Virtual Manufacturing - A Tool to Evaluate the Productivity and Affordability of New Product

Dr. D.N. Raut[1] , Dhanraj B. Waghmare [2]
[1] Professor and Head,
[2] Lecturer, Parshvanath College of Engineering, G.B. Road, Thane (W)
rautdn@sify.com, dbwaghmare@rediffmail.com

ABSTRACT

Virtual Manufacturing (VM) is one of the key technologies that allow going beyond the assumptions driving the old acquisition strategies. VM can be used for the systems which are developed and verified but never actually undergo actual production runs. This paper discusses the various aspects of VM that can be used for evaluating the productivity and affordability of new products. It is observed that VM can significantly improve production flexibility, hence reduce the fixed costs; and VM can substantially improve the decision making process of acquisition managers by reliably predicting schedules, risks and costs. Thus it is a very effective tool to evaluate the producibility and affordability of new products.

INTRODUCTION

It is known that acquisition strategies require the capability to prove the manufacture ability and affordability of new product/systems prior to the commitment of large production resources and/or to shelving the system for restart in the future. Loosing the manufacturing capability and experience in production is a major risk in the current manufacturing environment (6, 8). Maintaining the state-of-the art manufacturing proficiency without actually building/manufacturing the product is a major challenge. Virtual Manufacturing meets the above challenges by providing the capability, in essence, to continue manufacturing in the virtual world of the computer. Through the use of distributed manufacturing modeling and simulation, VM enables the enterprises to evaluate the producibility and affordability of new product and/or process concepts with respect to risks, their impacts on manufacturing capabilities, production capacity, and cost.

Virtual Manufacturing is one of the key technologies that allow going beyond the assumptions driving the old acquisition strategies. It provides the following fundamental changes:

1. VM can be used to "prove out" the production processes, resulting in "pre-production hardened systems" - i.e., the systems which are developed and verified but never actually undergo actual production runs;
2. VM can significantly improve production flexibility, and hence, reduce the fixed costs; and
3. VM can substantially improve the decision making process of acquisition managers by reliably predicting schedule, risks, and costs.

LITERATURE REVIEW

According to the Air Force Man Tech "Virtual Manufacturing is an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control" in a manufacturing enterprise (6,10).

It is clear from the results of the Virtual Manufacturing Workshop organized by Air Force Man Tech (11, 12) that a single definition of VM is proposed to capture design, production, and control aspects of manufacturing: The Design-Centered VM adds manufacturing information to the Integrated Product and Process /design (IPPD) process with the intent of allowing simulation of many manufacturing alternatives and the creation of many "soft" prototypes by "Manufacturing in the Computer". The Production-Centered VM adds simulation capability to manufacturing process models with the purpose of allowing inexpensive, fast evaluation of many processing alternatives. The Control-Centered VM uses machine control models in simulations, the goal of which is process optimization during actual production.

Vision of VM: The vision of Virtual Manufacturing is to provide a capability to Manufacture in the Computer. VM will ultimately provide a modeling and simulation environment so powerful that the design, fabrication/assembly of any product including the associated manufacturing processes, can be simulated in the physical and virtual between the physical and virtual manufacturing is shown in Figure 1.

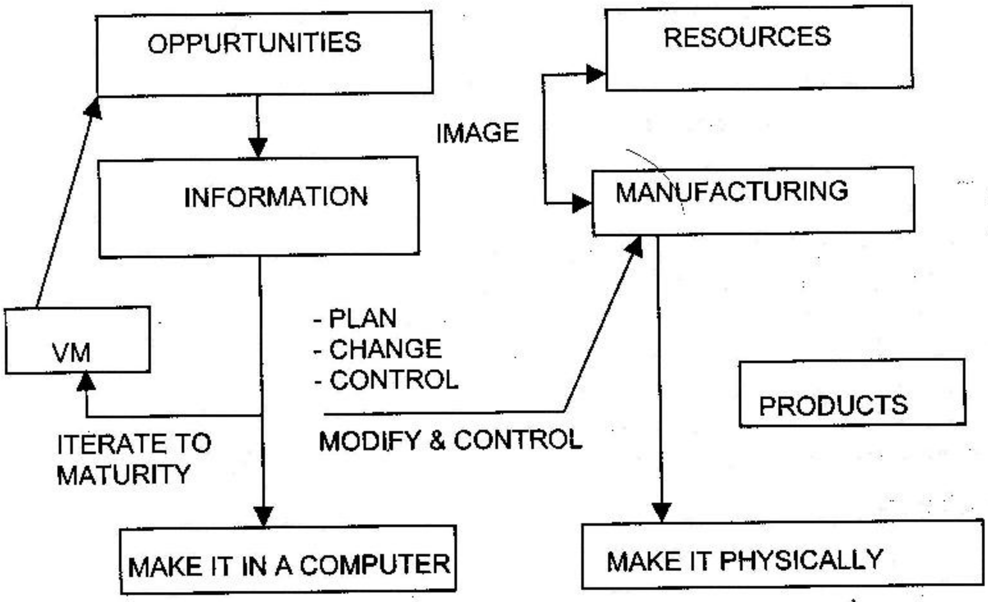

Fig. 1: Comparison between Physical and Virtual Manufacturing

VM Concepts: VM supports implementation of lean/agile manufacturing to achieve improvements in enterprise flexibility and economy. The use of simulation results in manufacturing systems those are less risky to change. Computer assisted model-based planning and control systems require less coordinating communications. The models provide a basis for sharing knowledge between organizations. VM based systems are expected to enhance operations by providing timely answers to the questions: Can we make the product? What are the alternatives? When can we deliver the product? How much will it cost?

The relation between the existing enterprise and the market force in creating a new product, the needed changes, the bottlenecks, and the requirements for the new product development are highlighted in Figure 2.

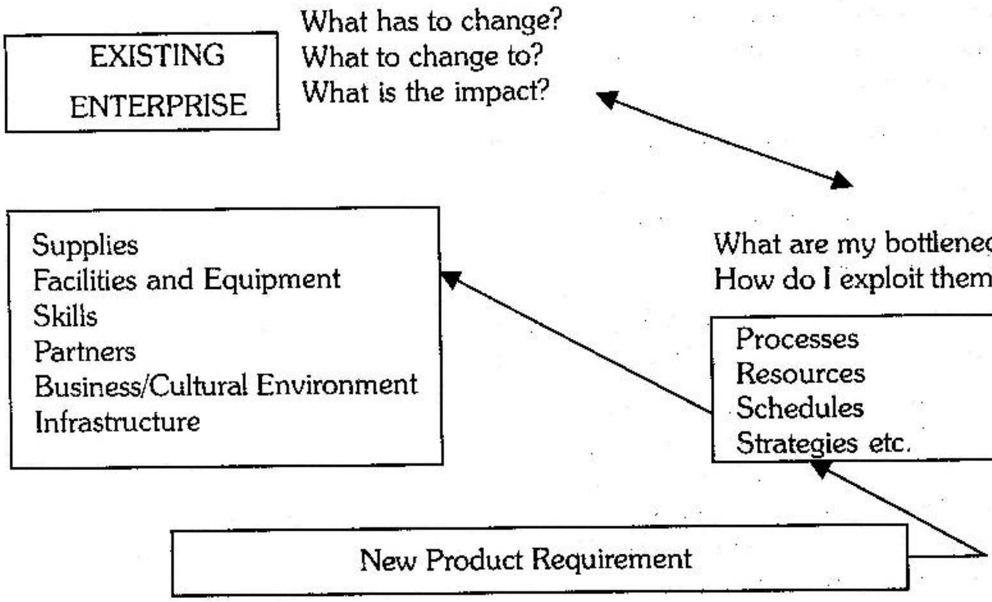

Fig 2: Requirements for new Product Development

VM relies on modeling and simulation technology to simulate the production process and to enable us "make it virtually". It is an application of modeling and simulation, but extends that discipline beyond the conventional use. VM supplements the IPPD process since it provides a pathway for the manufacturing knowledge to be migrated to the early phases in the life cycle. VM also adds simulation to the Virtual Enterprise (VE) concept and Virtual Prototyping. VM must be integrated with all the relevant enterprise functional areas via a trade-off mechanism.

The expected benefits of VM are summarized below :

- Preparedness for market trend,
- Affordability,
- Shorter cycle times,
- Producible prototypes,
- Flexibility,
- Quality,
- Responsiveness, and
- Customer satisfaction.

Virtual Manufacturing as an emerging technology looks for the development of appropriate new tools and techniques for its successful implementation and realization.

Some of the existing tools that can be effectively incorporated for realizing VM include (9): Design tools, production tools, quality tools, artificial intelligence (AI) tools, computer science tools, management tools and mathematical tools.

The Technical Workshop results indicated that the technologies critical to VM could be organized into the following major categories (12): Visualization; Environment construction technologies; Modeling technologies; Representation; Meta-modeling; Integrating infrastructure and architecture; Simulation; Methodology; Integration of legacy data; Manufacturing characterization; Verification, validation, and measurement; Workflow; and Cross-functional trades.

VM environment enables a shortening and simplification of the life cycle, by improving the realibility of analyses and accelerating decisions through the use of modeling and simulation. VM helps to evaluate product making using simulation and supports operations to provide timely response to the Integrated Product and Process Design (IPPD) functions in the development of new products and/or processes. Collections of objects in a VM environment may also simulate the entire manufacturing enterprise to provide rapid response to customer requirements. Customers with multiple VM-based supplier organizations can use models of their suppliers' enterprises to provide knowledge to an Enterprise Capabilities Expert. Vertical partners can contribute to capabilities models for use in the knowledge based computer programs that will evaluate customer requirements and supplier capabilities to establish the organizations desirous of responding to specific customer needs. VM also will support rapid technology transfer by enabling the sharing of the advanced manufacturing capabilities between cooperating organizations. VM applications and VM tools of one organization may be shared by means of the National Information Highway to the operations of manufacturing partners. Some of the specific areas of applications are : corporate memory, capital investment, supplier management, product design, cost estimation, risk management, customer interface, functional interface, and shop floor.

RESULTS AND DISCUSSIONS

Based on the literature search to identify the key issues for realizing VM, it can be summarized that new integration technologies and philosophies are emerging. Visualization hardware and software is becoming more affordable and widespread. New modeling and model abstraction techniques are appearing. The most important set of technologies centers on modeling and simulation. Some of the key areas that require attention in modeling and simulation are: model object selection (what to model);

degree of abstraction; level of depth; flexibility and maintenance of models; integration of different models; and model validation. The results are discussed under the following headings:

Flexible Manufacturing:

The discussion with a National Research Group from Oak Ridge National Laboratory, Sandia National Laboratories indicated that the research in telerobotics and flexible manufacturing systems though showed progress, it would be practically impossible to totally replace human with robots. Maturity in existing and emerging technologies (both hardware and software) is needed to see potential success in this area.

Lean Manufacturing:

Womack et al. (13) in their book on "The Machine that Changed the World" addressed the future of the automobile and extensively discussed the importance of lean production. A team spent five year exploring the differences between mass production and lean production in one enormous industry. They have been both insiders with access to vast amount of proprietary information and daily contact with industry leaders, and outsiders with a broad perspective, often very critical, on existing practices. In this process they have become convinced that the principles of lean production can be applied equally in every industry across the globe and that the conversion to lean production will have profound effect on human society - it will truly change the world.

Virtual Prototyping:

The discussion with a rapid prototyping user group revealed that the customers have difficulty is accepting "Virtual Prototyping" as one of the means of acquisition for the following reasons: There exists a significant difference in the prototype they see "Virtually in the computer" and the real product they receive; One can show a colorful, attractive, and high quality product "virtually in the computer", however, the real product may differ in various aspects - including functional and aesthetic aspects - of what was seen in the computer. Virtual Prototyping is still in the experimental stage and it will take a few more years to mature in terms of technology (visualization, representation, abstraction, and appropriate hardware and software) and be used by vendors and consumers.

Virtual Quality:

The discussion with the users of TQM and ISQ/QS 9000 showed that virtual manufacturing concepts will aid significantly the way business will be done in the future for the following reasons: Once the VM technologies mature, the concept of building quality in the product is much easier even before the product is made and hence the concept of "Right First Time" will have much more meaning in terms of Quality Standards. Quality is defined as "Fitness for Purpose", and the VM technologies will make it happen since the customers can make "changes virtually" in the product and make it fit for the intended purpose even before the product is made. In terms of quality, VM can go beyond the customer satisfaction and help in achieving Quality Function Development (QFD).

Virtual Reality:

Despite the enthusiasm surrounding virtual reality (VR), there is a substantial gap between current technology and that needed to bring virtual environments closer to reality. That is the conclusion of a National Research Council committee report on 3D computer-generated worlds with which people can interact. According to the committee, certain areas hold the most promise for practical uses of VR: training, hazardous operations, medicine and health care, design, manufacturing, and marketing. Using VR and telerobotics, one can or will be able to explore the ocean floor and outer space, dig up a 10-ton container of hazardous waste, take a submarine trip through the human circulatory system, and try out products not yet manufactured, for example.

Virtual Organization and Agile Manufacturing:

In the search for agility, companies will rely increasingly on virtual enterprises, virtual manufacturing, and virtual reality. Goals of virtual manufacturing include analyzing design, product, and process alternatives for viability, cost and risk; integrating product and process development; improving customer response time and cost estimates; and retaining corporate knowledge. The Society of Manufacturing Engineering developed a videotape on "Agile Manufacturing: Moving to the Next Level" (1). The video addressed "agility" as the new survival concept for global manufacturing competitiveness and indicated that the emerging concept of agility is based on the factors: markets of all nations are combining into a single global economy; rapid change in the global market place is inevitable; the explosion of technology makes every country a potential competitor; customers are demanding customized products with short lead times. Goldman et al., (3) in their book on "Agile Competitors and Virtual Organization: Strategies for Enriching the Customer" addressed how to confront and thrive on change and uncertainty.

VM Concepts in Engineering Education:

The increasing access to Internet and the World Wide Web has expanded the variety of media by which universities are able to offer distance-learning opportunities. Most recently courses and whole degree programs are being developed for delivery via the Internet. At present, VM concepts and web-based tools are effectively being used in engineering education for training, distance learning, laboratory education, and testing of students. Some of the other VM concepts/tools such as virtual reality (7), virtual prototyping, virtual quality, virtual laboratory, virtual factory system (2), and modeling and simulation technology are being tested for effective use in engineering education.

Realization of VM:

The STEP standard (5) is intended for long-term development and uses a widely available language called Express to describe the complexities of solid geometry. STEP, also referred to as ISO 10303, is an international standard for the exchange of product model data. Designers and engineers should be aware of its capabilities, how it might be used, and what developers have planned for it. The supermodel database, in progress, will be web compatible and the entire supply chain can access it. The Web based languages such as SGML (Standard Generalized Markup Language), HTML (Hyper Text Markup Language), and XML (extensible Markup Language) are helpful in implementing VM. SMMS software (4) developed by RTSe (USA), Inc., is an ideal product for creating, managing, and publishing metadata to improve overall management of large data archives. SMMS can also be used in the realization of VM.

Research Relevant to VM:

The Virtual Manufacturing Technical Workshop (12) identified technologies that are critical to virtual manufacturing. The technologies were classified under Core Technology, Enabling Technology, Show Stopper Technology, and Common Technology. The Core Technologies identified and reported are: VM methodology for process characterization; technologies to simulate assembly operations; declarative representation of product and processes; natural language for VM meta-model; cost database and integration; VM user interface (communication between VM knowledge base and user); VM verification & validation methods, algorithms & tools; process model and simulation validation; methodology for using a VM system; VM framework (guidelines, integration standards, etc.); methodology for design abstraction; tools to relate conceptual design with possible manufacturing methods and processes and cost estimates based on manufacturing features; manufacturing engineering automation (knowledge-based computer applications to perform manufacturing engineering decision making); and simulation architecture.

It is seen that some of the technologies listed above and other related technologies are being studied by government agencies, academia, and industry in the U.S. and other nations. It is necessary to coordinate and bridge the gaps in randomly emerging technologies related to VM and mature them. Some of the technologies that need immediate attention are: selective addition to animation, shop floor based generic models, metrics, representation, and integration.

4. CONCLUSION

The potential scope of VM is very large. What is important is that a time phased, realizable scope for VM be defined. VM should be implemented incrementally starting at unit product/process level, then at subsystem level and finally at system level. The manufacturing process and the scope of VM products should be improved in the "big M" manufacturing domain: concept through production including marketing, sales, and service. Disagreement remains on what VM is and the key issues for realizing VM - there is a need to define VM more precisely.

5. REFERENCES

1. **Agility** (1994), "Agile Manufacturing: Moving to the Next Level", A Manufacturing Insight Video by SME, VT516-2393.
2. **Dessouky M.M. et al.** (1998), "Virtual Factory Teaching System in Support of Manufacturing Education", Journal of Engineering Education, Vol. 87, No. 4 pp. 459-467.
3. **Goldman S.L., Nagel, R.N. and Preiss, K,** (1995), Agile Competitors and Virtual Organizations: Strategies for Enriching the Customer, Von Nostrand Reinhold, New York.
4. **Goodchild M. F.** (2000), "Manage Your Metadata", Geo Info Systems, Vol.10, No. 5, p. 43-54.
5. **Hardwick M.** (2000), "What You Should Know About STEP", Machine Design, Vol. 72, No. 13, pp. 98-102.
6. **Hitchcock, Baker and Brink,** (1994), "The Role of Hybrid Systems Theory in Virtual Manufacturing", Proc. IEEE Symposium on Computer-Aided Control Systems Design (CACSD), IEEE, New York, pp. 345-50.
7. **Impelluso T. and Metoyer-Guidry T.** (2001), "Virtual Reality and Learning by Design: Tools for Integrating Mechanical Engineering Concepts", Journal of Engineering Education, Vol.90, 4, pp. 527-534.
8. **Kessler W. C., Shumaker G.C. and Hitchcock M.F.** (1993), "Early Manufacturing Consideration in Design", In AGARD, Integrated Airframe Technology, Dec., 7p.
9. www-vr/.umich.edu/beier/papers/compit2000/webbasedvr.htm
10. www.isr.umd.edu/labs/cim/virtual
11. **VM** (1994), "Virtual Manufacturing User Workshop", Report, Lawrence Associate Inc., Dayton, Ohio, August 1994.
12. **VM** (1995), "Virtual Manufacturing Technical Workshop", Report, Lawrence Associate Inc., Dayton, Ohio, January 26, 1995.

——— • • • ———