2004

Review of 3D Visualization Tool Usage for Select Manufacturing Firms

Damarius J. Washington

Review of 3D Visualization Tool Usage for Select Manufacturing Firms

REVIEW OF 3D VISUALIZATION TOOL USAGE FOR SELECT MANUFACTURING FIRMS

A Research Paper
Submitted in
Partial Fulfillment
of the Requirements for the
Masters of Arts Degree

Damarius J. Washington
University of Northern Iowa
December 2004

Approved by:

Ali E. Kashef

Advisor ________________ Date 12/13/04

Ronald O'Meara

Graduate Faculty ________________ Date 12-13-04

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Today's world is composed of many complex industries. Companies invest money into software to create and/or engineer the products they produce for their customers. Current production processes utilize computer-aided design (CAD)/computer-aided engineering (CAE), and computer-aided manufacturing (CAM) technology to create complex parts that have different needs, raw materials, and tolerances. According to experts, "the trends of manufacturing companies' worldwide are changing over time", and "The time to market has been identified as a key factor in profitability; it is the development time and not the cost that is critical" (Rehg, 2002). To expand on this concept, leading producers of goods have incorporated the use of virtual tools to speed their products into the market and streamline their production and manufacturing processes. Utilization of 3-D visualization software allows manufacturers to fully design and test their products in a digital world (Waurzyniak, 2003).

The increase of computing power and memory in personal computers has paved the way for CAD applications and electronic tooling. The increased computing power has contributed to the emergence of more powerful CAD applications with more specialization as well. The costs of these cutting edge digital manufacturing software can be expensive, but the larger businesses that compete on a global scale realize the importance of cutting the time to market for new products. Software makers of these electronic visualization tools include Teamcenter Manufacturing, Tecnomatix Technologies, and Delmia Corporation. Large manufacturers often use multiple software applications to digitally develop and test their products due to the increase of supplied parts and subassemblies that are produced collaboratively (Waurzyniak, 2003).

A potential customers' understanding of a product/software can help them avoid the trial and error process when making a purchasing decision that involves visualization and virtual electronic tooling. By matching their business needs with features and applications available, a manufacturing firm can make an informed choice of software for their specific applications. The uses of virtual tooling will be made apparent in this study.

Statement of the Problem

The problem of the research is to determine areas of effective uses of virtual tooling in manufacturing.

Statement of Purpose

The purpose of this research is to assist business decision makers who choose software upgrades and CIM application usage in manufacturing firms. They can then utilize this research to make informed decisions regarding production application usage within their business. The purpose of this research is to examine which methods and uses of virtual reality are helpful in increasing efficiency within the production and manufacturing of goods via case studies, interviews with manufacturing personnel, and most importantly a survey of manufacturing professionals. The survey will be sent to manufacturing employees within an agricultural equipment corporation.

Statement of Need

The need for this study is based on the fact that there are many different manufacturing computer applications available for use and any assistance in selecting the proper tooling for the types of jobs a select business conducts is crucial to efficiency within the business. Furthermore, the enhancement of computer technology now allow engineers, manufacturers, and designers greater control over their product designs so the selection of an optimal drawing/drafting package is critical. Now that producers have globalized their operations, the use of new technologies to foster communication and efficiency is required.

Research Questions

1. How is virtual reality and 3D tooling being used within manufacturing?
2. What applications of VR use have been proven helpful in manufacturing?

Assumptions

The following assumptions were made for this study:

1. The employees' responses were based on their experience in the industry.
2. The employees surveyed have visualization tooling available for use to accomplish manufacturing goals.
3. The employees have various 3D tooling applications available for their manufacturing use.

Delimitations

The study was limited for proximity to a Fortune 500 agricultural manufacturing firm with less than 5000 employees located in the NE area of Iowa.

Definition of Terms

The following terms are defined based on their usage in this study:

1. CAD-computer aided drafting is the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation (Rehg, 2001).
2. CAE-computer aided engineering is the analysis and evaluation of the engineering design using computer-based techniques to calculate product operational, functional, and manufacturing parameters too complex for classical methods (Rehg, 2001).
3. CAM-computer aided manufacturing is the effective use of computer technology in the planning, management, and control of production for the enterprise (Rehg, 2001).
4. 3D Visualization tooling is electronic, computer-based tooling that utilizes virtual environments and/or three-dimensional graphics to enhance production concepts (M.Ryken, personal communication, March 15, 2004).
5. Concurrent engineering implies that the design of a product and the

systems to manufacture, service, and ultimately dispose of the product are considered from the initial design concept (Rehg, 2001).

6. Solid modeling is a mathematically complete and unambiguous representation of part geometry with all the physical, mechanical, electrical and thermal properties of the actual model (Rehg, 2001).

7. Virtual reality is an artificial environment created with computer hardware and software and presented to the user in such a way that it appears and feels like a real environment (Webopedia.com, 2004).

8. Virtual tooling is the process of equipping a factory with machinery and tools for a particular manufacturing process noting a focus of a system forming virtual images (Random House Webster's College Dictionary, 2nd edition 1999).

9. Ergonomics is an applied science that coordinates the design of devices, systems, and physical working conditions with the capacities and requirements of the worker. Also called human engineering (Random House Webster's College Dictionary, 2nd edition 1999).

10. Collision detection enables realistic rendering for graphics, haptics and sounds in a virtual world (http://horizons.free.fr/eng/tech/rv_dossiers/lib_detect_coll.htm#virtuel, 2004).

11. Histogram is a bar graph distribution in which the bars are displayed proportionate to the corresponding frequencies (Random House Webster's College Dictionary, 2nd edition 1999).

12. Virtual technology is the branch of knowledge that deals with applied science, engineering and the industrial arts, etc. that are of, existing on, or by means of computers (Random House Webster's College Dictionary, 2nd edition 1999).

REVIEW OF LITERATURE

The use of virtual reality (VR) for production and manufacturing enhancement was due to the fact that virtual reality has been increasing in use in other areas. Initially VR was widely used in the entertainment sectors for video gaming and still is. The immersion of virtual technologies in the entertainment sector led to the spillage of this technology into the manufacturing arena (Schmitz, 1995). The use of models and body mapping set the stage for the use of these technologies. Video games are now able to virtually ensure that the way a professional athlete looks in person is the way they will look on a video game and at the same time retain his/her attributes of speed and skill.

The fact of the matter is that three-dimensional (3D) tooling is here to stay and will be used from now on. By using virtual technologies, companies have realized the effects of slashing the product design cycle and the increased financial benefits that occur when the product is the first of its kind to hit the market. The efficient use of virtual technology is increased when companies find many diverse applications of this technology in as many areas of their business as possible.

Automobile Industry

The automotive producers have been using virtual tooling for over a decade when they realized the cost benefits (Waurzyniak, 2003). The advances in the virtual tooling abilities have led to this increased usage and reliability of virtual tooling. With more and more manufacturing operations becoming global competitors, it is important for companies to collaborate with supply networks around the world. Concurrent engineering teams are seeing the value in these simulation and virtual technologies, since not all people involved in the manufacturing processes can understand 2D drawings

(Owen, 1997). As stated, the increase in globalization, advance technology and the use of multi-functional teams are driving the need for virtual tooling usage in the automotive industry in addition to other industries.

Agricultural Industry

A certain agricultural firm located in NE Iowa has been using virtual reality tooling for the last four years to meet their business needs (M.Ryken, personal communication, March 15, 2004). Virtual tooling has enabled them to find uses for this type of software and hardware to improve their products in the areas of design, testing, and ergonomics. With virtual reality laboratories, they have been able to integrate this virtual tooling with other standard product improvement techniques to add value to their products (T. R. Johnson, personal communication, March 14, 2004).

The stated agricultural equipment producer has found ways to improve their tooling changes via usage of visualization tooling. As shown in Figure 1, a particular work line needed tooling changes to accommodate additional gages. This setup was then modeled in a virtual environment using the VisMockup and VisJack software. Figure 2 and Figure 3 support this information by providing more examples of how this visualization tooling can be used. Furthermore, virtual reality tooling can optimize manufacturing processes and collaboration with suppliers, dealers, and customers (Deere & Company Supply Management, 2003)

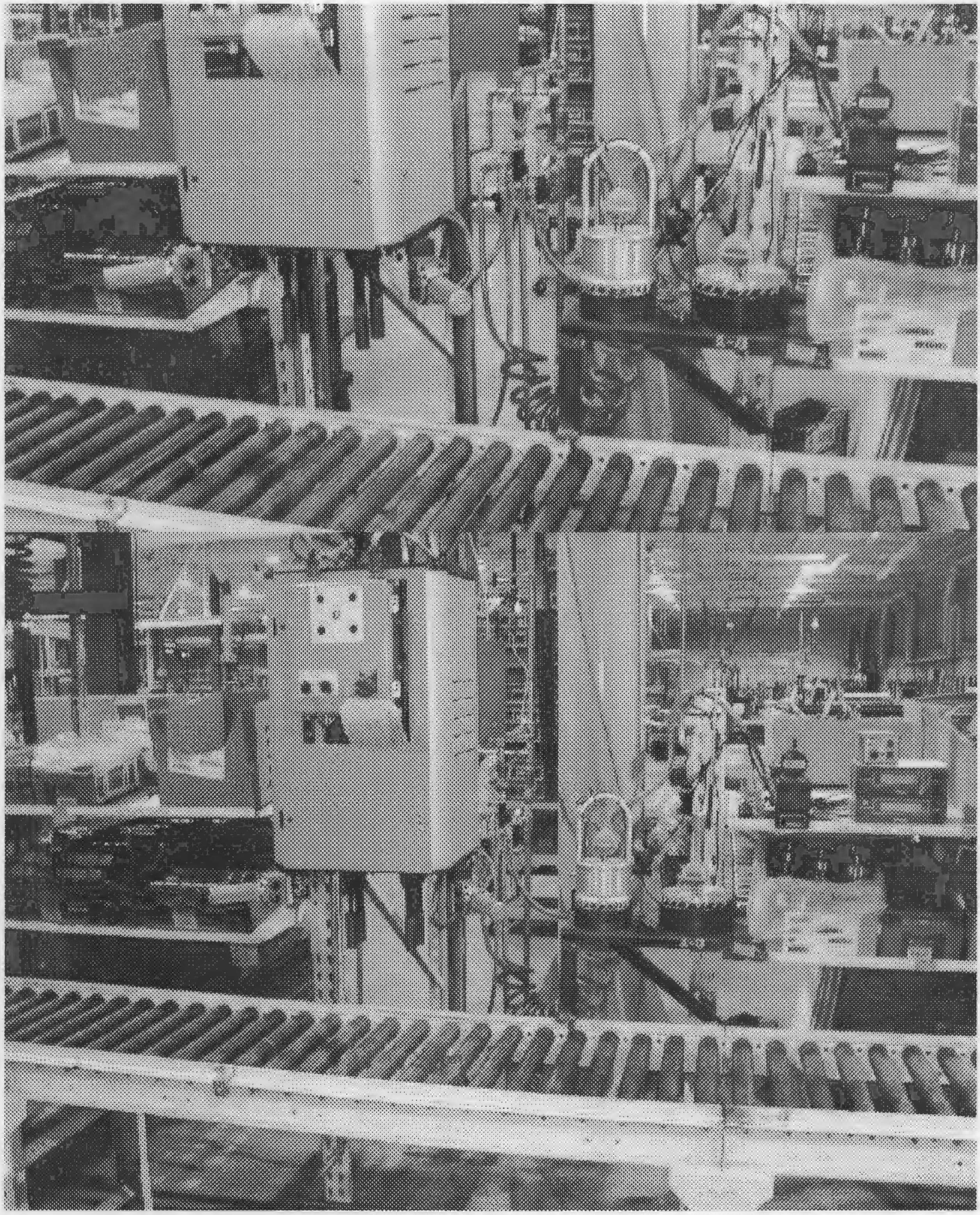

Figure 1. Current Assembly Line Setup

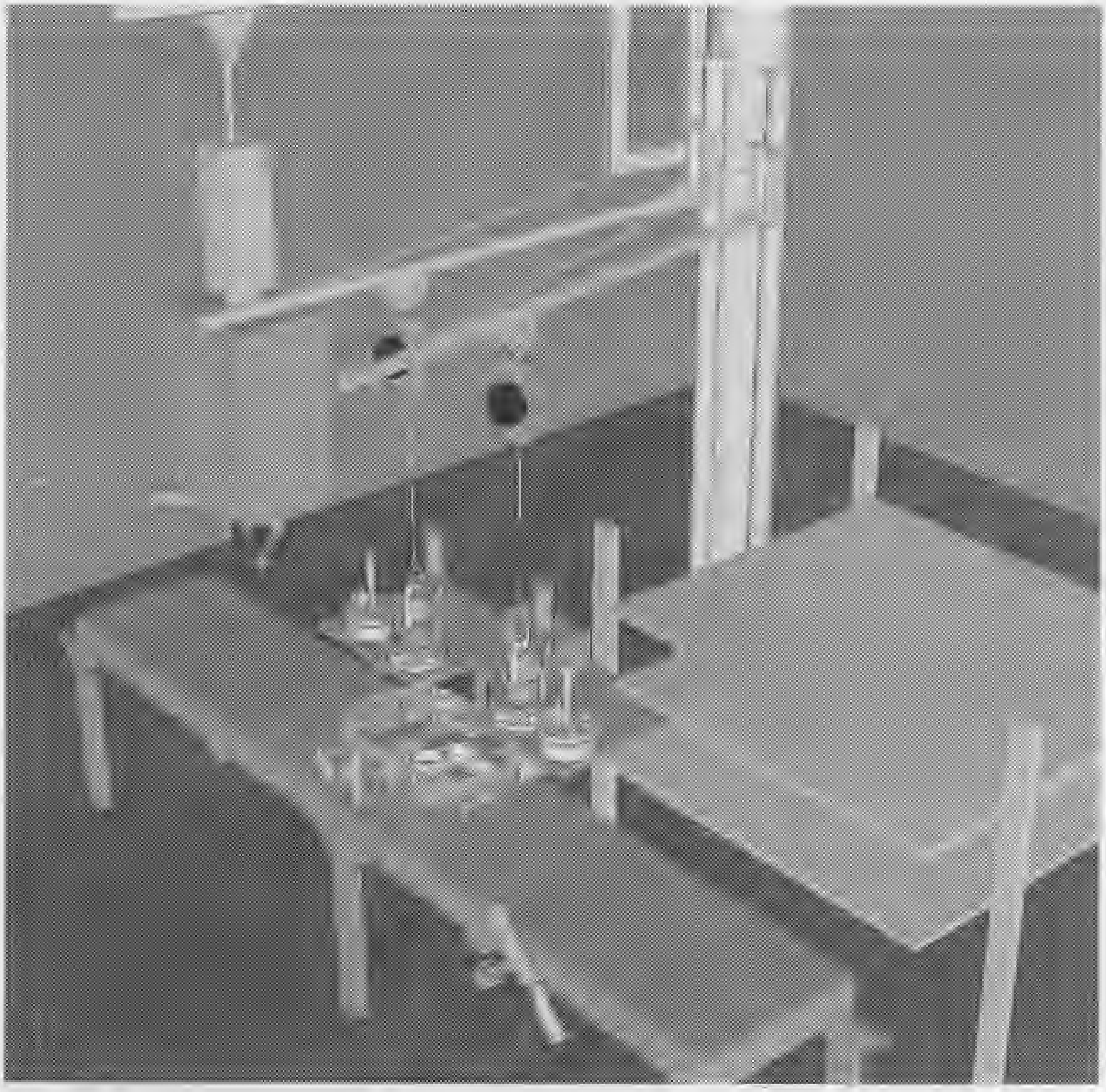

Figure 2. Current Assembly Line Setup in VisMockup Software application

Figure 3. VisMockup application being used for tooling ergonomics

METHODOLOGY

The purpose of this study was to determine the uses and functions of certain visualization software currently in use to produce, design and mistake-proof manufactured products. Furthermore, an explanation of these applications will be illustrated to show the uses of virtual reality and electronic tooling. The use of case studies, magazine articles, Internet sources and interviews with manufacturing engineers will contribute to this research. The integration of a Likert 5-point scale to the perceived value of the core areas of virtual tool usage and corroborating the results with the input of experienced manufacturing personnel, a collection of effective applications emerged based on the current use of premium electronic tooling. The 5 points on the scale were 1 =Waste of Time, 2= Not Helpful, 3= Helpful, 4=Very Helpful, and 5=Requirement.

In addition to the case studies, magazine articles and Internet sources, the main research instrument is the survey (See Appendix A for the survey). Thirty manufacturing personnel experienced in the areas of design, industrial, process and quality engineering, and manufacturing support services were randomly chosen for this survey by their job titles and involvement with agricultural tractor production teams. They received surveys since they use and rely heavily on virtual tools in their production needs. Furthermore, employees with backgrounds in reliability and virtual reality also completed the survey. The survey was distributed to 30 manufacturing professionals involved in the New Product Programs group of the firm. A total of 21 of 30 (70%) surveys were completed and returned. The data accrued from the survey was entered and tabulated using the spreadsheet software Microsoft Excel for availability. After the survey results were obtained, the spreadsheet was formatted and is listed as Table 2. The survey was tested via email to see if it could be completed within 15 minutes and returned. All survey data is illustrated in Table 2 and the additional comments are listed in the recommendations.

For validity, the help and 20+ years of experience of two manufacturing managers were consulted. They read the survey to check for clarity to ensure that survey sample would understand the questions and to verify that the questions were on target with this research. Moreover, they also completed the survey via email to ensure that it could be completed in less than 15 minutes as planned. Measures of central tendency and frequency were calculated and kept in an Excel spreadsheet for statistical analysis.

FINDINGS

The survey produced the following results shown in Table 2. Those surveyed answered the set of questions listed below. According to experienced manufacturing engineers, the use of virtual tools is helpful in various manufacturing areas. In fact, 9 out of 21 (43%) of those surveyed believed virtual tooling is a requirement within manufacturing. Furthermore 10 out of 21 respondents (53%) felt that virtual tool usage in manufacturing was very helpful. According to the survey data answer averages, 61 of 63 (97%) believed that virtual tooling was most helpful when used for ergonomics, facility engineering (plant layouts) and manufacturing in general. An example of ergonomic virtual tooling usage is displayed in Figure 3. They supported this by commenting that the broad use of virtual tooling isn't feasible at this time, citing the lack of funding to supply a whole enterprise with capable computers and training. Thus, more training and higher budgets would be better to increase the usage and effectiveness of this tooling. On the other hand, the use of virtual tooling to collaborate with colleagues in different locations that work on the same projects has many benefits. As illustrated above, 3D virtual tooling usage has plenty of benefits and effective uses.

Although the use of virtual tools in manufacturing is increasing, there are areas for improvement. For example, virtual tooling usage can be improved in the areas of collision detection between models and the overall usage in manufacturing as it had the second lowest average answer (3.53 ~ helpful). This is attributed to the lack of training and preparation of manufacturing engineers to use visualization tooling. At the same time, the lack of computing resources adds to this problem as the information systems costs can be upwards of $100,000 per unit (Owen, 1997). Even though it can be proven that virtual tooling usage has value, there are also some gaps that limit its effectiveness in certain applications.

The measures of central tendency have been an integral part of statistics, so many examples of these tools are incorporated within this research. Table 1 illustrates the standard deviation and averages for each sample question that was on the survey. This table was constructed to show the mean values for each question and the variance.

Table 1.
Computed Survey Question Averages & Standard Deviations

Central Tendency Measures	Effectiveness of Virtual Tooling for Various Applications: helpful to personal position	overall manufacturing helpfulness	prototype helpfulness	ergonomic helpfulness	plant layout helpfulness	telecommunication helpfulness	helpfulness in decreasing product design time	helpful for collision detection during virtual modeling	helpful within concurrent engineering teams	helpfulness of virtual training	helpfulness of virtual tools to decrease product costs
Averages	3.86	4.33	3.43	3.71	3.67	3.62	3.43	3.52	4.24	3.95	3.95
Standard Deviation	1.1	0.7	0.7	0.6	0.7	0.8	0.9	0.9	0.7	0.7	0.9

Based on the set of questions and rating scale listed in Appendix A, the answers were tabulated in Table 2. The first column lists the role of the person completing the survey. The second column heading lists the amount of experience in the manufacturing discipline the participant has on the job and/or in the field in term of years. The following column headings list the survey question topic for that specific question. Summarily, the survey sample's actual answers to the 11 survey questions are listed.

Table 2.
Collected Survey Data

		Helpfulness/Effectiveness of Virtual Tooling for Various Applications:										
Mfg Role	**Yrs in Mfg**	Helpful to personal position	Overall manufacturing helpfulness	Prototype helpfulness	Ergonomic helpfulness	Plant layout helpfulness	Telecommunication helpfulness	Helpfulness in decreasing product design time	Helpful for collision detection during virtual modeling	Helpful within concurrent engineering teams	Helpfulness of virtual training	Helpfulness of virtual tools to decrease product costs
Eng Tech	10-19	4	4	4	4	4	4	4	4	4	4	4
Eng Tech	0-1	1	4	4	3	3	4	4	4	4	4	4
IE	20+	4	4	3	3	3	3	2	2	4	4	5
Modeler	6-9	4	4	4	4	4	4	4	4	4	4	4
IE	20+	3	4	4	4	3	3	4	4	3	4	4
VR Modeler	10-19	5	5	3	4	5	5	5	5	5	5	4
NPP Processor	1-5	5	5	3	3	3	5	3	3	5	5	3
QE	20+	3	3	3	4	3	3	3	3	3	4	3
Tool designer	10-19	2	4	3	3	3	4	3	4	4	4	5
Supervisory/Management	10-19	3	3	2	4	4	3	3	4	4	4	4
Process Engineer	20+	5	5	2	3	3	5	2	3	5	3	3
Supervisory/Management	6-9	3	5	3	3	4	3	2	2	5	5	3
Supervisory/Management	20+	4	4	4	4	4	3	3	4	4	4	4
Supervisory/Management	20+	5	5	4	4	4	4	4	4	4	4	5
Quality Engineer	1-5	4	5	4	5	5	4	4	3	5	4	5
Process Engineer	20+	5	5	4	4	4	3	3	3	5	4	4
Manufacturing Engineer	20+	5	4	4	4	3	3	3	5	3	3	3
Reliability Engineer	20+	4	4	4	4	4	2	3	3	4	4	4
Process Engineer	20+	4	5	4	3	3	4	5	5	5	4	5
Supervisory/Management	20+	5	5	3	4	5	4	5	2	5	4	5
Manufacturing Engineer	6-9	3	4	3	4	3	3	3	3	4	2	2

A histogram illustrating the manufacturing experience of those surveyed is apparent in Figure 4. The experience of the personnel was grouped into 5 categories for convenience. The purpose of this is to show the variety of manufacturing experience of the sample group.

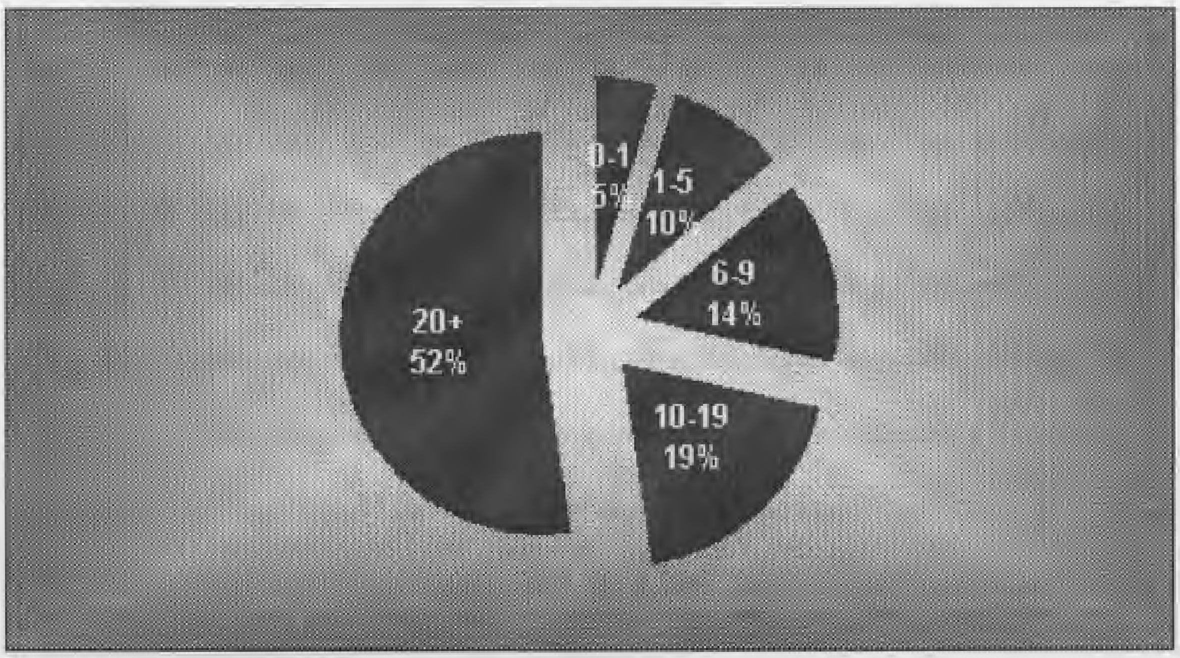

Figure 4. Histogram – Manufacturing Experience in Years of the Survey Sample.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It can be concluded that 3D visualization tooling is widely used in manufacturing/production firms for them to meet their business needs. According to the my interview with virtual reality engineers M. Ryken and T. R. Johnson, virtual tooling is being used within manufacturing for rapid prototyping, ergonomics, facility engineering, networking, shortening product design time, electronic builds, concurrent engineering, training, and in decreasing overall product costs. The amount of product cycle time is getting shorter according to the results of the surveys, and the usage of these electronic tooling packages such as VisJack and VisMockup is increasing. However, the learning curves of most manufacturing professionals differ. From the comments section of the survey it was expressed that many engineers lack the training to adequately use this software to the fullest extent possible. This paired with a shortened product delivery process, doesn't bode well to the use of these newer technologies. Furthermore, according to most manufacturing personnel, the greatest gain from 3D visualization usage occur when the product cycle time can be reduced.

The usage of virtual tooling in manufacturing has proven effective in a multitude of applications. This research has illustrated that currently virtual tooling is most useful in general manufacturing, whereas collision detection is an area where virtual tooling does the worst job. The integrity of the modeling must be as accurate as possible for this to work. Within a business that has many thousands of parts of different materials and mechanical properties, virtual tooling usage is not the best. In the same manner, when producers don't adequately train their manufacturing engineers in the use of these visualization technologies, it becomes difficult for that producer to get the most positive results from this tooling set.

Recommendations

The following recommendations are made as a result of this study:

1. Determine methods to immediately train new manufacturing engineers in the use of virtual electronic tooling.
2. Production management should determine how to get the software, hardware and integral models to manufacturing personnel in a timely manner to utilize available virtual tooling in an efficient manner.
3. Recognize the limitations of virtual tooling, as it doesn't work well in determining the interference between parts.
4. Use 3D visualization tooling whenever possible to illustrate 2D drawings for personnel that aren't experienced with reading drawings.
5. Distinctions should be made between 3D visualization tooling and 3D modeling with assigned properties.
6. It is critical for most employees within the manufacturing discipline to become familiar with virtual tooling for that company to stay competitive.

REFERENCES

Ames, B. (2002). Reed Business Information. *Design News, 57, 24-26.* Retrieved February 10, 2003 from Infotrac database.

CAD-Software.org. (2003, February). CAD software products and reviews. Retrieved February 23, 2003 from http://www.cad-software.org

Chang, H. (2001). A model of computerization of manufacturing systems: an international approach. Retrieved 2 Mar 2003 from http://www.sciencedirect.com.unistar.uni.edu

Chang. W. (2003). Researching design trends for the redesign of product form. Design Studies, 24, 173-180.

Deere & Company Supply Management (2003). *Virtual Reality Design Review.* [Internal website] Retrieved 22 July 2003 from http://www.90.deere.com/suppmgmt/business_processes/

Electronic Visualization Laboratory. (2004). *University of Illinois at Chicago IEEE VR 2004* [Brochure]. Chicago, IL: IEEE.

Fraenkel, J.R. & Wallen, N.E. (2003). *How to design and evaluate research in education.* (5th ed.). Thousand Oaks, CA: Sage.

Hsieh, C. (2002, November). PC based multi-material integrated CAD system for layered manufacturing. Retrieved February 23, 2003 from http://0wwwlib.uni.com.unistar.uni.edu/dissertations/fullcit/3055061

Moltenbrey, K. (2000). Engineering Metamorphosis. *Computer Graphics World, 23, 52.* Retrieved February 10, 2003 from the Infotrac database.

Owen, J. (1997). Virtual manufacturing. *Manufacturing Engineering*, 119, 4. Retrieved March 23, 2004 from the ABI/INFORM GLOBAL database.

Publication Manual of the American Psychological Association (5th ed.). (2001). Washington, DC: American Psychological Association.

Phoenix Technologies Incorporated (2004). *Real Time 3D Motion Tracking.* [Brochure]. Burnaby, Canada: Author.

Rehg, J. A., & Kraebber, H.W. (2001). *Computer-Integrated Manufacturing* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Schmitz, B. (1995). Great expectations: the future of virtual design. *Computer – Aided Engineering*, 14, 10. Retrieved March 23, 2004 from the ABI/INFORM GLOBAL database.

Summers, D. (2003). *Quality.* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

Waurzyniak, P. (2003). Digital manufacturing taking hold. Manufacturing Engineering, 130, 47. Retrieved March 15, 2004 from the ABI/INFORM GLOBAL database.

Youson, M. (2002). The Design Council. *Engineering, 243, 23-25.* Retrieved February 10, 2003 from the Infotrac database.

APPENDICES

Appendix A

Damarius J. Washington
1815 W 3rd St
Waterloo, IA 50701
April 13, 2004

Dear Manufacturing Professional:

Enclosed is a survey used to gain an insight into the advantages, disadvantages and capabilities of 3D visualization tooling. If you have any experiences with electronic builds and/or rapid prototyping, your responses to these questions can be very helpful for this study.

I've chosen you for this study because you're known as a professional within the manufacturing realm. In your respective areas of interest as process engineers, industrial engineers, quality engineers, design engineers, engineering technicians, engineering analyst, the use of these visualization tools has been increased rapidly to enhance and shorten the production process.

I would be thankful if you would please take 10-15 minutes to complete this survey and return it to me via email prior to April 23, 2004. All responses will remain confidential. Please let me know if you're interested in viewing the results of this survey.

Thanks for your support.

Sincerely,

Damarius J. Washington
Assembly Quality Engineer - John Deere Waterloo Works
Graduate Student – University of Northern Iowa

Attachment

Appendix B

3D Tooling Usage Survey

Recent trends in technology drive the usage and transformation of the market. The beginnings of engineering consisted of drafting a design by hand. As computers evolved into the powerful personal machines we have today, Computer Aided Design & Drafting became the primary manner that products were conceived. Things are still designed in design software's but the methods in which they are manufactured and processed have evolved. Current producers are focusing on the manufacturing processes to determine if the product can be made for profit most efficiently. 3D visualization tooling is making this the normal approach. You have been selected for this survey because it has been brought to my attention that you are a user of 3D software and electronic tooling in your career. Please take 5-10 minutes to complete this survey.

What is your primary role in Manufacturing?

Supervisory/Management
Engineering Technician
Industrial Engineer
Process Engineer
Quality Engineer
Modeler
Other__________

How many years have you been employed in the Manufacturing field?

0-1
1-5
6-9
10-19
20+

Using the rating scale listed below, please answer the following questions:

1= Waste of Time
2= Not Helpful
3= Helpful
4= Very helpful
5= Requirement

1. How has the increased use of 3D electronic tooling helped your job?

2. What is your opinion of 3D visualization tooling usage in Manufacturing?

3. What is your opinion on the use of rapid prototypes within manufacturing?

4. How has 3D visualization tooling helped ergonomics in your production area?

5. How has 3D visualization tooling helped with plant layouts in your area?

6. How has 3D visualization tooling helped communication with colleagues/co-workers long distances from you?

7. How helpful is electronic visualization tooling in decreasing product design time?

8. How helpful is 3D tooling with collision detection of solid models that must assemble?

9. How helpful is the usage of 3D visualization tooling within concurrent engineering teams?

10. What is your perception of 3D visualization tool usage for training?

11. How helpful is an expensive set of electronic tooling that decreases the overall cost of the product from 40-60%?

Do you have any other comments and/or suggestions regarding the use of electronic 3D visualization tooling? If so, please write them in space below:

____
____
____
____
____
____

Thank you for taking the time to complete this survey. If you would like to see the tabulated results, please email me at WashingtonDamariusJ@johndeere.com.