and most capable machine tools. NX CAM provides the full range of functions to address high speed surface machining, multi-function mill-turning, and 5-axis machining. CAM Express provides powerful NC programming with low total cost of ownership [16].Just the built up the better DM system software used in the competitive manufacturing is:-

a) Delmia (Dussaults system)&Catia d) Robmaster
b) Solidmod e) AutoCAD
c) Tecnomatix f) NX CAM

3.5 Types

3.5.1 On Demand

1) Additive **-** Additive manufacturing is the "process of joining materials to make objects from 3D model data, usually layer upon layer." Digital Additive manufacturing is highly automated which means less man hours and machine utilization, and therefore reduced cost By incorporating model data from digitized open sources, products can be produced quickly, efficiently, and cheaply.[9]
2) Rapid **-** Much like Additive manufacturing, Rapid manufacturing uses digital 3D CAD models to rapidly produce a product that can be complicated in shape and heterogeneous in material composition. Rapid prototyping are the used based on the STL file for a digital 3D CAD basis virtual design to produce a real module with a prototyping process such as DFM, STL etc. Rapid manufacturing utilizes not only the digital information process, but also the digital physical process. Digital information governs the physical process of adding material layer by layer until the product is complete. Both the information and physical processes are necessary for rapid manufacturing to be flexible in design, cheap, and efficient[18].

3.5.2 Cloud-Based Design and Manufacturing.

Cloud-Based Design (CBD) refers to a model that incorporates social network sites, cloud computing, and other web technologies to aid in cloud design services. This type of system must be cloud computing-based, be accessible from mobile devices, and must be able to manage complex information. Autodesk 1-2-3D is an example CBD[17]. Cloud-Based Manufacturing (CBM) refers to a model that utilizes the access to open information from various resources to develop reconfigurable production lines to improve efficiency, reduce costs, and improve response to customer needs [17].

4. Case Study

4.1 Mahindra & Mahindra Tech

The painted body of the Maxximo mini-truck is transported inside the new assembly shop for operations. The car body is moved along using a hanger system in the underbody areas and on transfer lines. The system was initially designed to carry the car body with the doors closed. After analyzing the conceptual flow of assembly, other possible assembly operations were analyzed. It was found that in order to reduce production time, some assembly operations could be executed when the car body is on the hanger, as long as the doors could be opened to a certain extent, which will enable operators to work inside the cabin area. Manufacturing engineers used Process Simulate to validate hanger design that could support sufficient door opening. The limit to which the doors can be opened was calculated based on the virtual 3D simulation, instead of waiting for actual parts to arrive at plant. Drawings provided by suppliers were maintained in different layers in the same file, resulting in duplication of data and unnecessarily large files, which degrade visualization performance. To resolve these issues, Factory CAD was used to create 3D plant layouts for all of the Chakan plant production lines, including body and trim, chassis and final (TCF). "Providing the essentials needed to create detailed and intelligent factory models, Factory CAD allowed our planners to use 'smart objects' to represent their factory resources," says, senior manager, IT and PLM, Chakan plant, Mahindra Vehicles (Maharashtra) [20].

4.2 Tata Motors service

DELMIA solutions at Tata Motors have enabled the assessment of equipment and logistics planning in a virtual world. Assembly process issues, such as interference, tool accessibility and working posture have been detected earlier, thanks to simulation. From there it has been straightforward to implement the necessary improvements at the initial stages of product design, ensuring that the manufacturing requirements are met. Tata Motors is the first Indian company that has implemented DELMIA solutions from end-to-end [19].

"We are delighted at, and feel proud of, the great benefits we gained through DELMIA solutions during our recent design and manufacturing engineering projects," commented CEO. Often, assembly lines are shared among multiple models of vehicles. Introducing another model into an existing assembly line invariably introduces problems as the complexity level increases (for example NANO Car start 2008 production start).At Tata Motors, these issues are quickly identified and solved by performing a virtual line balancing operation that takes all the variables into consideration. Through the 3D simulation of assembly processes and tests, such as clash, interference or tool accessibility, the finer details can also be ironed out in advance.

5. Benefits And Limitations

- **Benefits:**

By exploiting digital manufacturing, manufacturing enterprises expect to achieve the following [8]:

1) Shortened product development. 2) Strong industry network and alliances.
3) Early validation of manufacturing processes. 4) Faster production ramp-up.
5) Faster time to market. 6) Reduced manufacturing costs.
7) Improved product quality. 8) Enhanced product knowledge dissemination.
9) Reduction in errors. 10) Increase in flexibility.

- **Limitations:**

1)IGES include large file size.
2) Long processing time.
3) The restriction of information exchange to shape data only.

6. End User Future Scope

The segments that the manufacturing companies see as offering the greatest potential for benefitting from the digital transformation to industry 4.0 include research and development (in which a total of 78% of companies see great or very great potential), warehousing and logistics (74%), production (73%), services (72%), procurement and purchasing (69%) and sales (56%).There is huge demand for transformation in research and development, in procurement and purchasing and in production. These areas are traditionally heavy users of technological applications and innovations and are likely to remain so in the future. In the companies we surveyed, warehousing and logistics, sales and services seem to be the business segments that have so far undergone relatively little transformation to industry 4.0 but that offer substantial potential for benefitting from it.

Most respondents agree that Swiss manufacturing companies are not yet making full use of the increased productivity and improved efficiency that industry 4.0 applications offer. Many respondents see the main advantage of industry 4.0 as the ability to reduce costs further and to remain competitive. They see substantial potential across all segments of their company and across the entire value chain. However, delays in achieving industry 4.0 standardization remain a challenge. There is a need for standardized interfaces so that the machines in smart factories are able to communicate with each other and share data seamlessly with other smart infrastructure in the 'internet of things, services, data and people' to achieve smart mobility, a smart grid, smart logistics and smart homes and buildings. In a world that is changing exponentially, there is a need to shift from 'push' to 'pull'. The world has traditionally been organized around labor, with many assets and knowledge pools focused on efficiency. Superior engineering from Switzerland allowed higher prices, and planning and driving change ('push') was required. To benefit from exponential growth, companies need to organize around digital power, tap in to external pools of knowledge, combine assets, gain better knowledge about markets, industries and customer preferences ('pull') and focus on scalable learning.

4. Conclusions

Digital manufacturing incorporates technologies for the virtual representation of factories, buildings, resources, machine systems equipment, labor staff and their skills, as well as for the closer integration of product and process development through modeling and simulation. Closing the gap between the product definition and the actual manufacturing production activities within the enterprise, fully transforming tacit manufacturing knowledge into tangible, and, finally, digital knowledge, optimizing data management, and developing standard models are some key priorities.

Digital manufacturing is key for adaptation and based on modern tools and techniques for engineering, control, supervision and management in a network. Taking into account the dynamic of markets and inn ovation the industrial engineering has a key role in the fast adaptation and complexity when factories are seen as scalable products. Optimization of a systems, data management and knowledge are new challenges for engineers and their work. This is the new era of manufacturing-the digital manufacturing.

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