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Virtual Manufacturing

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***Abstract*: Virtual engineering is an emerging technology which integrates geometric models and related engineering tools such as design, analysis, simulation, optimization and decision making tools within computer-generated environment that facilitates multidisciplinary collaborative product development. In manufacturing, the major component of virtual engineering is Virtual Manufacturing (VM). VM use computer aided design models and simulations of manufacturing for production of manufactured products. VM provides the capability to "Manufacture in the computer" and has the ability to interchange models between their use in simulation and control environments. An innovative and effective solution to overcome recent product development lifecycle problems in manufacturing industries is the application of Virtual Reality (VR) and Augmented Reality (AR) technologies to simulate and improve the manufacturing processes before they are carried out. This would ensure that activities such as design, planning, simulation, machining are done right-the-first-time without subsequent rework and modifications. The challenge is to design and integrate VR and AR in Virtual Manufacturing Systems (VMS) that could enhance manufacturing processes and product development process leading to shorter lead time, reduced cost, more efficient and improved quality with clean and green process. The paper aims at providing a review on virtual manufacturing: definition, its origin, types, benefits, virtual manufacturing systems, applications, future and challenges to overcome the drawbacks associated by adopting VM.**

***Keywords*: Virtual engineering, virtual manufacturing, virtual reality, augmented reality, virtual environment**

1. Introduction

Manufacturing is an indispensable part of the economy and is the central activity that encompasses product, process, resources and plant. The competition between the industries is becoming tougher and challenging at present economic scenario of global integration. So in order to adapt rapid changing market demands and win-win situation, modern manufacturing enterprises must solve TQCS questions (reduce manufacturing time, best quality, lowest cost, optimal service). Nowadays the industrial world is undergoing profound changes as products are more and more complex, processes are highly-sophisticated and use micro-technology and mechatronics as market demands [1]. The competitive advantage in manufacturing has shifted from the mass-production archetype to one that is based on fast responsiveness and on flexibility [2].

In this complex and evaluative environment, industrialists must know about their processes before trying them in order to get it right the first time. To achieve this goal, the use of a virtual manufacturing environment will provide a computer-based environment to simulate individual manufacturing processes and the total manufacturing enterprise. Virtual Manufacturing systems enable early optimization of cost, quality and time drivers, achieve integrated product, process and resource design [3]. Virtual manufacturing eliminates material waste and faulty design. It provides better understanding of a process without making of prototype models.

Virtual Manufacturing greatly reduces the product and process development cycle. It also provides a platform to train new operators on a particular machine without having to waste precious machine time [4]. VM is the reflection of actual manufacturing process on computer, that is adopting the computer simulation and virtual reality technology, with the aid of high performance computer and high-speed network, conducting the coordination work on the computer, realizing the product design, technology planning, processing and manufacturing, performance analysis, quality inspection, and the control and management of each procedure of enterprise, processes of product manufacturing in order to enhance the decision-making and control ability of each procedure of manufacturing.

VM technology is bringing a revolutionary change to the worldwide manufacturing industry [5]. Virtual Manufacturing system [6] is a computer system which can produce the similar information concerning manufacturing system structure, states and behaviors as one can observe in real manufacturing systems. K. Iwata, M. Onosato attempt to show the possibility of a new manufacturing style in the 21st century in its cultural aspect rather than its technological and economical aspects which is based on each individual person, not on a factory [7].

2. Problems in manufacturing

A. Problems inside Manufacturing

K. Iwata explained factory based manufacturing systems has certain issues in current scenario. There is a difficulty of acquiring advanced manufacturing technology concepts and skills in companies or factories [8]. R. Wise reviewed that in order to obtain more profits from the product users several industries try to expand their business scope from design and manufacturing to all services of product life-cycle [9]. L. Alting in his paper explained that to promote product reuse/recycle and safety of wastes, manufacturing industries must have more responsibilities on their products [10]. The long-term employment of labor in the manufacturing industry becomes more and more difficult.

B. Problems of manufacturing with respect to social circumstances

People come to prefer a tailor-made product rather than one by mass-production. B.J. Pine explains that the user wants to fit new product to new life style, climate, culture, and other products in individual possession. Artificial teeth and eyeglasses are old examples, and order made Personal Computer is a new example of this tendency [11]. At the beginning of 20th century these are the few problems observed in markets, consumers, logistics, natural resources, labor which are probably caused by the dispute between the social situation and the manufacturing scheme of mass-production.

3. New manufacturing technologies

The manufacturing process in earlier are carried out in an efficient way under controlled conditions and concentrated much on manufacturing resources such as labor, facilities, materials, money, knowledge and information in closed environment of a factory. Under the advanced manufacturing technologies and economics, the current situation has the following emerging situations in manufacturing.

One can get all manufacturing knowledge and information from anywhere outside factories, even from home through the progress of the information and communication technology such as internet and multi-media [13]. The progress of CAD/CAM/CAE facilitates alternative design by using product/process model data and reduces the design cost for product customization [14]. The possibility of economical production for a single part or a small batch of parts in new forming processes is due to rapid prototyping [15, 16]. The concept of virtual organizations like virtual enterprises [17, 18] decomposes the manufacturing functions included in a factory into autonomous modules. The combination of information technology and production technology has greatly changed traditional manufacturing industries. Many activities in manufacturing systems can be carried out using computer systems; the concept of virtual manufacturing (VM) has now evolved [19].

4. Definitions of virtual manufacturing

Generally, one defines “Virtual Manufacturing is nothing but manufacturing in the computer” [20]. Presently, Virtual Manufacturing has no unique/standard definition. But few definitions proposed on VM are as follows: [22]

VM is a concept of executing manufacturing processes in computers as well as in the real world, where virtual models allow for prediction of potential problems for product functionality and manufacturability before real manufacturing occurs by Professor Gloria J. Wiens [21]. VM is the integrated application of simulation, modeling and analysis technologies and tools to enhance manufacturing design and production decisions and control at all process levels by Professor Edward Lin [22]. VM is a map of practical manufacturing process on computer that is to conduct cooperative work on computer by applying computer simulation and virtual reality technique under support of high-performance computer and super-speed network and to realize product design, art planning, processing manufacturing, performance analysis, quality inspection and essential process of product manufacturing in all-level process management and control in enterprises so as to enhance all decision-making and control capacity in manufacturing process by Professor Xiao Tianyuan offered comparatively complete definition to current research and developing situation of manufacture [23].

5. History of virtual manufacturing

Virtual Manufacturing is the advanced form of Computer Aided Manufacturing based on Virtual reality and Augmented Reality. The concept of artificial reality already appeared in 1970s by Miron Krueger and with the notion of this virtual reality concept was introduced by Jaron Lanier in 1989. In 1990 the concepts of Virtual World and Virtual Environments appeared. Virtual reality is defined as a computer generated interactive and immersive 3D environment simulating reality [27]. The term VM first came into prominence in the early 1990s, in U.S. Department of Defense Virtual Manufacturing Initiative. Both the concept and the term have recently gained wide international acceptance and broadened in scope. For the first half of the 1990s, pioneering work in this field has been done by a handful of major organizations, mainly in the aerospace, earthmoving equipment, and automobile industries, plus a few specialized academic research groups. Recently accelerating worldwide market interest has become evident, fueled by price and performance improvements in the hardware and software technologies required and by increased awareness of the huge potential of virtual manufacturing. Virtual manufacturing can be considered one of the enabling technologies for the rapidly developing information technology infrastructure [28]. In product manufacturing techniques and organization, virtual reality has become the basis of virtual manufacturing aimed at meeting the expectations of the users/buyers of products, also as to their low cost and lead time. Virtual manufacturing includes the rapid improvement of manufacturing processes without drawing on the machines operating time fund [29].

6. Types of virtual manufacturing

Virtual manufacturing can be categorized into three groups according to the,

A. Type of product and process design [30]

Design-oriented Virtual Manufacturing: During the design phase design oriented VM provides manufacturing information to the design engineer. The parts or the whole machine are simulated and evaluated to test the manufacturability and assembly ability. The purpose is to optimize product design and process design. Through manufacturing simulation to accomplish manufacturing goals such as Design for Assembly (DFA), quality, flexibility.

B. Type of system integration

According to the definitions proposed by Onosato and Iwata [4], every manufacturing system can be decomposed into two different sub-systems:

- *Real Physical System (RPS):* An RPS is composed of substantial entities such as materials, parts and machines that exist in the real world.
- *Real Informational System (RIS):* An RIS involves the activities of information processing and decision making.
- *Virtual Physical System (VPS):* A compute r system that simulates the responses of a real physical system is a virtual physical system, which can be represented by a factory model, product model, and a production process model. The production process models are used to determine the interactions between the factory model and each of the product models.
- *Virtual Information System (VIS):* A computer system that simulates a RIS and generates control commands for the RPS is called a 'virtual-informational system (VIS).

C. Type of functional usage

- VM is used in the interactive simulation of various manufacturing processes such as virtual prototyping, virtual machining, virtual inspection, virtual assembly and virtual operational system [31].
- Virtual Prototyping (VP) mainly deals with the processes, tooling, and equipment such as injection molding processes [32]. VM is allied to the Virtual Prototyping, the Virtual CAD and Virtual CAM made most of the time by simulation [33]. Roger W Pryor discussed in his paper on the potential real benefits that can be realized through cost saving, minimization of number of prototype models [34].
- Virtual machining mainly deals with cutting processes such as turning, milling, drilling and grinding, etc. The VM technology is used to study the factors affecting the quality, machining time and costs based on modeling and simulation of the material removal process as well as the relative motion between the tool and the workpiece.
- Virtual inspection makes use of the VM technology to model and simulate the inspection process, and the physical and mechanical properties of the inspection equipment.

In Virtual Assembly, VM is mainly used to investigate the assembly processes, the mechanical and physical characteristics of the equipment and tooling, theinterrelationship among different parts and the factors affecting the quality based on modeling and simulation [35]. A virtual assembly environment would enable a user to evaluate parts that are designed to fit together with other parts. Issues such as handling ease of assembly and order of assembly can be studied with virtual assembly [36, 37].

- Virtual operational control makes use of VM technology to investigate the material flow and information flow as well as the factors affecting the operation of a manufacturing system. manufacturing, on the other hand, one can consider virtual reality as a tool which offers visualization for VM. The most comprehensive definition has been proposed by the Institute for Systems Research, University of Maryland, and discussed by Lin E is "an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control." The definition of VM given by a Bath University project team deserves attention. According to this definition: computer-based information that provide a representation of the properties and behaviours of an actualized product." Some researchers present VM with respect to virtual reality (VR). On one hand, Bowyer presents VM as a virtual world for "Virtual Manufacturing is the use of a desktop virtual reality system for the computer aided design of components and processes for manufacturing - for creating viewing three dimensional engineering models to be passed to numerically controlled machines for real manufacturing". This definition emphasizes the functions aiding the machining process [26].

7. Vision of virtual manufacturing

The vision of Virtual Manufacturing is to provide a capability to make it in the computer [38]. VM provides a modeling and simulation environment such that the design, analysis and fabrication/assembly of any product including the associated manufacturing processes which can be simulated in the computer. Figure 1 represents the vision on VM.

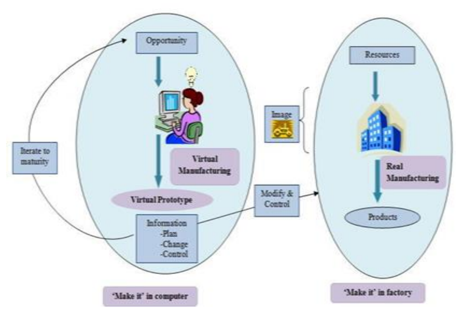

Fig.1. Vision of Virtual Manufacturing

The needs for VM are technology and development for models and simulations, virtual infrastructures and tools for working in virtual spaces such as CAM/CAM [39]. The scope of VM varies from workshop practice to company areas. To establish a theoretical approach of VM, knowledge of CAD and Virtual Prototyping (VP) is essential. VM characterizes virtualization of the real to the realization of the virtual.

8. Benefits of virtual manufacturing

Virtual Manufacturing builds confidence to manufacturers of knowing the delivery of quality products to market on time and within the initial investment. The benefits of VM [39] from product point of view, it will improve quality of the product, reduce number of physical prototype models, allows simulations of multiple manufacturing products, optimize the design of product and processes. And from production point of view, it will improve the confidence in the process, reduce material waste, reduce tooling cost, lowers manufacturing cost and optimizes manufacturing processes [40].

Implementing VM contributes several benefits such as ensuring higher quality of the tools, lesser cycle time for production of parts without false start, optimize the design for manufacturing [41] and assembly system for better producibility, flexibility in mix production of multiple products, quick response to customers about the impact of investment and delivery schedule with improved accuracy, good relations with the customers.

9. Virtual manufacturing systems

VM integrates manufacturing activities dealing with models and simulations, instead of objects and their operations in the real world. VM systems produce digital information to facilitate physical manufacturing processes. The concept, significance, and related key technology of VM were addressed by Lawrence Associate Inc. [42] while the contribution and achievements of VM were overviewed by Shukla [43]. Kimura [20] explained a typical VM system consists of a manufacturing resource model, a manufacturing environment model, a product model, and a virtual prototyping model. Onosato and Iwata [44] developed the concept of a VM system, and Kimura [20] described the product and process model of a VM system. Based on the concept and the model, Iwata et al. [4] proposed a general modeling and simulation architecture for a VM system. J. Gausemeier et al. [45] has developed a cyberbike VM system for the real-time simulation of an enterprise that produces bicycles. With the use of a VM system, people can observe the information in terms of the structure, states, and behaviors equivalent to a real manufacturing environment, in a virtual environment [46, 47]. Virtual manufacturing systems [48] are synthetic environment designed to exhibit manufacturing systems operation on a reality virtuality continuum. The reality–virtuality state exhibited by the manufacturing system falls into the following categories

- *Reality:* Real manufacturing operation
- *Augmented reality:* Manufacturing system control is augmented by the use of electronic hardware and computer software in order to facilitate managers with more micro- and macro-level parameters for accurate decision making leading to higher profitability.
- *Augmented virtuality:* Consist of higher level of virtuality than augmented reality. In augmented virtuality, a higher proportion of elements are synthetic in nature
- *Virtuality:* Encompasses immersion in a completely synthetic environment. The integration of virtual reality technology into the conceptual design and process planning stages reduces design time and cost [49].

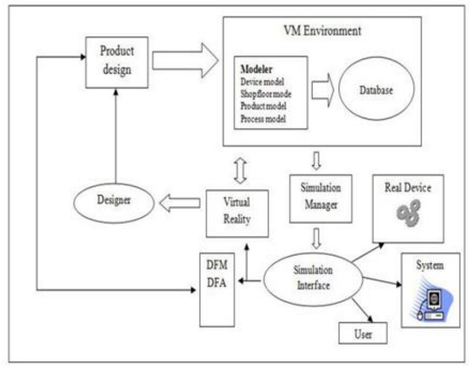

Fig. 2. Virtual Manufacturing Systems

Virtual manufacturing system as shown in fig. 2 is a representation of the complex real manufacturing system, consisting of various interacting, interrelated, and interdependent sub-systems and processes represented by abstract models.

Virtual manufacturing systems focused on specific applications like geometric modeling, product modeling, production system modeling, etc. These systems are very complicated, not modularized, not easy to construct, calibrate, or validate, not adaptable, and not easy to reuse. One of the possible reasons for this is that most of the system models are built hysterically, without first identifying the logical system structure. Therefore, for the purpose of construction of a comprehensive VM system, an unmistakable system structure, based on the various aspects of the real production process, is the necessary prerequisite [50].

The system structure helps in identifying the interactions, interrelations and functioning of various elements of the whole VM system. The interpretation of the dynamic relationships between various system elements facilitates the validation, calibration and verification of the individual system components as well as the whole VM system [42].

Virtual manufacturing must cope with many models of various types of product and process and require a large amount of computation simulating the behavior of equipment on a shop floor. In order to deal with this complexity in manufacturing, it is necessary to approach an open system architecture of modeling and simulation for virtual manufacturing systems [51].

K. Iwata [4] developed a modeling and simulation framework for virtual manufacturing systems, a modeling method integrating various simulation resources, and a control mechanism for distributed simulation. Based on K. Iwata's open system architecture, H. Hanwu explained a new modeling and simulation architecture for virtual manufacturing system. In H Hanwu and co-authors opinion, modeling means to set up a virtual manufacturing environment and simulation means to achieve virtual manufacturing activities. Figure represents the outline of VM environment. architecture, transactions between members and methods of measuring performance and controlling behavior.

10. Methods and simulation tools used in virtual manufacturing systems

VM has two main core activities. The first one is the "Modeling Activity" which determines what to model and degree of thought that is needed. The second on is the "Simulation Activity" which represents model in a computer based environment and compare to the response of the real system with degree of accuracy and precision. The following methods are necessary to achieve VM system:

Manufacturing characterization confines measure and analyze the variables that influence material transformation during manufacturing. Modeling and representation technologies provide different kinds of models for representation, standardization the processes in such a way that the information can be shared between all software applications (Knowledge based systems, Object oriented, feature based models). Visualization, environment construction technologies includes Virtual reality techniques, augmented reality technology, graphical user interfaces for representation of information to the user in a meaningful manner and easily comprehensible. Verification, validation and measurement the tools and methodologies needed to support the verification and validation of a virtual manufacturing system. Multi discipline optimization: VM and simulation are usually no self-standing research disciplines, they often are used in combination with "traditional" manufacturing research. Nowadays numerous tools are available for simulating manufacturing levels. Table 1 shows the overview of simulation tools applicable in manufacturing process.

Table 1. Overview of simulation tools [3]

Level of Manufacturing	Simulation Type	Targets	Priority
Factory Shopfloor	✓ Flow simulation ✓ Business process simulation	• Storage and logistics • Production values • Production planning and control	Low
Manufacturing Systems	✓ Flow simulation	• Layout of the system • Material flow • System capacity • Control plans • Planning	Intermediate
Manufacturing machine tool	✓ Flow simulation ✓ 3D kinematic simulation using commercial software	• Layout of specific cell • Programming • Testing	High
Components	✓ Finite element analysis ✓ Multibody simulation	• Structural (Static and Thermal) • Non Linear analysis • Dynamic analysis	Complex
Manufacturing processes	✓ Finite element analysis	• Cutting processes: surface properties, thermal effects, tool wear / life time, chip creation • Metal forming processes: formfill, material flow, residual stress, cracks	Very complex

11. Applications of virtual manufacturing

The virtual manufacturing has been successfully applied to many fields such as, automobile manufacturing, aeronautics and astronautics, railway locomotives, communication, education and so on, which has an overpowering influence on industrial circles

A. Automotive domain

The Integrated-Computer Aided Research on Virtual Engineering Design and Prototyping Lab of Wisconsin University developed a set of virtual foundry platform which make use of solid glasses to observe three-dimensional image, establish multifarious geometric model by language and make sure geometry size and place with data glove. American Daimler Chrysler Automotive Company adopted virtual prototype technology in their research of automobile part and thus shortened the developing period. American Caterpillar Co., the world's leading manufacturer of engineering machinery and construction equipment, applied virtual prototype technology in the design optimization and the internal visibility evaluation of loaders. The shape design using the virtual technology can be modified and evaluated at any time. The modeling data after scheme confirming can be directly used for the stamping tool design, simulation and processing, even for the marketing and propaganda. Application of VM is used in automobile factory shop floor and also in car driving simulation. Song Cheng describes a case research of D auto-company's virtual paint shop established with the technology of three dimensional simulations. Song Cheng depicted various equipments, structural objects, the way of establishing model, concerning contents and the simulation process of the whole shop and provide relatively real virtual shop and equipments' datum for the engineers.

B. Aerospace domain

Virtual Manufacturing in aerospace industry is used in FEA to design and optimize parts, e.g. reduce the weight of frames by integral construction, in 3D-kinematics simulation to program automatic riveting machines, and few works dealing with augmented reality and virtual reality to support complex assembly and service tasks in aircraft design. The aero engine model created in virtual environment describes where tools are developed and used to help manufacturing and design engineers to take action and decisions on problems normally solved only by experience. Henrik R explained application of VM in aircraft domain by considering Turbine Exhaust Casing (TEC). TEC is manufactured by fabrication and about 200 welds are needed to manufacture the product. Issues have been identified with the robustness of the geometrical tolerances created during production. Several welding sequence concepts were investigated to find a more robust manufacturing sequence. From the welding simulations it was shown that the residual stresses could be lowered using a different welding sequence. Moreover, to further avoid the issue with geometrical tolerances a pre-deformation was given to the product before welding, the amount of needed pre-deformation was calculated by the virtual welding simulation tool.

C. Healthcare domain

Healthcare is one of the biggest adopters of virtual reality which encompasses surgery simulation, phobia treatment, robotic surgery and skills training. One of the advantages of this technology is that it allows healthcare professionals to learn new skills as well as refreshing existing ones in a safe environment. Plus, it allows this without causing any danger to the patients. Virtual manufacturing applications in the healthcare industry are associated with Virtual Simulation is an important technologic method accounting for complex design and testing of designing proposal. Yongkang Ma explains in his research that the elements such as welding robots and fixtures of workstation for body-in-white welding are analysed and optimized using digital modelling method of work-station. Many leading areas of medical technology innovation including robot-assisted surgery, augmented reality (AR) surgery, computer-assisted surgery (CAS), image-guided surgery (IGS), surgical navigation, multi-modality image fusion, medical imaging 3D reconstruction, pre-operative surgical planning, virtual colonoscopy, virtual surgical simulation, virtual reality exposure therapy (VRET), and VR physical rehabilitation and motor skills training. Stent design influences the post-procedural hemodynamic and solid mechanical environment of the stented artery by introducing non-physiologic flow patterns and elevated vessel strain. This alteration in the mechanical environment is known to be an important factor in the long-term performance of stented vessels. Because of their critical function, stent design is validated by methods such as FEA.

D. Home Appliance domain

The virtual kitchen equipment system developed by a Japanese company Matsushita allows customers to experience functions of a variety of equipment in virtual kitchen environment before the purchase of actual equipment. These choosing results can be stored and send to the production department through computer network and be manufactured.

E. Other applications of VM explicated by Li Liu

Product shape style designs of conventional automobiles adopt the plastic to manufacture the shape model. The shape design using the virtual technology can be modified and evaluated at any time. In the shape design of other products such as building and decoration, cosmetic packing, communication, etc. has great advantages. In piping system design, through the implementation of virtual technology, the designer can enter into virtual assembly by conducting piping layout and check the potential interference and other problems. Product movement and dynamics simulation displays the product behavior and dynamically perform the product performance. The product design must solve the movement coordination and cooperation of each link on the production line. The usage of simulation technology can intuitively conduct the configuration and design, and guarantee the working coordination. In Product assembly simulation the coordination and assembly property of mechanical product is the place where most errors of the designers emerge. In the past, the error at final stage leads to the scrapping of parts and delay manufacture product which causes more economic losses and damage.

The implementation of virtual assembly technology can conduct the verification in the stage of design, and ensure the correctness of design to avoid the loss. The adoption of virtual reality technology in virtual prototype suitably helps in 3D modeling of products, and then set the model into VE to control, simulate and analyze. Simulation and optimization of the productive process of enterprise are used in the productive technology by formulating the products, man power of the factory, reasonable allocation of manufacturing resources, material storage and transportation system. LIU Qing-ling addressed the VM system provides the working environment of collaboration for the virtual enterprise partners, that affords collaboration support for each link of the whole course of orders of users, originality in product, design, production of parts, set assembling, sales and after sales and services

F. Virtual teaching platform of digital design and manufacturing

To promote students' learning interest and improve teaching effects Jianping Liu and Qing Yang adopts a virtual teaching platform of digital design and manufacturing in innovation teaching methodology. Yu Zhang explains virtual reality technology in program-based learning helps students to establish their spatial concepts and enhance their understanding on engineering drawings. Huang Xin represents motion simulation of entire product mechanisms could be achieved by means of the function of intelligent simulation. Liu Jianping suggests that with the help of the CAD software, students can easily understand how to read technical drawing and replicate same in software, and the cost of design can also be saved.

G. Virtual Training

Hazim El-Mounayri concluded that the architecture of a virtual training environment (VTE) was used to develop the corresponding system for the case of CNC milling. A recent application of VE based training includes training for operation of engineering facilities, CNC manufacturing. The Learning Environments Agent (LEA) engine includes a hierarchical process knowledge base engine, an unstructured knowledge base engine for lecture delivery; a rule based expert system for natural-language understanding, and an interface for driving human-like virtual characters. Integrated Virtual Reality Environment for Synthesis and Simulation engine was used to drive the virtual environment, display the engineering facility and manage a multimodal input from a variety of sources. A general geometric modeling approach is based on modeling precisely the geometries involved in the machining operation, including work-piece geometry and tool geometry [98, 99].

12. Future research directions of virtual manufacturing

According to Xi Junjie, the research on virtual manufacturing technology is still at the stage of system framework and general technology, while the application-oriented research on the key technology needs to be developed. The future research directions are as follows:

- VP technology and system of assembly simulation, production process, scheduling simulation and NC machining process simulation should be based on photo realistic animation.
- Man-machine cooperation solution in virtual environment and virtual manufacturing with the virtual reality technology.
- Virtual manufacturing and green manufacturing technology [101, 102] will be integrated. Technical support should be provided to green manufacturing. The simulation of green design, manufacturing, assembly, need to be realized.
- The distributed/collaborative simulation technology [103] of the hybrid model based on complex system.
- Requirements of a large amount of CPU power for real-time simulation.
- Open system architecture for virtual manufacturing research based on the distributed processing environments.

13. Drawbacks in virtual manufacturing

Firstly, setup of VM system requires huge capital investment for material, simulation software and human. Secondly with respect to availability of simulation model, each time at each level a new model has to be built even though the previous model has been already done. Thirdly compatibility of VM software and hardware is essential for better effectiveness as software depends on latest IT technology. By considering the above mentioned drawbacks, several hot topics are proposed in VM research area:

In human-computer interfaces users expect to interact with the computer in a human like manner. Development of good interfaces not only graphical but also mixtures of text, voice, visual interface are required. Any kind of planning activity can be supported and improved by simulation. The goal to be reached is to implement integration of simulation systems in planning and design tools so that the benefits can be achieved by minimum effort. Computer Aided Design (CAD) data has to be influenced by automatic generation of simulation models. The goal is to automatically create ready-to-run simulation models out of CAD data with extra information. To make use of adaptation of CAD model to specific need instead of creating a totally new CAD model. A major drawback is the combination of real and simulated hardware in machine tool and manufacturing system development known as Hybrid System Simulation. Real devices, like the machine controller, would be linked to a simulated model of the machine to test the machine's behaviour during manufacturing. The aim of Virtual Protyping is to approach for reliable and very accurate simulation models, which are able to show nearly realistic behaviour under static and dynamic stress conditions. The task of VM is to combine results of different kinds of simulation to predict a nearly realistic behaviour of machine tool, tool and work piece during machining process

14. Conclusion

The modern concept of virtual engineering is the result of computer graphic technology, virtual reality and augmented reality technology, modeling and simulation technology, which changes basically the conventional manufacturing mode of design, trial & error manufacturing, design modifying, scale production and plays a significant role in product & process development. Virtual manufacturing stimulates the need to engineering design in terms of manufacturability and better efficiency in manufacturing.

This review paper presents the origin, concepts, types, systems, applications and drawbacks of Virtual Manufacturing. The benefits of VM have been highlighted and status of recent applications of VM has been discussed in important potential domains such as automotive, aerospace, education, healthcare, training and home appliances. This paper clearly emphasizes the use of virtual environment and virtual manufacturing systems in industries. It is important to realize from this review that VR and AR technology in VM are not simply for visualization purposes, instead offers improved methods of interaction and visualization through suitable design, simulation and analysis, where it can be applied in real engineering problems.

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