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SOLID MODELING:
USE AND IMPLEMENTATION

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by

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Abstract

This project studies how geometric solid modeling is implemented and utilized in small and medium sized manufacturing companies. Data were collected by comparing the functional characteristics of several commercially available solid modeling packages, surveying relevant literature, and conducting interviews with key employees of small and medium sized manufacturing companies. All of the companies that were interviewed were still trying to integrate solid modeling throughout the organization. These companies used solid modeling for new designs but few used it for concurrent engineering or CAM purposes, which are some of the benefits that CAD vendors claim affect the manufacturing process the most. Although these companies are not at the stage of full solid modeling implementation, they have observed benefits such as decreased design time and increased design quality from using solid modeling.

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Introduction

Since the invention of mass production, it has been the goal of manufacturing companies to increase productivity and reduce costs. To do so, engineering and manufacturing companies are changing over from two-dimensional CAD packages to solid modeling packages. There are various solid modeling programs on the market that claim to increase efficiency and reduce design costs. Although the merits of two-dimensional drafting are essential to design, solid modeling extends the engineering design capabilities far beyond those of 2-dimensional drafting.[1]

This project will investigate the capabilities of three-dimensional geometric solid modeling systems and the extent that they are utilized in small and medium sized companies. It will also examine the impact of implementing three-dimensional geometric solid modeling systems into small and medium sized companies. Through these evaluations, the overall benefits and costs of changing over to a solid modeling system can be established.

This information is not only of great interest to the engineering faculty and students at WPI, but also to businesses who are making the transition from two dimensional computer aided drafting (CAD) to three dimensional solid modeling. By examining the interviews with various manufacturing companies, trade journals, and marketing documentation, we will describe three-dimensional solid modeling applications and their influences in modern day industry.

[1] Bulkeley, Debra, "Solid Modeling: The Competitive Edge in Design" Design News:2-3. Supplement 1999

Literature Review

Introduction

In order to structure the project it was necessary to proceed with the background research first. Since the study investigates how geometric solid modeling package will affect a manufacturing company and its products, it will be necessary to first understand how such companies work. By understanding the internal workings of the organization, vital relationships between the departments and personnel can be recognized. In order to understand how organizations are affected by the implementation of solid modeling programs, the capabilities and features of the various commercial solid-modeling applications on the market must be researched.

The ways in which these interactions affect the total structure of the organization will depend on certain relationships. These relationships govern the day-to-day activities and regulate workflow between departments. Knowledge of these relationships will give a better understanding of the impact that a solid modeler may have on an organization.

Concurrent engineering is being implemented by many organizations; therefore, it is necessary to know how it operates and how it is implemented. By understanding the factors involved in concurrent engineering, it will be easier to understand how concurrent engineering will benefit the total organization. This tool, combined with the power of solid modeling will influence the management and the other departments involved in maintaining order of documentation and information.

Product Data Management (PDM) is the product that combines concurrent engineering and computer-aided design. PDM is a tool that manages information throughout the organization and aids in creating total interoperability. Maintaining this control of information will aid in the development of design process methodology and set a standard for defining product quality.

The introduction of computer aided design (CAD) systems in companies has increased rapidly as organization technology demands increase. Understanding how these systems operate will increase the awareness of how they affect the organization in general. Various user groups and expositions were visited to gain more information about the solid modeling programs; the trip reports are documented in appendix B.

The history of various computer aided design systems is vital to understanding how they evolved from two-dimensional design applications into virtual geometric solid modeling systems. Understanding the origins of CAD reveals how technology and business have both evolved, creating a dependence upon one another.

The latest advancements of technology have evolved into parametric and variational design modeling. A majority of today's CAD packages fall into these categories. Therefore, it will be necessary to research these topics in order to fully understand present day CAD programs.

Before a study can be performed and a paper written, it is first necessary to understand the topic. This knowledge can only be gained through extensive background research of the topics that are involved in the implementation and integration of the solid modeling applications in the work place. Once this understanding is acquired, analysis of the overall efficiency and acquired product design quality can be measured.

Organizational Change and Behavior

Organizational change and behavior within an organization is a complex subject that involves the entire company. If CAD and/or solid modeling are introduced into the organization, everyday workflow may change and affect the behavior or routines in various departments and individuals. To fully implement CAD and solid modeling into an organization many short term and long term commitments must be set and achieved throughout the entire organization. These goals may include regular design review meetings or set documentation procedures.

These goals require a "technology plan" for successfully integrating CAD and manufacturing.[2] This plan includes increasing communication between departments with such things as design process methodology and concurrent engineering. These two processes aid in managing organization workflow and controlling the interoperability of documentation between departments to better increase design time and quality.

A simple example of a technology plan may include a procedure for designing a new product. A concept may be conceived in the marketing department. The idea is then relayed to sales who determines the customer needs and requirements. It then may be passed to the engineering department to determine feasibility and the manufacturing and production requirements for the product. Then the product is later handed back to sales, marketing, purchasing, or management or it may be sent to production and eventually released to the customer.

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[2] Gaynor, Gerald, Achieving The Competitive Edge Through Integrated Technology Management (New York: McGraw-Hill, 1991) 165.

Integrating solid modeling or any CAD system into a technology plan will have an effect on all the departments involved. For instance, marketing could use a rendered drawing of a product to show to customers. Several important issues that may limit the complete implementation a CAD application into a technology plan may include employee training, computer system upgrades, application support, and customization[3].

Concurrent Engineering

"Developing a new product involves passing the emerging concept from one department (or function) to another, i.e. from Research to Design, and thence to Development, Production Planning, Estimating, Tooling, Manufacture and Assembly. This 'over the wall' approach can be inefficient."[4] If the barriers between functions were removed then product development would be accelerated. Concurrent engineering does just that by "overlapping the activities of sequential functions."[5] The result is a reduction in the time to market for a product, as well as high motivation of the staff involved.

Concurrent Engineering is a product development process where, "a product design and its manufacturing process are developed simultaneously, cross functional groups are used to accomplish integration, and the voice of the customer is included in the product development process."[6] This teaming of people with different expertise, such as people with expertise in production, marketing, finance, service, or other relevant areas, avoids the 'over

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[3] (Gaynor 1991, 160)

[4] Smith, Robert P.: "Concurrent Engineering –its procedures and pitfalls." IEEE Transactions on Engineering Management: 215-218. London, October 1993.

[5] (Smith 1993, 178)

[6] Smith, Robert P.: " The Historical Roots of Concurrent Engineering Fundamentals. "IEEE Transactions on Engineering Management: 67. London, February 1997.

the wall' design process. 'Over the wall' design is where a designer creates a product simply to meet its design requirements and often neglects to consider manufacturing and other aspects of the product's design that will cause the design to need revisions later. The designer just passes the design to manufacturing department, which will send it back for revision. Concurrent Engineering puts a representative of the manufacturing department, as well as representatives from any other department that can have an impact on the design, on a team with the design engineers so that all factors are considered throughout the design process. This process eliminates the time that a design spends being shuffled between departments as well as the time it takes to revise the design to meet each department's requirements. The result is a noticeable reduction in development lead-time and improved quality of design.

Another reason for using Concurrent Engineering, other than its reduction of development lead-time, is the ability to quickly utilize new production methods. Design engineers may not have sufficient knowledge of a new manufacturing process to design a product that can use it, whereas a person from the manufacturing department would have that knowledge and can share it with the designer. This ensures that the design is made by the best possible process from the start.

The four different methods for implementing Concurrent Engineering are:

1) Requiring approval by other departments.

2) Establishing a liaison department that is responsible for coordinating the activities of other departments.

3) Forming all interested parties into one cross-functional team to ensure integration.

4) Using job rotation to ensure that functional cross pollination occurs.[7]

It is obvious that a company's objective in taking on a developmental project is to make money. The only way to make a profit in the manufacturing business is to design a product and get it to production as quickly as possible, hopefully faster than the competition. This can only be done by organizations with good engineering design practices. "Good engineering design practice has always been and will always be, the inclusion of the customer, the manufacturing process, and all relevant functions into the product development process."[8]

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[7] (Smith 1997, 67)

[8] (Smith 1997, 70)

Interoperability

The uniqueness of the various solid modeling applications available to companies may give the designer and engineers all the necessary tools to create and improve products, but they introduce problems that slow down file management and data exchange. Exchange of data between proprietary solid modelers becomes cumbersome, with each system having its own "native" file format. To compensate for this imbalance many solid modeling vendors and support companies are focusing on data interoperability.

Interoperability is the ability to bring external data into an application, manipulate the data as if it were "native," and output it in a standard format so that it can be used by other applications[9]. In the case of designers and engineers, this may mean exchanging solid models with vendors, suppliers or even the customer. Exchange of this type of data is made either between internal CAD systems (from one CAD to another CAD within the same organization), between various companies (company to company) possibly using different CAD systems, or between CAD systems and other application systems in the organization. The inability to transfer data accurately in any of these cases will decrease workflow efficiency and possibly limit product design.

Typical solutions implemented in industry for dealing with transferring solid model data include three different strategies[10]. The simplest strategy is to ensure that both the recipient and sender have identical applications. Another strategy is to recreate the model

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[9] Design News "Pathways to Interoperability." Design News, Special Supplement, 1999:

[10] Design News "Pathways to Interoperability. *The starting point for 'interoperability': 3D Models"* Design News, Special Supplement, September 6, 1999:

with another application to produce two identical models. The final possibility is to use a data translator to convert one file type into another.

Each of these three solutions has succeeded in industry but each has unique flaws that prevent true interoperability. Ensuring that both the recipient and sender systems are identical becomes costly for companies if their main CAD systems differ. Matters become even more complex if more than two applications are involved.

Recreating CAD data from one system to another is also costly due to the time spent recreating the object or assemblies. This method may not insure complete accuracy of the model or that design intent which may be embedded in the model is retained. However, this method is used widely in industry as a method of data conversion.

Universal translators are the alternative to many of the manual methods mentioned above. This method works by first creating a model on a solid modeler and then transferring the model to the translator in a neutral format like IGES or STEP. The translator then changes the model data into a format usable by the target CAD system. Independent translators seldom include mathematics applications that can analyze complex geometry such as those built into the solid modeling applications themselves. This allows the possibility for translators to corrupt models, lose data, or lose features in the translation.

Solutions for this translation dilemma are becoming the focus for CAD vendors and support companies. Complete interoperability implementations between all the available applications becomes a conflict of interest for most vendors. Vendors would prefer to secure seats by keeping users with proprietary seats. In the absence of suitable translators or interoperability features, the price to translate existing data into another application format would be too high. This ultimately discourages companies from switching from one CAD application to another. Nearly every solid modeling software company is in the process of incorporating interoperability, in some manner, into their application.

Design Process Methodology

The design process is a life cycle that can vary greatly depending upon the project. It is a complex process that results in the invention or improvement of a device. In *Design of Machinery* by Robert L. Norton, a ten-step design process is presented.

First in the design process is identifying a need. This step is done either by the client, or someone higher up in the company for which the engineer works. This need is often very vague and unstructured. This leaves the engineer with the task of structuring the unstructured problem.

Norton[11] states that the most important phase in the design process is one that is often over looked, background research. The engineer should first look to see if the problem presented has ever been solved before. If it has, then the project might end here. Even so, the engineer could take an existing design and improve upon it. Either way, Norton states that there is no reason to "reinvent the wheel". During this phase, existing products should be examined, experiments should be administered, and literature searches done. If proper research is not done in the beginning, it will result in more work in the end.

The next step is to develop a goal statement. This statement should be concise, however it should not narrow the options. Norton[12] suggests using functional visualization to avoid this pitfall.

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[11] Norton, Robert L. Design of Machinery, 2nd Ed., (Boston, McGraw-Hill, 1999), 9.
[12] (Norton, 1999,9)

Once the goal statement is developed, the next step in the design process is to make a list of performance specifications. Performance specifications define what the system or device should do, not how to do it. This step helps to constrain the problem without over-restricting it.

Next comes one of the hardest steps in the design process, ideation and invention. This is when the engineer brainstorms as many possible solutions to the problem as possible. The engineer should refrain from judging the quality of the solutions and not disregard any ideas at this point.[13]

After a multitude of solutions has been generated, it is time for analysis. Analysis can be as simple as a kinematic analysis to ensure that the model moves in the way that it was intended. Analysis can also go much further by determining the forces that the motion of the object will create, as well as determining the stresses that will be created by those forces. Without such analysis it is nearly impossible for an engineer to determine, with any degree of accuracy, whether or not a model will be able to function within given limits properly during operation. Now it is time to choose the best design to pursue. The performance of each design is determined and compared at this stage. It is helpful to use a decision matrix to evaluate the designs. This will help the designer make an informed decision as to which design to pursue.

The chosen design is now ready for detailed design. The design is detailed in assembly and part drawings, usually with the help of a CAD system. This is where all the dimensions and materials for the parts are chosen. This process will result in several iterations of the design.

[13] (Norton, 1999, 10)

Once the drawings are complete, a model of the design is usually constructed. An actual prototype of the design is the best way to test the design. This is usually expensive, but it may save the company money if flaws are found before production begins. A physical model also allows for testing.

Finally, the design is ready for the last stage in the process, production. Norton notes that it is important to use care early in the design process; doing so will avoid problems in the design that would not be apparent until the assembly of the finished product. This is will save the engineer much grief and embarrassment.[14]

Design Time and Quality

The behavior within a company is highly affected by time management issues. Each department or individual may have a different concept of time and the way it is managed. Controlling how time is managed will determine priorities and govern how the organization operates.

An example of these differences between various departments is demonstrated by a comparison between sales and engineering. Each department tends to clash with the ideals of the other with respect to time.

> *"The very nature of sales activity places a high premium on being able to make commitments to customers that the company can honor. This usually places heavy time pressures on the production end of the process. The very nature of design functions places a high premium on constant refinement, even if it takes more time to get the product finished.[15]"*

[14] (Norton, 1999, 13)
[15] Cohen, Fink, Gadon, and Willits, Effective Behavior in Organizations , Cases, Concepts, and Student Experiences, 6th Ed. (Boston, McGraw-Hill 1995) 351-353.

A way to measure effectiveness in an organization is to analyze conflicts that interrupt workflow. Conflicts between departments and individuals may include such things as: the concept of time management, the number of manufacturing units that are idle and waiting for parts, the total time to produce a part or operation, or the number of interruptions in a prescribed procedure[16]. Choosing which criteria to use to measure effectiveness is dependent upon what priorities the investigators want to analyze.

In the case of analyzing how solid modeling affects the efficiency of small or medium-sized companies, several criteria need to be used. These include a comparison of quality and time-savings between solid modeling and two-dimensional drafting in the following categories:

- Part Analysis
- Tool Manufacturing & Machine setup
- Engineering Design Change
- Design Process Completion
- Communication

By using these factors to compare the differences between the two types of systems, a basic understanding of how efficient each system is was determined. Information for these comparisons was gathered from independent case studies and "first hand" accounts.

Performing Case Studies

"Case studies of organizations may be defined as the systematic gathering of enough information about a particular organization to allow the investigator insight into the life of

[16] Harrison, Michael I., Diagnosing Organizations, 2nd Ed., (London, SAGE Publications, 1994) 42-43.

that organization."[17] Case studies may employ a number of data technologies such as life histories, documents, oral histories, in-depth interviews, and participant observations.

The use of interviews can often result in large amounts of information. "In some instances, a single lengthy interview may yield sufficient information to produce answers to the research question(s). In other circumstances, several interviews may be necessary, and these may require supplementation by field notes during direct observation, copies of journals or diary entries from the subject, or other forms of documentation."[18]

Personal documents can often be used to gain useful information. "Personal documents involve any written record created by the subject that concerned himself or herself and his or her experiences."[19] Common types of documents classified under this label include autobiographies, diaries and journals, letters, and memos written by an employee of the organization or a research investigation.

Journals and diaries can also produce large amounts of information for a researcher. "A diary or journal may be created at the specific request of a researcher as a contribution to some study."[20]

Company memos can be yet another source of useful documentation. "Memos may contain strictly work-related information or casual insider jokes and communications. They may reflect the tone and atmosphere of a work setting as well as the potential level of anxiety, stress, and morale of the writer."[21] Memos "may contain information relevant to

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[17] Berg, Bruce L. Qualitative Research Methods For The Social Sciences.(Boston, Allyn and Bacon, 1998) 212.
[18] (Berg, 1998, 213)
[19] (Berg, 1998, 214)
[20] (Berg, 1998, 215)
[21] (Berg, 1998, 215)

understanding the general organizational communications network used in the setting, the leadership hierarchy, various roles present in the setting and other structural elements."[22]

Ultimately, a case study is a way of observing an organization in order to gain an understanding of how that organization functions. There are many different means of collecting data in order to gain this understanding. The result of a case study should be an understanding of an organization that is adequate to answer the questions for which the case study was intended to answer.

Computer Aided Design

History

It is the goal of every manufacturing and design company to produce products as quickly as possible. Before CAD systems were created, designers worked with pen and paper on drafting tables designing parts in two dimensions. These drawings took great skill and knowledge to create, and if a mistake was made, the drawing had to be completely redone or drastically reworked. It was this reason that brought about the technology of two-dimensional CAD systems.

Two-dimensional CAD systems enabled designers to create two-dimensional drawings that could be easily modified without redrawing the part and helped to avoid the common problems associated with doing so. Furthermore, two-dimensional CAD systems had all standard drafting tools loaded into the software already making drafting that much quicker. Unfortunately, two-dimensional models simply do not convey enough information to be fully utilized as design tools. Three-dimensional wireframe and surface modelers were introduced in the early 1970s in an attempt to convey more design information. They

[22] (Berg, 1998, 215)

brought with them the ability to use CAD systems to create NC (numerical control) tool paths and perform simple engineering analyses. However, three-dimensional wireframe and surface modelers were insufficient for designs that are more complex.[23]

In the late 1970s solid modelers were introduced with the promise of producing "large savings throughout design and engineering...However, these savings did not materialize because the systems were unnatural and difficult to use."[24] The use of primitive solids, sweeping operations, and Boolean operations to combine the primitive solids to make complex solids was very different than what designers were used to, and therefore made it difficult to learn how to use these solid modelers.

When Parametric Technologies Corporation (PTC) introduced Pro/Engineer in 1988, it solved many of these problems, or at least reduced the number of problems. Pro/Engineer used parametric design, design features, and data associativity to make solid modeling a more intuitive and easy to use application. The addition of these features not only made solid modeling easier to use, it also made it much more productive. Parametric design made it so that one change within a model changed all the associated features and geometry at the same time, which saved a great deal of time. Design features such as fillets, chamfers, countersunk holes, through holes and many others made the solid modeler easier to understand since these features were called by their familiar names and not by the primitives used to create them. Data associativity helped with the overall flow of data from CAD to CAM (Computer Aided Manufacturing) systems. A change made on a model in the CAD system would automatically change in the CAM system, thus saving time and avoiding possible errors that could occur therein.

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[23] Lockhart, Shawna D. & Johnson, Cindy M., Engineering Design Communication: Conveying Design Through Graphics. (Reading Massachusetts, Addison-Wesely, 1999).

Soon, many commercial solid modelers emerged with capabilities similar to that of PTC's Pro/Engineer. Most solid modelers today use parametric design and design features very similar to those of Pro/Engineer. However, only the more expensive systems have data associativity (when the solid model is updated the associated model in another program, such as an analysis package, is automatically updated) unless downstream CAM packages are specifically programmed to work in conjunction with a certain solid modeler.

Functionality of Three-dimensional CAD

Three-dimensional CAD systems have evolved into quite complex programs. The most common and most powerful of the present day three-dimensional CAD systems are solid modelers. The reason why solid modelers have all but replaced two-dimensional CAD systems and three-dimensional wire-frame systems is that they convey much more information than do two-dimensional CAD systems and three-dimensional wire-frame systems. Unlike two-dimensional and three-dimensional wireframe programs, a solid modeler contains more information than just the lines and arcs that comprise the edges of the part. The geometry created in solid modelers has volume, which is recorded within the model. These volumes can then be used to calculate important engineering values such as mass properties, as well as creating surfaces that can be input into numerically controlled (NC) code quite easily.[25]

At the base of each solid modeler is a computational engine or kernel, which performs the basic mathematical functions of the system. These functions include Boolean operations, blending, mass properties, exporting of geometry, and chamfering and filleting.

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[24] Machover, Carl, The CAD/CAM Handbook, (New York, McGraw-Hill, 1996) 67.
[25] Lockhart, Shawna D. & Johnson, Cindy M., Engineering Design Communication: Conveying Design Through Graphics. (Reading Massachusetts, Addison-Wesely, 1999).

Currently there are two non-proprietary kernels on the market. These are the ACIS and the Parasolid kernels[26].

Beyond the kernels of each solid modeler, an important factor of each is the type of geometric modeler that it uses. The geometric modeler is a database that stores the geometry of the model so that it can be displayed by the computer. Constructive Solid Geometry (CSG), Boundary Representation (b-rep), and Hybrid databases are the three types that are used today. There are definite benefits to having any of these.

The benefit to using CSG is that it stores all of the primitive (basic) shapes that are combined to form the part in a tree. The tree is a design map that documents the history of the model (i.e. what shapes and methods were used to create the model). From this tree, shapes can easily be selected and changed.[27] However, this convenience comes with a cost. CSG requires that the model be completely re-evaluated in order to display, or render, the model whenever changes are made or whenever the view of the part is changed. This computation and re-rendering causes computer processors to slow down greatly with more complex models.

B-rep avoids the processor lag inherent in CSG by storing only the parts' faces, vertices, and edges.[28] Unfortunately, what b-rep gains in processor speed, it loses in convenience of modification. The primitive shapes are no longer stored. Instead one solid shape is stored and only its faces, edges and vertices can be changed.

Hybrid modelers are systems that incorporate both CSG and B-rep methods in order to utilize the benefits of both methods. Commonly a CSG tree is represented in the database

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[26] Bulkeley, Debra, "Solid Modeling: The Competitive Edge in Design" Design News:2-3. Supplement 1999
[27] Mackrell, John, The CAD/CAM Handbook, (New York, McGraw-Hill, 1996) 72.
[28] (Mackrell 1996, 72).

while b-rep is used for display purposes.[29] This allows the user to edit the primitives without causing the processor to lag nearly as much as it would if using CSG.

Another important feature of present-day solid modelers is relational modeling. The introduction of relational modeling was, arguably, one of the largest advancements in solid modeling. It allowed constraints to be placed on models that would permit users to modify a dimension without having to change each primitive within the model, as each primitive would automatically update its dimensions to fit the constraints applied to it. The creation of relational modeling also paved the way for timesaving functions such as Feature Based Modeling. The two types of relational modeling systems are parametric modeling and variational modeling systems.[30]

Parametric modeling relates different geometry within a model. If one of these geometries is changed, the rest of the geometry of the model changes accordingly. This is also known as dimension-driven modeling. This system is defined by sets of equations that are solved sequentially. Therefore, the order that the dimensions and constraints are applied defines the functionality of the model. [31]

The second type of system, called variational modeling, was developed after 1992. This system utilizes sets of non-sequential dimensions and constraints, which allows the dimensions and constraints to be applied and modified in any order. The geometric elements of a model are related through conditions of parallelism, coincidence, co-planarity, etc.

Both systems have advantages and disadvantages. The sequential computation of equations inherent in parametric modeling makes it difficult to modify the equations. On the other hand, the non-sequential computation built into variational systems make the equations

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[29] (Mackrell 1996, 72).
[30] Schussel, Martin D. and Chung, Jack C.H. The CAD/CAM Handbook, (New York, McGraw-Hill, 1996) 181

easy to modify. However, this flexibility comes with its own price as well. In order to solve a multitude of non-sequential equations simultaneously, much processor speed is required. This translates into slower computations unless the program is run on more expensive computer hardware.

Another characteristic of solid modelers is Feature Based Modeling (FBM). FBM is a way of creating common geometry such as holes, pockets, and protrusions, without having to create them from primitives[32]. Features are programmed into the solid modeling package with built-in constraints and relations. Therefore, the geometry that is created using FBM will automatically change when a model is altered. For example, a through-hole could be defined using a Boolean difference operation and a cylinder of sufficient length. However, if the design became thicker and the cylinder was not long enough, the hole would become a blind hole. In contrast, the through-hole feature understands the rule that it must pass completely through the part and will do so no matter how the part changes.

Prior to the introduction of relational modeling systems, specifically parametric modeling systems, solid modeling programs were counterintuitive and difficult to use.[33] Using parametric modeling and FBM solid modelers, CAD companies have made using these programs more natural, and have provided manufacturing organizations with a powerful engineering tool.

Beyond drawing complex three-dimensional shapes, solid modelers perform many more tasks that are useful to the designer. These tasks include determining mass properties, creating tool-paths for NC machines, and creating files to be used for rapid prototyping.

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[31] (Chung, and Schussel 1996,183)
[32] (Lockhart 1999, 211)
[33] Chung, Jack C.H. and Schussel, Martin D. The CAD/CAM Handbook, (New York, McGraw-Hill, 1996) 181.

It used to be a tedious task to find mass properties of objects. Complicated equations had to be used to find mass moments of inertia and it took a good deal of time to do so. This is no longer the case. Present-day solid modelers will determine such properties as moments of inertia, volume and mass. Automatically computing properties such as these saves the engineer time, allowing him/her to carry out other job functions.

In the past, when two-dimensional CAD systems were used, a design was made and then given to a machinist to be produced. Using today's solid modelers it is possible for a designer to design a part and then input a file into a NC machine, thus eliminating the step of manual programming or manually machining the part during the production process. This is another way in which solid modeler vendors claim that the solid modeling programs save vast amounts of time.[34]

Rapid prototyping has become a very useful tool in industry. It used to take large amounts of time to have prototypes produced for testing. Using solid modelers, and such processes as stereo-lithography, a prototype can be produced in hours rather than weeks. All of the solid modelers produced today come with rapid prototyping capabilities.[35]

Claims that solid modelers can be used from concept to production are supported by such functionalities as using a solid model to generate NC tool-paths and rapid prototyping. Conceivably, a designer could design a part and then make a prototype or maybe even the final product, without having a manufacturing expert ever look over the design. This rarely happens, but the fact remains that solid modelers do have the potential to reduce the time involved in the design process. We reviewed eight of the most popular solid modeling

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[34] Christman, Alan M. . The CAD/CAM Handbook, (New York, McGraw-Hill, 1996) 255.

[35] Krouse, John. . The CAD/CAM Handbook, (New York, McGraw-Hill, 1996) 16.

systems in order to gain enough knowledge about each system to be able to ask companies questions about the systems they are using. We evaluated such characteristics as cost, features and available add-on packages. These evaluations appear in appendix A.

Product Data Management

Due to the extensive use of CAD systems to design products, an abundance of CAD files accumulate within manufacturing companies. With so many files within a database, it becomes difficult to manage the files in order to keep revisions current and allow engineers to easily retrieve them for use within new designs. Product Data Management (PDM) systems were introduced to remedy these problems and make it easier for engineers to find the data that they need so that they can spend their time designing rather than searching through databases.[36]

PDMs are programs in which CAD files are stored and managed. These programs set up strict protocols that must be met in order to input a file into the system. These strict protocols bring order and consistency to the engineering data. Once a file is in the system it can then be accessed from other computers that are on the same network as the PDM system. When a file is modified and resaved the file within the PDM will automatically update itself to conform with the latest revision. Many PDM systems will only allow one designer to modify a file at one time to prevent one engineer from changing another engineer's design without him/her knowing about it.[37]

A benefit of using PDM is the ease of finding files that are used frequently in a number of designs. This is common when a company uses many standard parts in many

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[36] Puttré, Michael. " How PDM opens windows on design Improvements" Design News: October 21, 1996 < http://www.manufacturing.net/magazine/dn/archives/1996/dn1021.96/feature5.htm >

different products. Rather than having to redraw these parts every time they are used, or search through a huge database to find them, they can be quickly retrieved and inserted into a design.[38]

Another benefit to using PDM is the accessibility of data throughout an organization. Instead of storing data on only one computer's hard drive, which would make that information available only to the person using that computer, it is stored on a network drive. From this network drive, any other computer on the network can access the information.[39]

With the enormous amounts of data that accumulates in manufacturing companies, file management will inevitably become an important issue. PDM is a remedy that many companies are now relying on to meet their file management needs.

CAD Vendor Claims

Undoubtedly many companies are making the transition from two-dimensional CAD systems to solid modeling systems.[40] It is evident that there are many benefits to having a solid modeling system in one's toolbox. The vendors of the three-dimensional solid modeling systems make many claims about their products. We were able to talk to several vendor representatives in person at trade shows and expositions in order to get an idea of what CAD vendors claimed their programs could do. (See Trip Reports appendices B) We found that most of these claims are based on subtle differences in the packages. For instance,

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[37] Toupin, Laurie Ann. "The changing face of PDM" Design News: February 7, 2000
< http://www.manufacturing.net/magazine/dn/archives/2000/dn0207.00/03f2026.htm >

[38] Puttré, Michael. " How PDM opens windows on design Improvements" Design News: October 21, 1996
< http://www.manufacturing.net/magazine/dn/archives/1996/dn1021.96/feature5.htm >

[39] Field, Karen Auguston. "PDM gets PDQ" Design News: October 19, 1998
< http://www.manufacturing.net/magazine/dn/archives/1998/dn1019.98/feature2.html >

[40] Kita, Tarou.:"Using 3D CAD for Improved Prototyping Efficiency." Time-Compression Technologies. Volume 5, No. 2. pp34-40.

Solid Edge claims that their package is better than other packages because it requires fewer mouse clicks to design a part. [41]

One of the main claims made by the companies is that their solid modeling systems reduce design time. They claim that by utilizing their features, such as sheet metal features or parts libraries, the design time can be minimized. SolidWorks claims that their product allows the designer to "...move through the design cycle in record time".[42] Solid Edge claims that by using their product, the designer is 36% more productive.[43] Although most of these claims are not backed up with substantial evidence, some companies boast product reviews by companies that use their product. Many CAD vendors are claiming that their customers' design cycle times have been reduced by nearly 30% by implementing that particular company's solid modeling system.

Another popular claim by these companies is that design quality can be increased by using their product. SolidWorks claims that their system " ... creates a design environment that fosters creativity and innovation, allowing your organization to bring better quality products to market faster at a lower cost."[44] These claims are based on the idea that by creating a three-dimensional model or assembly it is easier to work out the problems of a design. By having this three dimensional model it is easier to notice mistakes early on in the design as opposed to something that was designed on a two-dimensional system. A solid modeler allows the designer to have an instant "prototype" of the product without the expense of creating a physical prototype or final part.

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[41] Pamphlet from Solid Edge, "CAD with the Productivity Advantage", 13736 Riverport Drive, Maryland Heights, MO 63043.
[42] SolidWorks pamphlet "SolidWorks 99 Product Overview", p.1, 300 Baker Avenue, Concord MA 01742.
[43] Solid Edge pamphlet, "Cad with the Productivity Advantage", p.213736 Riverport Drive, Maryland Heights, MO 63043.
[44] SolidWorks pamplet, "SolidWorks Corporate Overview", p.1

Lastly, the solid modeling companies are claiming that their products are easy to use. Some of them incorporate features to aid the transition from two-dimensional CAD to three-dimensional solid modeling. Most of the companies boast a learning curve of only a few weeks.

Although many of these claims may be marketing hype, these are issues people are considering when purchasing a solid modeling system.

Methodology

Introduction

The purpose of this project is to study three-dimensional solid modeling applications and their effects in the manufacturing work place. Focus is being placed on small and medium sized manufacturing companies that have implemented or recently made a transition to integrate non-proprietary (commercially available) solid modeling applications. Special consideration is being placed on determining if companies are efficiently using solid modeling applications as a tool to achieve their desired engineering and design requirements. Effective use of this tool is based on whether or not the company utilizes the features of the solid modeling application that best benefit the design of their products.

For this project, the size of the companies is based on the number of CAD software licenses and workstation or PC combinations (also known as seats) available to the engineers and/or designers in the organization at any one time. A small company is considered to have a maximum of 10 seats, medium sized companies would have 10 to 30 seats, and larger companies have 30 or more seats.

Determining if the company being evaluated is using a particular application efficiently depends on several factors in the organization and in the solid modeler. These factors were determined through examining end user and company personnel interviews, documented case studies referencing implementation success and failure stories, and published literature such as product reviews and brochures. The true efficiency and effectiveness of geometric solid modeling in the manufacturing work place will be determined by isolating and evaluating these factors.

The interview questions are designed to incorporate ideas and thoughts from various members of the organization into one concise record. The interview question sheet is divided into seven categories. Each category contains specific questions to determine the implementation and use of solid modeling specific to the organization.

The first category is *Organizational Profile*. This category is necessary to develop an understanding of the companies' internal structures. This information covers the number of employees, number of CAD seats, etc that will be used to distinguish company size and determine which solid modeling packages they are using.

The second category is *Training and Experience*. It was felt that a knowledge of the companies' training methods would help to understand why or why not a company has succeeded in gaining benefits of time reduction and quality improvement from their solid modeler. It also determines if companies look at personal experience and training in solid modeling as a means of recruiting new employees or if it provides a means for advancement in the organization.

The third category is *Documentation Control and Standardization*. This category helps to understand the organization of files within the company. If a company is not tracking their revisions properly, then a model or its corresponding drawings may not be updated properly. This would result in a less efficient way to make use of the solid modeler's capabilities.

The fourth category is *Communication.* This category focuses on the effect solid modeling has on the companies' internal and external communication. This relates to concurrent engineering, design reviews, and communication with customers and vendors.

The fifth category is *Compatibility, Integration and Maintenance*. The questions in this category help determine if the solid modeler is able to integrate with the other programs, such as 2D CAD, other solid modelers, or view stations within the company. The questions also focus on vendor support and technology updates for the solid modeler. These questions help to establish any problems exist with the software that may impede the company from properly using the solid modeler.

The sixth and seventh categories are *Efficiency and Productivity* and *Quality*. One of the main goals of this project is to evaluate the solid modeling vendors' claims. These questions focus on the claims and the ways that the solid modeler actually improves the quality and efficiency of the design process in these companies.

The last category is *Satisfaction*. This category is designed to develop a conclusion on the companies' experiences with solid modeling. These questions will aid in gathering information on whether or not the solid modeler is meeting the needs of these companies. This gives the company the opportunity to specify the advantages and disadvantages of their solid modeling application.

The intended result will be a report that will demonstrate how solid modeling technology is currently being used by small and medium sized companies. The report will try to determine if solid modeling increases design quality and reduces design time. It will also investigate how companies can use these technologies to best benefit the design of their products.

Interviews and Surveys

We determined that the best way to obtain the information that we sought would be through personal interviews with various people in the engineering, management, and information technology departments at the companies that will be analyzed. The information that will be obtained through the interviews will be the overall view of the solid modeling package by the interviewees, and how they perceive that it has made an impact on their company and their company's products.

We decided that this was the best way to obtain this information for many reasons. The main reason was time. Observing how the solid modeling package affects a company and the company's product firsthand could take several months. This would also require that the observers spend a fair amount of time at the company, and have full access to many of the company's documents. With the time constraints of this project, the option of closely observing the company to obtain the information would be impossible. Therefore, it was determined that similar information could be obtained by interviewing several key employees of the company. These employees are the ones who work closely with the solid modelers and would therefore have the firsthand experience to answer our questions.

In order to conduct the interviews, we first identified the essential people that were interviewed. The main users of the solid modeling program are the most obvious of people to interview. From these interviews, information about changes in product design time and design quality was gathered. It was also of great benefit to interview the manufacturing engineers in these companies. Therefore, information about change orders, and reductions in manufacturing costs and time could be obtained.

We also determined that once contacts were made with the companies that would be interviewed, a copy of the interview questions would be faxed or transmitted via e-mail to the interviewees prior to the interview. See appendix C for a sample of the interview questions. Some questions were accompanied by some background information to ensure that the interviewees understood exactly what was being asked. For example, an excerpt from the sheet may look like this:

The solid modeling application companies claim that by providing the user with features such as sheet metal packages and part libraries the end user is far more productive, and the design time cycle can be drastically reduced.
Do you agree with the claim above? If so, explain what features or aspects of the solid modeling programs are reducing the time cycle.

The best way to obtain the information that our group sought was to conduct the interviews in person. One reason for this is so that the questions could be explained further if need be. Another reason is in case some of the interview questions lead towards other information that may be valuable to our study, but perhaps was not included in the interview questions. This allowed the interviewer to focus in on certain aspects of the interview that pertain more to the company being interviewed.

It was necessary to find companies to conduct interviews with in order to acquire the data needed to determine how solid modeling is implemented and utilized by small and medium sized manufacturing companies. Four companies in the New England area were contacted and sent a package outlining the project. These companies were chosen because of their size and for the fact that they have solid modeling packages. Once a response was received, a time was negotiated and the interviews were conducted based on the interview question sheets shown in appendix C.

Overall, by carefully planning the interview questions and having a thorough knowledge of the background information (i.e. the solid modeling programs), useful information could be obtained through interviews.

Results

Introduction

Each of the four companies that were interviewed used solid modeling as a tool to accomplish various engineering tasks. These tasks are dependent on the companies' product lines and design requirements. The extent to which solid modeling is implemented at each of these companies varies.

A brief overview of the company and the results of the interviews are presented alphabetically by the company's name. Included in the analysis is a brief description of what the company would like to do in the future with solid modeling that they are not currently doing. Also included in the analysis are the issues that the majority of the individuals, who are directly affected by solid modeling, hold. *Table #1, Company Comparison,* is a table showing basic characteristics of each company interviewed.

	Solid Modeling	No. of Solid Modeling Seats (1	No. of CAD Seats	Number of S.M. Users	Total Number of Engineers	No. of Years S.M. Implemente	Solid Model Parts Library	Solid Modeler (2)	Solid Modeler (3)	2D CAD (2)	2D CAD (3)	PDM Application	FEA/Analysis	CAD/CAM	Rapid Prototypes	Concurrent Engineering	In-House MIS Support	Out-Sourced Support
Gems Sensors	**X**	2	19	3	15	5		SD		ME	AC	**X**			**X**		**X**	**X**
Mott Corporation	**X**	8	8	4	10	4		PE		CK		**X**					**X**	**X**
Empire Plastics	**X**	3	3	2	2	2		SW	UG				**X**	**X**				
AAC Robotics	**X**	10	13	5	11	2	**X**	SD	IC	ME			**X**			**X**		**X**

AutoCAD	AC
CadKey	CK
IronCAD	IC
ME10	ME
Pro/Engineer	PE
Solid Works	SW
Solid Designer	SD
Unigraphics	UG

Notes:
1) Solid Modeling Seats are also include in the number of CAD seats
2) Refers to the companies primary application.
3) Refers to the companies secondary application or anticpated application.

Table #1
Company Comparison

Automated Assemblies Corp.
25 School St.
Clinton, MA 01510 USA

Company Overview

Automated Assemblies Corporation (AAC) is a manufacturer of industrial robots for plastic injection molding machines. Out of the eleven engineers employed at AAC, seven are mechanical engineers and four are electrical engineers. The names and positions of the interviewees are listed in the Acknowledgements section. AAC has been using CAD for thirteen years. Solid modeling has only been implemented there within the past two years. AAC uses ME10 for their two-dimensional drawings, and Solid Designer and IronCAD for their solid modeling programs. They initially implemented Solid Designer, and have recently purchased IronCAD. AAC believes that IronCAD offers more built-in functionality as part of their basic program, unlike Solid Designer, which requires additional add-on packages, purchased separately.

Training Methods

AAC has utilized various methods of training to teach solid modeling to their engineers. When Solid Designer was purchased, the vendor included a one-week training program as part of the purchase. All of the employees who would use the solid modeling program attended this program. They also noted that the offsite training is only beneficial if the trainee learns the basics of the solid modeling package prior to attending the class. Otherwise, too much time is devoted to learning the basic functionality, rather than the more complicated aspects of the program. The other training methods used at AAC involved using the tutorial accompanying the program, and by learning tips and strategies from fellow colleagues. All of those interviewed agreed that there is no substitution for hands on experience and many hours of usage.

Recruiting and Advancement

AAC does not use solid modeling experience as criterion for selecting new employees during the interview process nor do they use it exclusively for internal advancement. They do however believe that within the next few years it will become more important for existing and future employees to understand how to use solid modeling as a design tool.

File Management

At the time of the interviews, no Product Data Management (PDM) system was in use at AAC. Drawings and solid models are updated, maintained, and controlled manually by the engineers who use them. This system maintains revisions by special filenaming conventions used when each revision is made. Even with this system in place, several of the engineers indicated that problems do exist with using the wrong revision on a part. This mistake is generally not found until the parts reach the assembly floor.

Operation and Use

AAC currently relies heavily on their two-dimensional CAD package, ME10. ME10 is used in place of Annotator, the two-dimensional system that is incorporated into Solid Designer, for several reasons. One reason, simply put, is that all their engineers and designers are familiar with ME10 and need very little additional training. Another reason is due to their opinion that ME10 is a far superior two-dimensional program and very simple to use. There is no direct link to enable data associativity between the two applications. Therefore, when the model is changed, the multi-view drawing in ME10 is not automatically updated. When either the solid model or the drawing is modified, the engineers reported no problems with translating files between the two. This is because both of these programs are made by the same company and both use the same native file type. This system works well for the company, although it is extra work to go through this process of manually updating the drawings.

Technical Support

AAC does not have any dedicated computer support in house for their solid modeling or CAD systems but instead contract the service to an outside vendor. They did not mention any serious problems regarding updates for any of their applications. Updates and patches are installed whenever they become available either by the contracted service or by the engineers themselves. AAC utilizes the telephone line support offered by the vendors of their various applications and they seemed pleased with the overall support. It was noted that IronCAD keeps up very well with advancements in technology, whereas Solid Designer was a little slower to respond to advancements.

Communication

Although solid modeling has not improved the overall workflow of the company or the advancement of concurrent engineering, it has allowed for better communication. All of the engineers believed that one of the greatest impacts of solid modeling in the organization was to increase the visualization of a concept or product during a "design review" session. During these sessions, solid modeling allows people with less technical expertise to better visualize the part. Even for someone with a strong technical background, it can be difficult to visualize a complicated design or assembly by simply looking at a multi-view drawing. Solid modeling has reduced the amount of time needed for design reviews, by allowing for better visualization, and it has allowed for better input from all of the departments involved.

Vendor Claims

Although solid modeling has not been fully implemented, some time reduction has been realized. The robots produced by the company require many hoses, airlines, and cables (line routings) making it difficult to determine or visualize where to route the lines in a two-dimensional drawing. Therefore, prior to solid modeling, the line routing was not determined until the robot reached production floor. Solid modeling allows the designer to see where the lines should run and whether or not there will be enough room to run all of the cabling and hoses.

All of the interviewees believed there are plenty of opportunities for solid modeling to improve efficiency, but it is too soon to tell for sure. Since solid modeling is not used exclusively, it is difficult to acquire any quantitative data to prove change in efficiency. Currently, AAC is only using their solid modeling program on select projects. The majority of their design work is still done in two-dimensions. However, several engineers believed there were definite improvements in both quality and efficiency in the few projects that they have worked on using solid modeling exclusively. These engineers were however more proficient with the solid modeling application than the others who were not sure of any change in efficiency.

One reason why they believed solid modeling has increased the efficiency is because there is no need to pay attention to the various views in the drawing. In a two-dimensional drawing, care must be taken to ensure that when something is changed in one view, that it is changed in all views. Further care must be taken to make sure that there is no part interference in all the views. However, in a solid model, when any change is made the part can be dynamically rotated to check for interference in all directions. This was given as an example to show how solid modeling helped to reduce design time.

Overall, solid modeling had produced several definite benefits when used exclusively. The engineers believed that there was a definite time reduction in certain areas of the design process and a noticeable amount of reduction in engineering error. One of the engineers noted that on a recent project that use solid modeling he was able to find and correct more design errors early in the project, thus reducing the number of errors in the later stages of the design. Since all the components for the project were created in 3D he believed it was easier to spot errors or potential problems with component alignment and interference.

Solid modeling has allowed production to have better assembly drawings. If the production staff does not fully understand the assembly, it is the engineer's responsibility to assist them. With solid modeling the engineers are able to provide better assembly drawings or illustrations, thereby reducing the time needed in explaining the assembly.

Conclusion

Overall, the engineers at AAC were very satisfied with their solid modeling programs. One thing that they did desire is a stronger two-dimensional package within the solid modeling program. They feel that the two-dimensional programs that come with IronCAD and Solid Designer are inferior compared to ME10.

AAC Robotics still relies heavily on 2D CAD to design their systems. The various employees gave many reasons as to why the company has not gone to full solid modeling implementation.

The main reason that was agreed upon by all of the employees interviewed was the time for training. In order to have a user become proficient on a solid modeling system, the user has to spend many hours using the system. Reading the literature and attending a few training classes is only a small step towards learning a package. The only way to become proficient with a system is to use the system.

Although this seems obvious, it is not easy to get all of the engineers to spend enough time using the solid modeling program. One reason for this is time deadlines on a job. If an engineer knows a two-dimensional system well, then he or she prefers to do the job on that system because he or she will finish the job faster. It is difficult to design a part or assembly and learn a new solid modeling package at the same time. Therefore, the mechanical design engineer that one should not try to learn the solid modeling package while trying to design a new product. Instead, it is preferable to take an existing system, which was designed in a 2D CAD package, and model it in the solid modeling package. This way, the engineer can focus on learning the package.

In order to implement this type of training, an engineer would need to be taken away from his or her current tasks and be allowed to learn the system in the way described above. AAC Robotics does not have enough engineers to implement this type of training. It was indicated by one of the engineers that the ideal situation would be to bring in a temporary engineer to take over the duties of the engineer while he or she is training on the system. Otherwise, the loss of one of the engineers would result in missed deadlines, which is not acceptable business practice.

Another issue with implementing a solid modeling package lies in the hands of management. One engineer stated that taking small steps in implementing solid modeling is not working; they have been doing this for two years and are not fully utilizing solid modeling. Management must make a commitment to immerse the company completely into a solid modeling package. Although there will be some short-term difficulties in this approach, the long-term benefits of implementing such a system must be considered. One of AAC's employees also indicated that management is not fully aware of the complexity involved in learning a solid modeling package. Cooperation from management is a very crucial part when trying to implement a solid modeling system.

Lastly, the cost of implementing a solid modeling system is substantial. None of the employees interviewed seemed to think that the cost of off-site training was a deterrent. In fact, training is sometimes offered in a package provided by the solid modeling vendor. However, the "hidden" costs affect the company the most. As previously stated, AAC cannot afford to take one of its engineers off-line for the time period needed to learn a new system. Missing deadlines results in losing money and the possibility of the customer not returning in the future. In addition, the cost of hiring of a person to do fill-in work while an engineer is in training can be substantial. However, these costs have to be weighed against the benefits of implementing solid modeling.

One cost, which has been reduced in the past few years, is the cost of hardware and software. A typical solid modeling package costs much less than it did in the past. In fact, some packages cost 50% less than they did a few years ago. AAC has decided to change from Solid Designer to IronCAD for many reasons. One reason is that IronCAD comes with options in the basic package that would cost extra with Solid Designer. With the increased capabilities of the solid modeling systems, the hardware must be upgraded. At the time of the interview, AAC was considering purchasing new workstations. They were happy to find that they could purchase a "cutting edge" system, which will be more than adequate to handle the programs they are running, for less than $3000.

Overall, the largest setback to AAC Robotics seemed to be the lack of manpower. It is just not possible for them to give the engineers the time that they need using a solid modeler and become proficient with it. After all, someone who is not proficient with a system is not going to reap the benefits of the system.

Empire Precision Plastics Inc.
460 Oak St.
Rochester, NY 14608 USA

Company Overview

Empire Precision Plastics (referred to as: Empire) is a plastic injection molding firm with an in-house tooling design and manufacturing department.

The engineering department at Empire during the time of the interviews consisted of two engineers whose primary responsibilities were mold and tool design. The names and positions of the interviewees are listed in the Acknowledgements section. Solid modeling was introduced in the form of SolidWorks and has been used at Empire for the last two years. There are currently three out of the five CAD workstations in the organization capable of solid modeling. Not all of the workstations are being utilized at this time due to understaffing at Empire.

Training Methods

The vendor provided training for the use of SolidWorks. The engineers were satisfied with the training that they received. They were able to learn the program with relative ease; this was credited to the intuitiveness of the software. The knowledge gained from the vendor training was good enough to allow the engineers to carry out their day-to-day duties with the system with relative ease.

Recruiting and Advancement

The engineers said that if they considered recruiting another engineer, experience with and knowledge of a solid modeling system would be a large factor in determining that person's future at the company. However, due to the small number of employees at the company, experience with solid modeling does not affect the advancement rate of an employee.

File Management

Empire does make use of a PDM system to maintain its engineering files for their tooling and molds. They do not however have procedures for maintaining solid model files (electronic files) from customers. These files are typically stored away until needed or a customer sends a modified revision.

Operation and Use

The overall work flow at Empire has not been affected by the implementation of SolidWorks. SolidWorks does not have the capability to perform the functions necessary for Empire to increase its level of concurrent engineering. Since SolidWorks cannot create NC code, Empire is limited in how much they can do with this package. They are currently seeking a package that can handle their manufacturing needs. The engineers seemed to believe that with such a package, concurrent engineering and overall workflow in the organization would be affected greatly. In fact, the implementation of such a versatile package would eliminate the need for some of the manufacturing staff.

The engineers have had good luck with translating files in and out of SolidWorks. This allows them to import models from the various software packages that are used by their customers. The only problem they have encountered in data translation is in bringing in files from Solid Designer.

Technical Support

Empire receives software updates from SolidWorks on a regular basis. They are expedient in installing these updates into their system. The engineers rarely use any outside support for their system, however they did indicate that the telephone line help provided by

SolidWorks is quite beneficial. There is also personal support available, however Empire does not make use of it due to the cost.

Empire believes that SolidWorks keeps up with the advancements in technology of other packages in its price range. However, as indicated before, Empire's needs exceed the functionality that SolidWorks has to offer.

Communication

Due to the small number of employees and internal setup of the company, inter-departmental communication is not a primary concern.

Vendor Claims

The engineers at Empire believed that efficiency in design is determined by the amount of time that it takes to go from a design to finish tooling. Empire feels that in order to have optimum efficiency, their SM must be able to go from initial design, to a complete tool path, and then straight to automated manufacturing. If a software package can reduce the time to go through this process, then it has increased the efficiency of Empire.

Empire's engineers believe that a good solid modeling package is capable of reducing the time to develop a new product and the number of errors in a design. In mold making, the use of a solid modeler is very efficient. However, without the proper CAM components, the package is not doing all that it can for the company. The engineers stated that error reduction is a great benefit with solid modeling. Mistakes are far more apparent in a solid model than in a two-dimensional drawing. Such mistakes would require several revisions if the design were made in a two-dimensional package. However, with a solid model, these errors are easily detected and corrected.

Conclusion

Overall, Empire is not satisfied with their current solid modeler, SolidWorks. They are currently seeking a package with CAM capabilities to fully automate their entire manufacturing system. With such a package, a great time reduction and cost reduction would be achieved.

Empire is close to having full implementation of solid modeling in their organization. They rely heavily on solid modeling to create the molds for the injection molding process. Two-dimensional drawings are still used on occasion if the part is simple or if that is the format of the file provided by their customer.

For Empire, full implementation of solid modeling requires a package with more built in functionality than what they are currently using. Their current package, SolidWorks, does not allow them to create NC code. They currently have to use another package to create the NC code. This requires extra time and another employee to carry out this task.

Empire is currently evaluating such packages as Unigraphics and Pro/Engineer. These programs would allow them to create the NC code directly from the solid model. With this technology, the part could go directly from the solid model to the machining process.

Empire did not express any issues with the learning curve of their solid modeling package. They felt that SolidWorks was an intuitive package and they did not have any trouble with learning it. There was also no issue with the time commitment that must be made to implement a new package. They realize that the result of implementing a solid modeling package with more built-in functionality would far outweigh the costs associated with it.

When asked why they have only started looking for a more functional package now, and not previously when SolidWorks was first purchased, their response was cost. Several years ago, it was very expensive to buy a program such as Pro/Engineer with the add-ons necessary to create NC code. The prices have dropped considerably in the past two years, allowing the company to be able to afford this technology.

In conclusion, Empire is close to having a fully implemented solid modeling package. They are currently evaluating several programs and are hoping to change packages within the next few months.

GEMS Sensors Inc.
1 Cowles Rd.
Plainville, CT 06062 USA

Company Overview

GEMS Sensors (referred to as: GEMS) is a manufacturer of fluid level and flow indicators for original equipment manufacturers OEM, scientific, and test & measurement applications. The majority of GEMS' business is in new product design for applications in the OEM market. Product design and modification are done primarily in GEMS' engineering department.

The engineering department is divided into two major groups, level products and flow products. These two groups combined have fifteen engineers who are each responsible for a particular type of product. Solid modeling in the form of Solid Designer is used on two of the nineteen CAD workstations. GEMS has been a user of CAD in the form of ME10 for the past thirteen years, but has introduced solid modeling in the form of ME30 and later with Solid Designer. Solid modeling has been used at GEMS for the past five years.

Training Methods

The type of training that employees will receive depends upon their function within the company and their background. If an engineer will be extensively using the solid modeler then he or she will be sent to formal training from the vendor. If not, another employee will train him or her. GEMS has found that a combination of the two works best since the vendor training teaches the essential features and procedures, while the in-house training teaches more specific methods to satisfy specific needs of the company.

Recruitment and Advancement

Solid modeling experience is used as a criterion but not as a requirement when an individual is seeking employment or advancement at GEMS. For example if a drafter with 2D CAD experience learns solid modeling it is possible that he or she can advance into the position of product designer. The management believes that solid modeling experience is an important skill for any engineer or designer to possess. Knowing a particular solid modeling application is not critical either; the management feels that if one knows the basics of solid modeling, it makes it easier to learn a different solid modeling package.

File Management

Work Manager, a product data management (PDM) system from Co|Create, had been in place at GEMS prior to the introduction of solid modeling. However, the primary use of their PDM system is to maintain 2D CAD files. Solid Models may be stored in the PDM system but no procedure is in place or enforced to make sure it is done. The majority of the solid models are never updated when a revision or modification is made to the related 2D drawing.

Operation and Use

GEMS' primary use of solid modeling is for either new product design or major product modifications. In nearly all other cases, 2D CAD is used. The solid model data are also used for the creation of rapid prototypes for complex components and specialty designs. The engineers believe that the rapid prototypes aid in designing unique products quickly. These prototypes can also be used to create assembly aids, fixtures, and even preliminary production tooling. One engineer stated that solid modeling allows for an advantage in acquiring new company business. If two companies are competing for the same business, the one who can "bring more to the table" in terms of a final and/or working product has in most cases won. Other uses include printing 3D renderings showing the perceived product before it is actually produced. These printouts aid in sales negotiations, tool and fixture design, and even assembly of the products.

Technical Support

The current vendor of Solid Designer provides upgrades on a regular basis. However, the upgrades are installed either yearly or when problems arise. During the interviews, several engineers that use the application expressed that they felt that this is not frequent enough. They would like to see the upgrades installed as soon as they become available in order to fix bugs in the program as well as keep up with current technologies. On-line and telephone support is also offered by the vendor and is used quite often with much success. However, the solution to the problem is often to upgrade the software to the latest revision. Therefore, problems arise mainly due to the infrequency of the software updates. On-site help is also available but is rarely used due to the high costs involved.

The proposed solution to this dilemma, which was mentioned several times during the interviews, was to dedicate a person to the engineering department to support the CAD, solid modeling and other computer technologies. This engineering information technology (IT) person would be responsible for the upgrades, software, hardware, training, and interoperability issues exclusive to that department. He or she would also be responsible for working closely with the management information systems (MIS) department to ensure interoperability with other applications in the organization.

Communication

Although solid modeling has been at GEMS for quite a few years, the tool is somewhat limited within the engineering department. Solid modeling has been used very little to increase concurrent engineering or communicate data between various departments.

The only example to support interdepartmental communication is with a printout and/or rapid prototype of a component or assembly created from the solid modeler. During the interviews the majority of those interviewed stated that they realize the potential for using solid modeling, and plan on enhancing its influence thought the organization in the near future.

Vendor Claims

GEMS was unable to supply much information to prove the reduction of time and cost associated with the use of solid modeling. This is due primarily to the minimal implementation throughout the department let alone the entire organization. Instead, GEMS relies heavily upon the 2D drawings, even during the final stages of new product design. When asked to compare designing in 2D verses 3D, the conclusion from the all of those interviewed was that there is little difference in timesaving. The difference is in the result or final product. They believe that there is much more that can be done with the solid model than to create a 2D drawing. Such things would include rapid prototypes, NC machining, and analysis studies. GEMS is currently using solid modeling for all of these tasks.

Conclusion

In addition, the engineers stated that the solid models make errors and design flaws easier to detect, especially when individual components are assembled into the final product. The solid modeling also aids GEMS in increasing the overall aesthetics of their product's appearance.

Mott Corporation
84 Spring Lane
Farmington, CT 06032 3159 USA

Company Overview

Mott Corporation is a manufacturer of various liquid, liquid-solid, gas, and gas-solid filtration products and semiconductors. They also specialize in custom porous metal products. Of the ten engineers at Mott, only three are mechanical engineers and the rest are manufacturing engineers. The names and positions of the interviewees are listed in the Acknowledgements section. Solid modeling has only been implemented at Mott for four years. Mott uses CADKEY for their two-dimensional drawings and Pro/Engineer for their solid modeling program.

Training Methods

Training at Mott is provided, almost exclusively, by their vendor. It is the opinion of management that the training done by vendors cannot be done adequately by in-house employee-to-employee training. Furthermore, they feel that vendor training establishes a network with other companies that use the same solid modeler. This network can prove to be valuable since it allows Mott to see where its peers are technologically. Beyond vendor training, Mott tends to do little in-house training beyond one engineer occasionally asking another how to do a specific task.

Recruitment and Advancement

Experience with solid modeling systems is a criterion for selecting new employees at Mott. They have found that this is becoming increasingly true the more that they incorporate Pro/Engineer into the company.

File Management

Mott was in the process of incorporating Intralink, a PDM system made by PTC, at the time of the interviews. They had had Intralink for close to four months, and they were still in the process of getting it fully implemented on all of the workstations, as well as setting up all of the procedures necessary to use the program properly.

Due to the fact that Intralink hadn't been fully utilized, it was impossible to fully determine whether or not it would make a noticeable difference in design time or any other aspect of the manufacturing process. However, it was said that once the procedure was set and the engineers became more experience with the used of Intralink, that in the long run it should save time since all of the files would be saved in the correct places and all revisions would be updated automatically. The reason given for this was that the procedure for saving files on the PDM was so rigid and thorough that it would ensure that no mistake would be made, saving time later when it came time to make further changes.

The design engineering manager believes that installing a PDM will help create a powerful three-dimensional parts library in the future. However, until it is fully implemented and the engineers are familiar with it, the PDM will create a bottleneck that will slow down the transfer of files into the three-dimensional library. The structure that is built into the PDM is very rigid, in that files have to be stored in a specific way and a user cannot stray from the given format. This procedure takes time to set up, and the rigidity takes time to get used to. This is what creates the bottleneck. However, it is felt by those interviewed, that after the PDM is fully implemented, it will cause reductions in the time required to store and find files because they will be exactly where they are supposed to be.

Operation and Use

Mott still uses CADKEY for all of its two-dimensional drafting. Both of the engineers that were interviewed still found that they were faster designing complex mechanisms on two-dimensional CAD systems. This is primarily because of their degree of familiarity and experience with two-dimensional CAD systems, as opposed to the lack of experience with solid modeling CAD systems.

Conversion from two-dimensional to three-dimensional data posed a problem for Mott. A very large library of CADKEY files had been compiled over the years and most of the stock parts that they often used were still stored in only the two-dimensional library. Converting these files could take a long time because the design department is understaffed. The time required to convert the files would take away from the time to design new parts and would make it difficult to meet deadlines and make a profit.

Technical Support

Mott has a diligent MIS department that upgrades the revisions of Pro/Engineer frequently. The MIS department also does debugging and problem shooting, but often seeks help from online and telephone services. These services provide adequate coverage in order to keep the system going, but it often takes a good deal of time for the service representatives to solve the problem. It was mentioned that that the service providers know the programs very well, but do not know which programs have conflicts that may cause the system to crash.

Communication

Mott uses Pro/Engineer very little for concurrent engineering currently. Solid modeling has done little to change the workflow of the company. Mott plans to use

Pro/Engineer along with Webview to increase concurrent engineering within the organization. Webview allows solid modeling files to be viewed on computers in other departments that don't have Pro/Engineer.

While Pro/Engineer is used little for communication within the company, pictures created of parts and assemblies are often shown to customers. Solid models are easier to understand than two-dimensional drawings and give customers a better idea of the progress that is being made.

Vendor Claims

The engineers at Mott did notice a small amount of time savings, but it was not as drastic as they had hoped it would be. The engineers also noticed a reduction in mistakes made. They stated that, due to the nature of solid modeling, mistakes can be seen early in the design stage rather than after a prototype has been made.

Conclusion

In the future Mott hopes to be able to use Pro/Engineer to produce tool paths for NC machining as well as concurrent engineering. However, they were still in the process of implementing the programs necessary to do so when we interviewed them. Furthermore, the engineering department was understaffed at the time. The three mechanical engineers found it very difficult to keep up with all of the design tasks required of them and had little time to really gain familiarity with Pro/Engineer.

Mott Corporation has several issues that are currently preventing them from fully implementing solid modeling. The fist issue is the shortage of engineers in the design department. The second issue is the huge two-dimensional CADKEY parts library that would have to be converted to three-dimensional Pro/Engineer files.

At the time of the interview at Mott, there were three mechanical engineers working in the design department. According to those interviewed, in order to run efficiently, there had to be a minimum of five engineers. This forces the engineers that work at Mott to concentrate less on using the solid modeler to its full potential, and more on just getting the product ready for production. In turn, many parts are made exclusively with CADKEY because it is faster to use the standard parts already saved into the CADKEY library than to recreate them in three-dimensional part files.

A majority of Mott's standard parts were previously created and saved as CADKEY files. In order to fully implement the solid modeling system these parts would have to be modeled in Pro/Engineer. This would require an engineer to stop designing new parts and instead use his or her time to convert the files. This is just not feasible as Mott has deadlines to meet, and missing these deadlines would cost the company large amounts of money.

Overall, the largest setback to Mott Corporation seemed to be the lack of manpower. Without enough people to design their products in the first place, it is not feasible that the engineers could do the work required to fully implement solid modeler simultaneously. The company needs to evaluate the long-term benefits of having a fully implemented solid modeler, and decide if they are willing to make the short-term investment needed in order to realize those benefits.

Discussion

Introduction

We found from the interviews with the four companies that there are many problems involved with implementing a solid modeling package. Through the evaluation of these companies and how they are using their solid modeling programs, we observed that solid modeling implementation is a complicated issue. The main purposes of this study were to investigate the validity of the claims made by the solid modeling vendors and to see how these companies are using the solid modeling programs.

Time Reduction

The first claim made by CAD vendors was that a solid modeler could reduce the time to design a product. Although most of the companies that were interviewed do not use solid modeling exclusively for their new designs, the engineers gave some indication of a time reduction in their design cycle.

One way in which a solid modeler can reduce design time is by eliminating the complexity of making changes in a multi-view drawing. When designing in two dimensions, care must be taken to make the proper changes in all views, and to insure that there is no interference in all views of an assembly. When the part becomes complex, this task becomes more difficult. In two-dimensional designing, the engineer must work at a slower pace to ensure that no views are neglected. So, due to the better visualization provided by a solid model, a time savings can be realized. In addition, since the solid model drives its two-dimensional drawing, all the views are updated automatically when the model is changed.

The less experienced users of the solid modeling programs at all of the companies that were interviewed stated that there was not an overwhelming savings in time when designing in three-dimensions versus drawing in two-dimensions. This is because one still has to do all of the dimensioning and detailing of a multi-view drawing for manufacturing purposes. The solid modeling programs do not have the intelligence built in which would allow the designer to put all of the notes regarding machining, which includes adding tolerances, finishing notes, etc., into the model.

The more proficient users of the solid modeling programs at these four companies believed that the solid model definitely leads to a savings in time to design a product. This is due to their experience with the package and solid modeling as a whole. When a user naively designs using a solid modeler, he or she does not properly think out the modeling steps in advance. This is crucial to the design. It is far easier and faster to make changes to the model when the design intent is built into the model.

The solid model also saves time in design reviews by the various departments within a company. AAC Robotics noted that the time spent for design reviews is much less when the product is designed in a solid modeler. The justifying argument for this is the increased visualization provided by the solid model. A complicated assembly can be difficult to visualize, even for an experienced engineer, when designed in two-dimensions.

Lastly, the model can be used to make assembly drawings for the assembly floor, like at AAC. This allows the assembly workers to spend less time trying to figure out a complicated multi-view drawing. The solid model assembly is clear and easy to interpret. In the end, this will save the engineers' time because they are the ones who are questioned if an assembly worker does not understand the drawing.

Through these interviews, it was clear that there is some validity in the vendor claims of achieving time reduction by using a solid modeling program. There are various ways that companies can achieve a reduction in time. One way is to use the solid model in design reviews. The employees that were interviewed at AAC saw this as one of the greatest benefits of having a solid modeler. Another way is to use it for creating drawings to facilitate the assembly process. Lastly, time saving can be achieved with certain analysis packages that can be used with the solid modeling package. For instance, Empire Plastics saves time by using mold flow analysis to determine proper placement for the gates and knit lines in their molds. If the gates are positioned incorrectly then they have to be redone, which in turn wastes time. By making full use of the capabilities of a solid modeling system in the ways described above, timesavings throughout the organization can be realized.

Product Quality

Another claim by the solid modeling companies is that a company can see an increase in product quality by using solid modeling to develop their products. The companies interviewed do not have full implementation of their solid modeling programs, making it difficult to find information to justify this claim. However, the engineers did note some reductions in design errors.

The reduction in errors is mainly due to the improved visualization of the model. It is much easier to spot errors in a solid model than in a multi-view drawing. With the solid model, one can check for interference in an assembly. By animating an assembly, a visual check can be made to look for possible collision in the assembly. AAC Robotics used this feature and believed it was beneficial in detecting errors in the design stage.

The quality benefits that can be brought about by a solid modeling system are real. In the assembly process, using a three-dimensional assembly picture can reduce many errors that are associated with assembling complex components. For example, if two parts have a specific orientation to one another, it is easier to view this orientation with a three-dimensional model image. In some circumstances, the exact orientation of two parts may be unclear in a two-dimensional assembly drawing.

Solid modeling has been used by AAC to assist in concurrent engineering through the design reviews. The solid modeler enhances one's understanding of a complex assembly, thereby allowing one to have better input into the design. More input from different departments in an organization results in an increase in product quality. All companies using a solid modeler should take this approach to increase the quality of their products.

Quality benefits can be achieved by using add on programs that work with the solid modeler. AAC uses FEA on some of their designs to increase the quality of their products. Empire uses a mold flow analysis to determine the proper gating on their molds, which ensures a quality product. Such features as an animator to show the movement through the entire motion of a mechanism allow for a better quality product also.

Learning Curve

Lastly, the solid modeling companies claim that the learning curve for their products is small. However, from the interviews it seems engineers are finding it difficult to learn the programs. There are many factors that affect the learning curve of these programs.

One factor is the training approach. Some companies do not make use of vendor training. Some of the engineers believed that the vendor training was a good way to learn the programs, while others believed it was of little use. It was noted by three engineers at AAC that the best way to approach the vendor training is with an understanding of the program's basic functioning prior to attending the classes. This allows the user to learn the more difficult aspects of the program during the training, rather than focusing on the basic functionality of the program.

Another training method is to learn the program from fellow employees in the organization. This was a method used by all of the companies interviewed. However, our study revealed that there is no substitution for using the system. Hands on experience seemed to be the deciding factor in a person's proficiency with the solid modeling programs.

All of the companies who were involved in the interviews used different approaches to training. GEMS utilizes both outside training and inside training by fellow employees. The employee learns the basics of the program from outside vendor training. Fellow employees teach all of the specialized concepts of the program that GEMS uses often for their designs. They are happy with the results that they get from this combination in training.

Mott Corporation prefers to use strictly outside training. They feel that no one can teach the programs as well as the professionals. They claim this approach is the best approach.

AAC has used both off-site training and in-house training. They differ from GEMS in the sense that AAC believes someone should know the basics of the program, which are usually learned using the tutorial that comes with the program. All of the advanced techniques are learned through the vendor training. Upon completing that training, further assistance is given by fellow employees. Again, AAC is happy with this approach.

Empire uses the training supplied by the vendor. The rest of the learning process is self-taught by using the program. They feel this is all that is necessary because the software is intuitive and easy to use.

Conclusions

Overall, it appears that the claims made by solid modeling companies regarding a reduction in design time and an increase in design quality are real. Little can be said regarding the length of the learning curve. Companies must evaluate the benefits that can be achieved by implementing a solid modeling program, and tailor the program to their needs. Not every company will need an FEA program, analysis program or the ability to produce NC code. However, by realizing the power and potential that lies in a solid modeling package, a company can achieve design time reduction and an increase in design quality.

Conclusion

When this project first began, the intent was to determine the effect that solid modeling programs have had on small to medium sized manufacturing companies and to evaluate the claims made by solid modeling companies. After interviewing several employees from four companies that use solid modeling systems, we discovered that determining the effect on small and medium sized manufacturing companies might not be an attainable goal. None of the companies that were included in the project had fully implemented solid modeling throughout their organizations, making it difficult to analyze the effect that the solid modeling program had on these companies.

However, despite not being able to fully determine solid modeling's impact on these companies, we were able to determine the changes it made in the departments that did use it. We were also able to obtain information on why these companies were not able to implement solid modeling in the way that they had intended when they purchased it.

Although the solid modeling companies' claims are based upon companies that have fully implemented a solid modeling system, the validity of the solid modeling companies' claims were evaluated through the information gathered from the interviews. These claims proved to have some validity even for companies that do not fully utilize the capabilities of their solid modeling systems. While no quantitative documentation of time savings or improvements in quality was obtained through our study, the interviewees did agree that the solid modeler has led to a time savings and an increase in quality.

While our original goal may not have been completely fulfilled, useful information was gained. The gathered information from this study may prove to be useful to companies that want to acquire and implement solid-modeling systems in the future.

GLOSSARY

Associative geometry

A system that allows the user to locate newly defined graphic elements based on a relationship (for example, parallelism) with existing graphic elements. Elements placed associatively maintain the relationship when the existing graphic element is manipulated.

Boolean Operation

"Finding the union (addition), differences (subtraction), or intersection (common area) of two or more…"[45] solid objects.

Boundary Representation (B-rep)

A CAD database that uses Boolean functions to join objects and stores the resulting combination as a set of faces, edges, and vertices. [46]

Constructive Solid Geometry (CSG)

A CAD database that stores both the solid primitive and the Boolean operations that join them in a tree structure.[47]

DXF

A method of exchanging electronic drawings. This is a format defined by AutoDesk. It also communicates simple geometry based data between CAD/CAM packages. Typical data contained in this file type are in two-dimensional drawing or text form. Unfortunately DXF is not standardized and changes from release to release causing data transfer problems.[48]

Feature Based Modeling

Performs functions that were previously performed using primitive Boolean operations. Example: A through-hole could be defined using a Boolean difference operation and a cylinder of sufficient length. However, if the design became thicker and the cylinder was not long enough, the hole would become a blind hole. In

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[45] (Lockhart 1999, 604)
[46] (Machover 1996, 72)
[47] (Lockhart 1999, 195)
[48] (Time Compression Technologies. Volume 4: Issue 6)

contrast, the through-hole feature understands the rule that it must pass completely through the part and will do so not matter how the part changes.[49]

GUI

Computer-generated Graphical User Interface consisting of windows, icons and menus.

Hybrid

A solid modeling system that incorporates both CSG and B-rep methods in order to utilize the benefits of both methods. Commonly CSG is represented in the database while B-rep is used for display purposes.[50]

IGES

Initial Graphics Exchange Specification (ANSI Y14•26M standard [1.9] and [1.10]) is a file format that allows standardized exchange of files from one CAD/CAM package to another. This file type is monitored by specific regulations to make it universally readable without having complex translator software for each specific application. An IGES file contains essential engineering data such as physical shape and dimensions that are common to the majority of the packages on the market.[51]

Interoperability

Related to the examination of the information exchange between two specific CAD systems, and the ability of each CAD system to use such information.

ISO

International Standards Organization

Kernel

A computational engine built into the CAD "software to perform basic functions such as Boolean operations, blending, mass properties, exporting of geometry, and chamfering and filleting."[52]

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49 (Lockhart 1999, 211)
50 (Machover 1996, 72)
51 (Lockhart 1999, 198)
52 (Lockhart 1999, 198)

Kernel-based architecture

A GUI design in which the windowing services are provided by some proportion of the operating system itself or by a standard add-on module that resides along with the operating system in RAM or ROM based libraries. This provides high levels of interactivity, but with dependency on the architecture and available resources of a single computer.

Parametric CAD system

A type of modern CAD system that relates the geometry of different elements of a product. When the designer or user changes one element, the geometrically related elements of the product change as well.

Primitive

"A simple 3D shape, such as a box, cone, sphere, or torus, that can be combined to make more complex shapes."[53]

STL

Stereo Lithography is a file type used to export 3D surface geometry to rapid-prototyping systems or numerically controlled machines. STL transforms the surface of the object into triangular facets.[54]

Variational geometry

A method of representing a solid model as a set of inter-related equations defining its shape and dimensions. Variational geometry is based on a set of equations that are solved simultaneously, as opposed to parametric geometry where the equations are solved sequentially.[55]

Volumetric solid modeling

The use of solid models that are defined by spatial samples rather than geometric shapes defined mathematically.

Wireframe

A technique used to display an object as a framework of lines (as opposed to shaded surfaces). On most computers, objects displayed in wireframe can be rotated interactively. Wireframe is typically the default display style, and is a modeling method for both 2D and 3D CAD.

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53 (Lockhart 1999, Glossary)
54 (Lockhart 1999, Glossary)
55 (Mackrell 1996, 72)

BIBLIOGRAPHY

[1.] Aaas, Einar J. and Tore Steen. "Quantifying Design Quality Through Design Experiments". IEEE Transactions on Engineering Management. London, Spring 1994.

[2.] Berg, Bruce L. Qualitative Research Methods For The Social Sciences.(Boston, Allyn and Bacon, 1998)

[3.] Bulkeley, Debra, Spatial Technology changes the cost/benefit equation in CAD/CAM/CAE". (Design News, Special Supplement "3D Modeling", Spring 1999).

[4.] Cohen, Fink, Gadon, and Willits, Effective Behavior in Organizations , Cases, Concepts, and Student Experiences, 6th Ed. (Boston, McGraw-Hill 1995).

[5.] Design News, Heroes of CAD. (Design News, Special Supplement "CAD/CAM/CAE, & PDM", July 19, 1999).

[6.] Estes, W. Eugene and Arnold M. Ruskin, What every Engineer should know about Project Management, (New York, Marcel Dekker Inc. 1982).

[7.] Feischer, Mitchell and Jeffery K. Liker, "The Hidden Professionals: Product Designers and Their Impact on Design Quality." IEEE Transactions on Engineering Management. London, August 1992.

[8.] Gaynor, Gerald, Achieving The Competitive Edge Through Integrated Technology Management (New York: McGraw-Hill, 1991).

[9.] Harrison, Michael I., Diagnosing Organizations, 2nd Ed., (London, SAGE Publications, 1994).

[10.] Klingsheim, Karl and Einar J. Aas, "Modeling Design Quality. "Proceedings R&M DAE in Concurrent Engineering Workshop. 1991.

[11.] Kita, Tarou.:"Using 3D CAD for Improved Prototyping Efficiency." Time-Compression Technologies. Volume 5, No. 2

[12.] Leong, Alan and Robert P. Smith. "Is Design Quality a Function of Time". IEEE Transactions on Engineering Management. London, Spring 1996.

[13.] Lockhart, Shawna D. & Johnson, Cindy M., Engineering Design Communication: Conveying Design Through Graphics. (Reading Massachusetts, Addison-Wesely, 1999).

[14.] Machover, Carl, The CAD/CAM Handbook, McGraw-Hill, New York 1996.

[15.] Mendel, Alan, PDM and the Internet. (Mechanical Engineering; September 1999).

[16.] Miller, Ed.:" Coherent Data Management – Using PDM." Time-Compression Technologies. Volume 4, No. 5

[17.] Noaker, Paula M., Cam's Solid Modeling Connection. (Manufacturing Engineering; November 1996).

[18.] Norton, Robert L. Design of Machinery, 2nd Ed., (Boston, McGraw-Hill, 1999).

[19.] Smith, Robert P.: "Concurrent Engineering –its procedures and pitfalls." IEEE Transactions on Engineering Management. London, October 1993 .

[20.] Smith, Robert P.: " The Historical Roots of Concurrent Engineering Fundamentals". IEEE Transactions on Engineering Management. 67. London, February 1997.

APPENDICES

Appendix A

Solid Modeling Application Evaluation Forms

Appendix B

Trip Report

- Automation Manufacturing Exposition
- New England Pro/Users Group Meeting
- New England HP Co|Create Users Group Meeting

Appendix C

Interview Question Sheet

Appendix A

Solid Modeling Application Evaluation Forms

CADKEY 98 Design Suite – Baystate Technologies

IronCAD – Visionary Design Systems

Mechanical Desktop 4.0 - AutoDesk

Pro/Engineer 2000i – Parametric Technologies Corporation (PTC)

Solid Designer – Co|Create

Solid Edge – Unigraphics Solutions

Solid Works – Solid Works

Unigraphics – Unigraphics Solutions

CADKEY 98 Design Suite

Developer

Baystate Technologies

Vendors

Baystate Technologies

Overview

Kernel

ACIS 4.2

Geometric Model Type

Parametric

Import/Export Capabilities

IGES, SAT, STEP, STL, VRML, DXF, DGW, CADL

WMF, BMP, TIF, HPGL

Operating Systems & Platforms

Microsoft Widows 95, 98, Windows NT 4.0 or greater

System Requirements

Pentium class or greater processor
CD-ROM drive
64 MB RAM Minimum Recommended
95 MB Hard Disk Space
VGA (256 color) or better supported by Windows NT, 95, 98 or greater

Estimated Price

$3995

Unique Features

FastSURF

Surface modeling tool for creating complex, freeform surfaces. Contains surface and spline editing tools that create and analyze surface vectors and planes.

DRAFT-PAK

A library of fasteners and commonly used features used to speed up design process.

User Interface Review

CADKEY's GUI is a Windows based GUI that is very icon based and simple to use.

Comments

CADKEY's low price reflects its lack of features. CADKEY does not include all of the sheet metal, tubing, or plastic design packages as many other packages do. It is just a basis solid modeler. CAE and CAM programs have to be purchased from other companies and each differ in price according to their capabilities and if they are fully associative with CADKEY.

Evaluated / Updated By

Name: Peter Duperry	Date: 10/9/99
Name: Peter Duperry	Date: 10/11/99
Name: Peter Duperry	Date: 11/3/99
Name:	Date

IronCAD

Developer

Visionary Design Systems, VDS

Vendors

Visionary Design Systems, VDS

Overview

Kernel

ASIS 5.0
Parasolid

Geometric Model Type

Parametric

Import/Export Capabilities

3D CAD
IGES, SAT versions 1.5 – 5.0, STEP, STL, VRML 2.0

3D, 2D, Image Data
3DS, AVI, BMP, COB, DXF, DWG, EPS, GIF, JPEG, Kodak Photo CD, OBJ, POV, PCX, PNG, TGA, TIFF, Visual Basic Text, WMF

Operating Systems & Platforms

Microsoft Widows 95, 98, Windows NT 4.0 or greater

System Requirements

Pentium class or greater processor
CD-ROM drive
64 MB RAM Minimum Recommended
95 MB Hard Disk Space
VGA (256 color) or better supported by Windows NT, 95, 98 or greater
Support for OpenGL accelerated graphic hardware

Estimated Price

$5,000 – $6,000
$2,000 Special, expired 9/30/99

Unique Features

TriBall

A virtual interface tool that dynamically positions faces, features, parts, and assemblies

Smart-Snap

Virtual interface tool that allows users to automatically snap to reference features and locations on a basic shape or surface. This eliminates the operation of selecting endpoints, intersections, centers, and midpoints in most cases.

Shape Catalog

Built-in reference library of commonly used shapes and features that can be "dragged and dropped" into the work environment. Can also store custom parts and features such as bolt hole circles, slots, bolts, gears, and sheet metal components.

Direct Flow Architecture

First new solid modeling architecture in a decade. This architecture allows for the use of two kernels to be used at the same time.

Intellishape

Modeling feature that automatically recognizes basic shapes and geometry profiles in the solid model.

User Interface Review

IronCAD makes extensive use of a windows based Graphical User Interface (GUI) that is similar to that used by Solid Works, Solid Edge, and Pro/Desktop. This interface incorporates the typical point and click style command buttons but also incorporates a unique concept. The program eliminates the majority of the menu list commands and inputs. These commands are replaced with a virtual tool called a TriBall. The TriBall creates a local coordinate system on a defined object. Using the mouse to activate various elements on the TriBall controls this tool. Then by dragging or rotating the TriBall commands are implemented. Other unique interface features are the auto-snap and feature recognition abilities. They simplify user interaction and the use of the solid geometry "handles" that allow the user to stretch a part in real-time to change size or to change its position in space.

Comments

IronCAD is similar in many aspects to the competitor applications in the Windows Operating System environment. The real difference in this application is the focus on design, rather than learning how to use the application. The interface is simplified to the point where creating a new model is a simple drag and drop operation, rather than spending time to setup datum planes and relations. With this in mind, IronCAD may be suitable for other fields such as marketing and graphic design.

Recommendations

IronCAD is still new in the geometric modeling market. The product is only beginning to develop based on customer interaction and recommendations. Dropping everything and switching over to IronCAD may not be an answer to current solutions but may eventually be the best choice in the future based on the new design based features.

Evaluated / Updated By

Name: Jeremy Baillargeon	Date: 10/9/99
Name: Jeremy Baillargeon	Date: 11/3/99
Name:	Date
Name:	Date

Mechanical Desktop 4.0

Developer

AutoDesk

Vendors

Overview

Kernel

ACIS 5.0

Geometric Model Type

Parametric

Import/Export Capabilities

DWG, DXF™, DWF, IDF, STL, EPS, BMP, WMF, SAT, VDA-FS, and VRML

Operating Systems & Platforms

Windows 95/98/NT

System Requirements

Training: Pentium II processor, 96MB RAM,
Part modeling: 300MHz Pentium II processor, 128MB RAM,
Assemblies: 300MHz Pentium II processor, 256MB RAM

Estimated Price

Unique Features

User Interface Review

This program is Windows based with icons and pull down menus. A design tree charts the modeling history.

Comments

Mechanical Desktop 4 is a solid modeling package produced by AutoDesk. It operates on a Windows platform (Windows 95/98/NT). A main feature of this program is Assembly Centric Design. This allows the designer to edit blocks and external files directly from the assembly drawing. This program also allows the designer to open multiple drawings in the same session, therefore eliminating the need to open multiple programs. This allows one to copy and paste between drawings with great ease. Mechanical Desktop 4 use the ACIS 5 kernel. This allows greater model complexity with the use of blends sweeps and lofts. The program also allows for breakout section views and radial section views. Mechanical Desktop can also automatically generate detailed, bi-directionally associative views such as aligned, orthographic, isometric, auxiliary, section, partial section, offset section, isosection detail, broken, and user-defined.

Multiple file types can be both imported and exported. A time saving device, which is optional, is the Power Pack. This is a library of over 800,000 2D and 3D parts such as keyholes, screws, nuts, washers, steel shapes (such as U-,I-, T-, L-, Z-shapes). Screw Connection allows the user to select holes, nuts and washers based on the screw size selected. Mechanical Desktop 4 can also calculate the load and life ratings of bearings and calculate the correct screw size depending on the forces applied. Other features are FEA, Shaft Generator, Spring Generator, Belt, and Chain Generator. AutoDesk claims that the users generally see a 30% savings in design time with the use of Power Pack.

Recommendations

N/A

Evaluated / Updated By

Name: Anthony Gentile	Date 10/11/99
Name:	Date
Name:	Date
Name:	Date

Pro/Engineer 2000I

Developer

Parametric Technologies Corporation

Vendors

Parametric Technologies Corporation

Overview

Kernel

Parasolid

Geometric Model Type

Parametric

Import/Export Capabilities

3D, 2D, Image Data

AVI, BMP, COB, DXF, DWG, EPS, GIF, JPEG, Kodak Photo CD, COB, POV, PCX, PNG, TGA, TIFF

Operating Systems & Platforms

Microsoft NT 4.0, Microsoft Windows 95/98, Unix

Minimum System Requirements

Pentium processor
2Gb Hard Drive space
S3 Compatible Graphics card
Open GL Graphics card
Microsoft TCP/IP
Ethernet Network Adapter
Microsoft 3 Button Mouse
CD ROM
Monitor (Min: 1024 X 768 resolution and 256 colors)
(Some modules will not run on Microsoft Windows 95/98 workstations)

Estimated Price

Unique Features

Behavioral Modeling Extension (BMX)

BMX is a feature that enables engineers to optimally drive their product development through captured design requirements and goals.

Pro/Intralink

Pro/Intralink is a feature that enables users across an enterprise to access and control Pro/ENGINEER models via the Internet through interactive Web pages.

Plastic Advisor

Plastic Advisor simulates mold filling for injection molded plastic parts.

Routed Systems

The Routed Systems Option offers associative capabilities, and libraries, for electrical, cabling, and piping design.

Pro/NC

Pro/NC is an extensive CAM package that allows the user to create tool paths for several type of automated manufacturing processes.

User Interface Review

Unlike many other CAD packages that are designed for use in a Microsoft Windows Operating System, Pro/Engineer does not have the same familiar Windows UI. It is similar and not overly complicated but its use of pull-down menus rather than the familiar toolbars common in Windows take time to become accustomed to. Furthermore the pull down menus often give so many options that the user can easily get lost in them and forget which option to choose in order to accomplish the task at hand. Overall, with some getting used to, the UI is bearable.

Comments

Pro/Engineer is truly a concept to production CAD package. With all of the modules the user can design, analyze, and manufacture a part with fully associative programs that allow seamless integration between them. However, the software is not easy to learn and requires expensive hardware to use, but is worth the money for a company that starts with a concept for a part and follows through to the end of its production. Furthermore, Pro/Engineer is fully parametric; it tends to be very rigid when constraints are placed on geometry of a part. Often the user will find that the program has constrained a part of geometry that conflicts with the design intent and must then modify the model in a way that will avoid such a conflict. This rigidity does have its benefits though, in that it prevents under-constrained parts that could prove problematic later in the design.

Recommendations

Pro/Engineer may not be well suited for smaller companies focus strictly on the design of a part. Other CADs can accomplish the same designs without the large startup costs and training periods.

Evaluated / Updated By

Name: Peter Duperry   Date: 10/11/99
Name: Peter Duperry   Date: 10/12/99
Name: Peter Duperry   Date: 11/3/99

Solid Designer 7.1

Developer

Co|Create, HP

Vendors

Co|Create
Mission Systems

Overview

Kernel
- ACIS

Geometric Model Type
- Solid, no history tree

Import/Export Capabilities
- 3D CAD Import
  - IGES 3D 5.3, STEP A9203 & AP214, VRML
- 3D CAD Export
  - ACIS SAT 1.5 & 3.0, IGES 3D 5.3, STL, VRML 2.0
- 2D, Image Data
  - MI (ME10's native data format), IGES 2D, DXF (via MI-Translators)

Operating Systems & Platforms
- Microsoft Windows NT 4.0 or greater
- HP-UX 10.20
- SGI – IRIX
  - 6.2 (Indy & Indigo2)
  - 6.3 (O2)
  - 6.4 (Octane)
  - 6.5

System Requirements
- Windows NT
  - 128 MB RAM
  - 370 MB Hard Disk Space
  - CD-ROM Drive
- SGI
  - 128 MB RAM
  - 410 MB Hard Disk Space
  - CD-ROM Drive

HP

128 MB RAM
330 MB Hard Disk Space
CD-ROM Drive

Estimated Price

$8,000, price fluctuates depending on modules

Unique Features

N/A

User Interface Review

The user interface depends on what version of solid designer that is run. The current version 7.1 runs in a Unix platform or in a Unix shell on a Windows NT workstation. Users typically have the option of selecting commands from command buttons and onscreen menus or from drop down type menus. This seems to organize the command locations well. Either most of the commands are "on" or "off" type rather than "multiple choice". Running in a Unix shell becomes troublesome when trying to print or move files. Printing is only possible when done through a separate application named "Exceed", which copies a windowed on-screen image to the printer. File transfer is done through either Windows Explorer or a PDM such as Work Manager.

Comments

Solid Designer is currently in a transitional phase in product development and company structure. Recently one of their main distributors, Visionary Design Systems broke off partner relations with Co|Create to develop their own solid modeling package, IronCAD. To compensate for this, Co|Create must redistribute it's sales force and offices to fill in the missing gaps across the regions. The other partner that is still in good relations with Co|Create is Missions Systems, and will be the main secondary support organization for Solid Designer. Co|Create itself will expand internally to compensate for loss.

Newer releases of Solid designer 8.0+ will be focused on the Windows NT platform. It will include a similar user interface but also will include the typical Windows interface and OLE abilities. ME10, Co|Create's 2D drafting application, will also be moving to the new

Windows environment in version 9.0. These drastically new changes will take place in the later part of 1999 and the earlier part of 2000.

The main disadvantage of Solid Designer is the lack of features that come with the base package. Co|Create is more than willing to sell these add-ons rather than making them part of the package. This can become costly; depending on what capabilities the user would like.

Recommendations

Co|Create is putting a lot of emphasis on maintaining competition on the Windows application market. The new releases are somewhat similar to the current Solid Works and Solid Edge user interfaces but they still maintain many of the current style Unix command menus. This allows for easier transition from the Unix to NT platforms for most users. The other reason for this is many of the current customers of Solid Designer in Europe operate Linux operating systems, which is similar to the Western style Unix platforms. For this reason Co|Create will support the new user interface and the current Unix version as well

Solid Designer is an application that can handle large amounts of data well. This is due primarily to the absence of a model or history tree that is typically associated with solid models. To compensate for this, Solid Designer has a well-designed feature recognition capability.

Evaluated / Updated By

Name: Jeremy Baillargeon	Date: 10/13/99
Name:	Date
Name:	Date
Name:	Date

Solid Edge V7

Developer

Unigraphics

Vendors

Overview

Kernel

Parasolid

Geometric Model Type

Parametric, feature based

Import/Export Capabilities

Operating Systems & Platforms

Windows 95/98/NT

System Requirements

Estimated Price

$4995

Unique Features

- Xpres Route tubing package
- Plastics package

User Interface Review

This product is a Windows based package that is icon based. It uses a design tree to document the modeling process.

Comments

Solid Edge is a mid-ranged CAD package from Unigraphics Solutions, which is a Windows based program. A main feature of this package is STREAM technology. STREAM technology is the structure of Solid Edge and it allows optimization of workflow efficiency. Unigraphics claims that the STREAM technology makes Solid Edge so easy to use that most people need little or no classroom time to learn how to use the program. Solid Edge also claims a 45% reduction in mouse clicks, a 57% reduction in keystrokes, and improved productivity by 36% as compared to similar programs on the market. Unigraphics also claims that the transition from 2D to 3D is made easy and the training time is very short.

Solid Edge creates 3D models by three methods, sweeping, extruding or by revolving 2D profiles. Solid Edge is based upon Parasolid (kernel) core technology and can be used with any Parasolid-based CAD/CAM/CAE system. Solid Edge has concurrent assembly access, which means that multiple designers can work on the same assembly and they have instant access to the changes made by the other designers. There is a feature that explodes the assembly drawing but keeps the parts in the same orientation with respect to each other. Interpart relationships can be defined by commands such as mate, align, connect, ground and angular.

Multiple view drawings are automatically created when the part is modeled in 3D. From their views such as isometric and section views are generated from commands in the tool bar. When an individual part in an assembly is changed, it automatically updates the part in the assembly. The part can also be modified in the assembly view. If this is done, the part model and drawing are automatically updated to reflect the changes made in the assembly model.

Solid Edge also includes additional features that ease the design of sheet metal parts, tubing, and plastic parts. Solid Edge Sheet Metal allows the user to construct a sheet metal design in 3D and then flatten it out to the correct shape for manufacturing. It also has a special feature that automatically picks the points for bend and corner relief cuts. The tubing option called XpresRoute will automatically generate all of the paths that a tube can follow when the two end points for the tube are chosen. This allows the designer to see the different options available for the tube path. The user can also define a path for a tube to follow too. Then the program will check for interference between the tube path and the model. Plastic parts are easier to design with the help of tools for creating lips, parting lines, ribs and webbing. There are also tools for mold creation which define parting angles, add draft angles and shrink factors. It also allows the user to create mold cores and cavities directly from the part. Solid Edge also creates 2D drawings from the 3D model created by the user. When a dimension or feature is changed in the 3D model, the changes are automatically made in the 2D drawings.

Recommendations

N/A

Evaluated / Updated By

Name: Anthony Gentile	Date
Name:	Date
Name:	Date
Name:	Date

Solid Works

Developer

Dassault Systems S.A. (NASDAQ:DASTY)

Vendors

Overview

Kernel

ACIS and Parasolid

Geometric Model Type

Parametric, feature based

Import/Export Capabilities

DXF/DWG, STEP (AP203), IGES, ACIS (R1.7 and 2.0), STL, ACIS, VDAFS (VDA), TIF, VRML, Pro/Engineer files

Operating Systems & Platforms

Windows 95/98/NT

System Requirements

90MB of hard disk space, minimum RAM required is 64 Mb, Pentium 100 or greater.

Estimated Price

$3995

Unique Features

- Solid Works animator
- Photoworks
- Featureworks

User Interface Review

This program is Windows based with icons and pull down menus. A design tree documents the history of the model.

Comments

Solid Works contains an AutoCAD Command Line Emulator that makes it easy for the user to move from AutoCAD to Solid Works. This will help cut down the learning curve and transfer time moving from AutoCAD to Solid Works.

Section views of a drawing are easily created, eliminating the hassle of copying and editing parts of the drawing. Dimensioning is very easy, fast, just select the object to dimension, and Solid Works automatically dimensions it. If a change is made in any of the views, top, bottom, side, or 3D, the change is automatically carried throughout all of the rest the views, including the dimensions and assembly. This saves a great amount of design time and allows for better and faster engineering of designs.

Another feature of Solid Works is the ability to animate an assembly. A Collision Detection tool allows the user to spot any interference in an assembly. Solid Works also includes sheet metal design capabilities that allow the part to be drawn in 3D or flat.

Recommendations

N/A

Evaluated / Updated By

Name: Anthony Gentile	Date 10-11-99
Name:	Date
Name:	Date

Unigraphics

Developer

Unigraphics Solutions

Vendors

Unigraphics Solutions

Overview

Kernel

Parasolid

Geometric Model Type

Hybrid

Import/Export Capabilities

3D CAD

IGES, STEP, STL, DXF, CATIA

3D, 2D, Image Data

CADDS

Operating Systems & Platforms

System Requirements

Estimated Price

Additional Features

Animation and analysis modules, photo quality rendering, 2D drafting package, Assembly and component design, PDM software, Parts libraries, Rapid prototyping, and an extensive CAM package.

Unique Features

UG/Features Modeling

A module that contains parametrically defined features that are commonly used, such as several varieties of holes slots, pockets, chamfers, etc.. The module also has the ability to hollow out solid models to make thin-walled objects.

UG/Freeform Modeling

A module that aids in the creation and analysis of complex shapes like sweeps and curves.

UG/Mold Wizard

A module that contains tools for plastic mold design.

UG/CamBase

An extensive CAM package that include separate modules for creating tool paths for many types of machining processes such as NC machines, lathes, variable-axis milling, etc.

User Interface Review

A Windows based GUI. Simple to use and operate.

Comments

N/A

Recommendations

N/A

Evaluated / Updated By

Name: Peter Duperry	Date: 10/10/99
Name: Peter Duperry	Date: 11/3/99
Name:	Date
Name:	Date

Appendix B

Trip Report - Automated Manufacturing Exposition

Trip Report - New England Pro/User Group Meeting

Trip Report - HP Co|Create Users Group Meeting

Trip Report

Event

Automated Manufacturing Exposition

Date

October 6, 1999

Location

Worcester Centrum Centre
Worcester, Massachusetts

Persons Attending

Peter Duperry
Jeremy Baillargeon
Anthony Gentile

Objective

The objective of the Automated Manufacturing Exposition was to be an event that gathered the management and engineers from local manufacturing businesses and exposed them to the latest technologies in automated manufacturing. At this event many seminars and workshops were provided to "create a learning environment and promote the common business interest of users and suppliers of automated machinery, parts and services." A multitude of exhibitors had booths where information and demonstrations were given to anyone that was willing to listen.

Events

We did not attend any of the scheduled seminars as they were discussing topics that were not related to the information that we were seeking. Instead, the three of us sought out CAD vendor's to obtain information from something other than a web page.

Our first stop was at the Unigraphics Solutions booth. There we met Brian Flynn and Christian Paulsen from Pyramid Solution, Inc. Brian and Christian were in charge of demonstrating the Solid Edge CAD package. We discussed many topics with Brian and Christian who seemed more than willing to answer our questions and demonstrate how Solid Edge worked. From Brian and Christian we learned that Solid Edge uses the Parasolid kernel and we discussed the some of the benefits of using Parasolid rather than Asis.

From looking at the Graphic User Interface (GUI) it was obvious that Solid Edge's GUI was designed to look and operate much like that of Microsoft Windows. There were several toolbars, both on the top of the screen, as well as on the sides, which allowed for simple point and click operation. While watching Christian demonstrate drawing a few shapes it was apparent that these toolbars cut down on time greatly when compared to pull down menus.

After watching a few demonstrations of Solid Edge's more interesting features such as its piping, and sheet metal tools we were shown a study, done by an outside service, which compared Solid Edge, SolidWorks, Mechanical Desktop and another comparably priced CAD. This study showed Solid Edge to be faster, using less time, mouse clicks and keystrokes than the other programs. Brian also told us that the Solid Edge website had more case studies and reviews that we could look at to compare the packages.

Once we were done listening to Brian and Christian's sales pitches we moved on to the CADD Edge booth. There we met a salesman who was slightly less enthusiastic than those at the Solid Edge booth but still informative. From him we learned that Solid Works uses both the Parasolid and the Asis kernels, giving it slightly more flexibility. The GUI looked very much like that of Solid Edge's and from the few demonstrations provided, it seemed as easy to use as Solid Edge seemed. The salesman informed us that many of the people that developed Solid Works worked for other top CAD companies in the past and "brought there experience and expertise with them." Whether or not this translates into a better program isn't apparent from the simple demonstrations that we have seen.

We told the salesman that we had just talked to the people at the Solid Edge booth so he showed us how similar they were. He, of course, spent a good deal of time trying to convince us that Solid Works was superior to Solid Edge so we decided to move on to the next booth.

The next CAD related booth that we came to was Computer Aided Products, another Solid Works vendor. The salespersons at this booth stressed mainly that Solid Works claims to take less time to learn than other CAD programs do. Little more information was obtained from this booth because the Exposition ended while we talked.

Products/Vendors

We talked to only three of the hundred or so Vendors that were present at the exposition. Brochures and handouts of the following companies are available.

Pyramid Solutions, Inc., www.pyramidsolutions,com

Unigraphics Solutions' Solid Edge, www.solidedge.com

CADD Edge Inc.
Vendor of CAD software, hardware and services

Computer-Aided Products
Vendor of CAD software, hardware and services

Conclusions & Recommendations

The Automated Manufacturing Exposition provided some useful information about Solid Edge and Solid Works. I personally got a better understanding of the GUI that the two programs use, as I have never used either. Most of the other information that the Vendor's conveyed to us were things that we could have found on their WebPages, but overall I feel that I have a better understanding of the two programs than I did previously.

The one recommendation that I can give is mainly a reminder for me to be sure to take notes on the next such trip so that more information can be retained and conveyed.

Trip Report

Event

New England Pro/User Group Meeting
http://www.neprouser.org

Date

October 7, 1999

Location

Massachusetts Bay Community College
Wesley, Massachusetts

Persons Attending

Jeremy Baillargeon

Objective

The NE Pro/User group meeting is intended to be an event that gathers local users of products produced by Parametric Technologies Corporation (PTC). At each of the events several presentations are given to demonstrate new products, address old concerns, and demonstrate new features and techniques. It also allows other users to communicate with each other and exchange ideas and comments about products and other issues in the field and give feed back to PTC to enable better product development. In other words, it's a way of finding the "voice of the customer".

Events

The agenda varied from the program due to several unforeseen events. However all the scheduled events did take place during the day. It began with a presentation demonstrating the new features of Intralink 2.0, and then followed by a keynote address regarding future product development. Then a final demonstration was given on a rarely used feature of Pro/Engineer. After the assembly, there was a vendor show and several "break-out" sessions and mini-presentations.

Intralink 2.0 is a product data management (PDM) application that is replacing PTC's former application, Pro/PDM. The new program allows users to manage solid models, parts, and assemblies in a "voting" type manner. When a project is initiated or implemented it needs certain approvals and authorizations before moving from one sign stage to the next. Intralink provides that ability by putting hold, restriction, and authorizations on various items. Intralink is an option for a Pro/Engineer PDM system but is not the only one that is compatible.

Liz Carnahan, vice president of Engineering research and development at PTC, gave the keynote address. Her presentation regarded several items concerning product releases, product enhances, performance improvements, and future developments. Some important items she addressed were the incredible increase performance and features in the new product releases due to new C++ and GUI interfaces. She also mentioned a new term, "Y2K Freeze". According to her, some companies are putting a freeze on purchasing new products or upgrading existing products now due to the Y2K issue. Companies want to make it past the first of the year and then begin new upgrades in the later part of January and into February. This puts the focus of new releases into the first quarter of the year 2000.

Kristen Resca gave the final demonstration from Integen. She demonstrated the merge feature in Pro/Engineer. The merge feature has several advantages that allow the user to relate various components and relate the two with constraints without drawing individual parts.

Products/Vendors

Being a Pro/User group show, there was little focus on PTC advertising since most of the attendees were already sold on the product. However, the majority of the vendors offered services or add-on modules that interface with the PTC products. Only a few vendors attending offered products that fit context of the IQP topic. Brochures and handouts of the following companies are available.

Immersive Design, http://www.immdesign.com

Product visualization and animation application for communication and analysis

Prescient technologies, Inc., http://prescienttech.com

Product deals with quality of documentation and exchange

Conclusions & Comments

The overall road trip and convention provided little in vendor information. It did however produce some valuable PDM knowledge for the Pro/Engineering environment. The vendor show also provided little direct information as mentioned above. It was hoped that more emphasis on application performance would have been covered. The event was however, as expected, directed towards people already sold on the product, so little effort was given comparing it to the competition.

The flow of the operation was rather choppy and somewhat one-sided. Since the meeting was only possible through support by vendors and grants from PTC, there was a lot of favoritism going on. Especially directed towards the VP from PTC. Most of the users observed were they very rude and had egos bigger then can be imagined. As if showing off their expertise as a Pro/E wizard was the only reason for attending the event at all.

On a final note, the products from PTC still seem more complicated then they need to be. The user interaction still requires a broad knowledge of the command locations and the internal structure of the options due to its text based menu system. This is illustrated through the majority of the products displayed, including Intralink. It was intriguing that this issue did not arise during the discussions at the show. It almost seems that the users grew accustomed to this system and will accept it. As an outsider, and having used other applications besides PTC's, there is quite a difference between the competition. Well if you have a niche market and a customer that believes the product "does" what they want. Even if it's not "how" they want it done, it is hard for a competitor to take that away from them, especially if the customer built itself around the product. What ever happened to the product being built around the customer?

Trip Report

Event

HP Co|Create Users Group Meeting

Date

October 13, 1999

Location

HP Regional Office
Glastonbury, Connecticut

Persons Attending

Jeremy Baillargeon

Objective

The objective of the Co|Create users group meeting is to expose current users of Solid Designer and other HP driven products to show new product releases and product improvements. The meeting also includes small breakout sessions, called round-tables, where attendees are allowed to interact with the actual developers and representatives to answer any questions or concerns with the product. Also at the show are Co|Create Partners, these are companies that offer support and services for the HP products. They have the opportunity to present their company and service to the attendees.

Events

The meeting consisted of three main parts. The first one was an introduction of the new releases of Solid Designer and ME10, two of Co|Create's most popular applications. They also presented one of their new products called OneSpace. This application is a universal viewing and communication tool that is to be universally compatible with other solid modeling programs such as Pro/E, Unigraphics, and Solid Works to name a few.

The second part of the meeting dealt with presentations by HP & Co|Create partners. The only one attending was Missionary Systems. They offer complete product support and service, including hardware and software. They are rapidly gaining market share since Visionary Design Systems withdraw from HP.

The final portion of the meeting included various round-table breakout sessions that allowed customers to discuss one-on-one with representatives and developers. The users were encouraged to bring models with them and try to solve problems they were having.

Conclusions & Comments

The meeting covered most of the concerns the users had through demonstrations and presentations. The organization of the meeting was in small group format. This allowed a tighter discussion group and conversations between members.

Appendix C

Interview Question Sheet

WPI
INTERACTIVE QUALIFYING PROJECT

Solid Modeling

Implementation and Integration Analysis

Introduction

Thank you for participating in this study. The sharing your professional experience and expertise with regard to this subject area are greatly appreciated. The following questions are designed to stimulate your thoughts and opinions on various aspects of the implementation and integration of solid modeling in your organization. Please take a moment to review these questions prior to the personal interviews scheduled later this week. Thank you again.

Organization Profile

- ♦ How many engineers are employed in the organization?
- ♦ When was Computer Aided Design (CAD) first implemented into your organization?
- ♦ How many CAD seats are currently available in your organization?
- ♦ Of the number of CAD seats available, how many are capable of producing solid models?
- ♦ What brand(s) of solid modeling software does your company use?
- ♦ How long has the solid modeling application been in use at this company?

Training and Experience

- ♦ What are the typical methods used to train and teach solid modeling in your organization?
- ♦ Of the types listed above, which methods would you consider are most beneficial? What methods would you like to employ?

- Is solid modeling experience a critical criterion when reviewing resumes for perspective employees in your engineering department? In other departments?

- Is solid modeling experience a criterion for advancement in your company?

Documentation Control and Standardization

- Are solid modeling part and assembly files maintained in a Product Data Management (PDM) system?

- If solid modeling files are integrated into a PDM system, how are they controlled and maintained?

- Has solid modeling files, data, or images been used to accomplish concurrent engineering and design in your company?

- Has solid modeling effected the overall work flow in various departments or in the overall organization?

- Has the solid modeling practice been incorporated into any national or international standards program (ie. International Standards Organization)? If so explain briefly.

Communication

- In what way does solid modeling influence communication within the various departments of the organization?

- In what way has solid modeling been used to communicate ideas, designs, concepts, or data to vendors, suppliers, or customers outside the organization?

- How would you describe the security of your solid model files once sent outside the organization?

- Is solid modeling used as a tool to advertise products or services offered by your organization?

- Is solid modeling used to communicate new product concepts or revisions to customers in hopes of increasing sales?

Compatibility, Integration, and Maintenance

- Does interoperability (universal data exchange) exist with your current solid modeler and other programs used throughout your organization?

- What are the factors on determining a suitable degree of interoperability in your organization?

- Are upgrades or enhancements available for your particular solid modeler on a regular basis?

- If so, are the upgrades or enhancements controlled and installed on a regular basis? If not, explain reasons why?

- What types of on-line, phone, or personal support are available for your solid modeler?

- Does the support service offer suitable coverage for the organizational needs? What would you like to have offered in solid modeling support?

- How well do you feel your solid modeling application keeps up with current advancements in technology or feature enhancements offered by competitive products?

Efficiency and Productivity

- How do you define efficiency?

- Has solid modeling improved workflow efficiency?

- Did solid modeling affect interactions between departments in the organization? For example, did it increase concurrent engineering within your company? How?

Quality

- Has solid modeling reduced the amount of product recalls? By what percentage?

- Has solid modeling reduced the amount of change orders for a design? If so, what do you feel was the reason for this?

- Does solid modeling reduce the amount of time for the development of a new product? If so, what aspect of the solid modeling program is most responsible for this?

- Solid modeling vendors claim that their products can save companies money. They justify this by stating that solid modelers reduce the design cycle, the number of errors in the design, and reduce the amount of work needed to manufacture a product. (i.e. many applications can calculate the bend radius and relief cuts of a sheet metal part, therefore reducing or eliminating an engineering fee imposed by the sheet metal company). Have you found this to be true? Please explain reasoning.

Satisfaction

- Overall, are you satisfied with all aspects of the solid modeler that your company purchased?

- If you had the option of using solid modeling in other ways, what would they be? How would it benefit your organization?