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Technological Applications of Solid Modeling and Parametric Features

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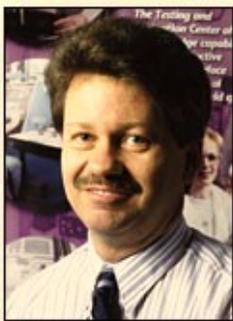
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Introduction

Computer-Aided Machining, Computer-Aided Inspection, and Sterolithography are all processes that can use a three-dimensional part directly from a solid modeling CAD file. A common database is a very important part of implementing manufacturing design, assembly, and inspection of parts. With the changing nature of technology, it has become very necessary for industrial technology faculty members, particularly in

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manufacturing, to spend adequate time in adapting current technology, which will be appropriate for industry and educational programs.

Purpose

This article addresses technologies that can benefit from the use of solid modeling and parametric features with respect to current and affordable technology. The sudden surge in low-cost, high speed computing has established the infrastructure to implement powerful, parametric software programs. For educational institutions, some of these programs are available at a very reasonable cost. Based on a recent project completed by the authors that focused on gear metrology, this paper will discuss various ways by which solid modeling and parametric programming was able to save Oak Ridge Gear Metrology Center valuable development hours. Other industry specific applications are discussed as well.

CAD/CAM's Solid Modeling

By 1996, the major Computer-Aided-Manufacturing (CAM) software vendors were at the International Manufacturing Technology Show (IMTS) in full force, proving they could machine from solids (Noaker, 1996). Until recently, solid modeling technology was not a viable component on PC-based CAM software because cost and computational demands limited solid modeling to high end engineering workstations. That trend is changing as solid modeling software prices fall and Windows 95 and NT-based technology gains popularity (Noaker, 1996). Because of these changes, CAD/CAM has met with immediate interest and strong demand from education and industry.

In response to this trend, CAD/CAM vendors are packing fairly low-cost solid modeling functionality into their systems and companies that specialize in solid modeling software are providing CAM functionality. According to Noaker (1996), a current entry into the affordable solids modeling market is Parametric Technology Corporation's PT/Modeler software. Built on the core technology of Pro/Engineer, it could have an enormous impact on the sales of mid-range systems. Most recently, Parametric Technology and Addison-Wesley teamed up together to offer the Pro/Engineer student collection. Students that can afford the hardware requirement can now run the Pro/Engineer Student Collection at an affordable price when compared with the cost of Pro/Engineer standard product.

Computer-Aided Inspection of Parts Using a Solid Model

Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) has emerged as a significant factor in the design and manufacturing processes. CAD/CAM has emerged as a tool that is used by both small and large companies. Many CAD/CAM systems are designed and intended to automate manual functions, whether they are engineering analysis, conceptual design, drafting, or documentation.

Three-dimensional (3-D) modeling gives a complete CAD/CAM representation. Three-dimensional CAD systems consist of wire-frame, surface, and solid modeling systems. Their three-dimensional capability is necessary to both thoroughly describe all features of a mechanical part and to provide multi-axis computer control of machine tools such as lathes, milling centers, and coordinate measuring machines.

To support automatic measuring analysis and other important applications, measurement must be associated with surfaces and other geometric entities within an unambiguous mathematical representation of a precisely enclosed and filled volume (Bolluyt, 1997). This can be accomplished by using a solid model of the parts to be measured. However, measurements and tolerances attached to graphic entities such as lines in a computer-generated drawing do not provide a suitable basis for supporting applications that go much beyond drafting. This is why a solid model of the part is important when simulating an inspection process using computer-aided inspection.

Solid Modeling of Gears for the Oak Ridge Gear Metrology Center

Researching Pro/Engineer as a solid modeling software package to model gears was a funded project with the Oak Ridge Gear Metrology Center in Oak Ridge, Tennessee. This project was supported in part by a summer appointment to the United States Department of Energy Faculty Research Participation Program at the Oak Ridge National Laboratory. The faculty research program was administered by the Oak Ridge Institute for Science and Education. The project title was "Solid Modeling of Computer Generative Gear Parts to Inspect and Measure Gears Using A CMM." The project provided computer hardware, software, training, travel and relief time to conduct the research.

The Center selected Pro/Engineer because the software was able to make changes to the gear design by using parametric input. Since the gear file was parametric, the authors had the capability to create a variety of spur and helical gears from one model.

After modeling a gear within Pro/Engineer, it was exported into a software package called CimStation. CimStation is an interactive software environment for the design, simulation, and off-line programming of automated manufacturing workcells. In addition, CimStation is an inspection simulation package that can simulate a variety of

coordinate measuring machines (CMM). The inspection module of CimStation allows one to create, edit and simulate CMM part programs.

Engineers at the Oak Ridge Gear Metrology Center wanted to be able to create solid models of Master Gears so that the gear inspection simulation could be performed within a computer environment before the actual inspection. The result of this project was to reduce lead-time for inspecting Master Gears. It was expected that computer-aided inspected models of gears and computer generative coordinate measuring machine programs would greatly enhance the efficiency of the Gear Metrology Center.

Pro/Engineer uses a unique parametric, feature-driven, solid modeling technology that spans the entire product development cycle. The parts created in Pro/Engineer serve as the core database for all other Pro/Engineer applications. The other application modules such as Pro/Detail (for producing drawings), Pro/Assembly (for assembling two or more parts), and Pro/Manufacture (for manufacturing processes such as CNC and inspection) reference the parts that each application module utilizes (Utz & Cox, 1995). The software's single data base structure enhances design integrity by capturing changes anywhere in the process and automatically updating the model and all engineering deliverables, such as drawings, molds, and toolpaths (Noaker, 1996).

Rapid Prototyping

Rapid Prototyping is another technology that requires a solid model of the part to be prototyped. Recently, there has been an abundance of new technology for rapidly developing prototypes. This current technology is so new that no one name has yet to be chosen for it (Brauer, 1994). Rapid prototyping is one terminology surfacing, and it appears to be the most accepted. Other terminology used include desktop manufacturing, optical fabrication systems, and 3D devices (Medler, 1990). Rapid prototyping may be used for design reviews, design verification, manufacturability, patterns

for molds, and presentations (Medler, 1990).

Rapid prototyping was first introduced in 1984 and became commercially available in 1988 through 3D Systems, Inc. when it sold its first stereolithography (SLA) machine (Jacobs, 1992). Meier, Smith, and Devlin (1995), stated that many other methods of rapid prototyping have been developed including selective-laser sintering (SLA), laminated-object-manufacturing (LOM), fused deposition modeling (FDM) and, solid ballistic-partice-manufacturing (BPM).

Additive layer manufacturing utilizing rapid prototyping technologies has given industries unique capabilities to fabricate prototypes and designs directly from CAD databases. One of the items driving the development of these technologies is the increased use and acceptance of solid and surface modeling CAD systems (Meier, Smith, & Devlin, 1995, p.19). Pro/Engineer is one of many solid modeling software packages that can create a SLA file from its database. This SLA file can be used to create a prototype part via stereolithography or other rapid prototyping technique.

A faculty member in the Department of Manufacturing Systems at North Carolina A&T State University recently successfully acquired the funds to purchase a Sterolithography system for the department. A laboratory will soon be developed around this technology and will be integrated into their present curriculum. Creating solid models of parts will be an important part of the laboratory. Parametric features in the models will allow for rapid design changes when needed.

A Common Database

During the 1980s, CAD wireframe was implemented. This created a semi-automated drafting-based design climate. Instead of concurrent design, a formal review procedure was installed between designer and drafter. According to Paul (1995), we are currently in this phase of design automation. This process has created the use of multiple databases in design, analysis, and manufacturing.

However, the use of multiple databases can present significant design and manufacturing problems. For example, the drawing is the master design, resulting in 50% to 90% of all significant drawings having missing or incorrect dimensions in the total project. The multi-database product definition environment is the basis for reduced product quality, resulting in a high number of engineering changes. Table 1 lists these and two additional problems as were identified by Paul (1995) that are created by using multiple databases during the life cycle of the product.

Computer-aided machining, computer-aided inspection, and sterolithography, as stated earlier are all process that can use a three-dimensional part directly from a solid modeling CAD file. Figure 1 shows the relationship among these design elements in the manufacturing process.

Since the databases from these designs have common properties, the solution would be a product that easily integrates the databases into a common database. A common database solves the problems identified by Paul (1995) by creating an engineering-based design environment, using a single product definition database for the design, drafting, analysis, and manufacturing phase such as CAM, CAI, and SLA. This allows for concurrent data flow, along with the improvements identified by Paul (1995), also listed in Table 1.

A common database is a very important part of the implementation of concurrent engineering. In concurrent engineering, the primary focus is on the integration of teams of people with a stake in the products, design tools and techniques, and information about the product and the processes used to develop and manufacture it (Ullam, 1997, p.9). Concurrent engineering is being implemented by many companies in order to compete more efficiently in a global market. Pro/Engineer is an excellent tool to use when implementing concurrent engineering into the mechanical design process. It is a parametric-based, solid modeling system. This means the models are dimension driven, simple to

Multiple Database	Common Database
The drawing is the master design, resulting in 50% to 90% of all significant drawings having missing or incorrect dimensions.	The assembly model database is the master design, which results in approximately 0% of engineering-released drawings having missing or incorrect dimensions.
The multi-database product definition environment is the basis for reduced product quality, resulting in a high number of engineering changes.	A single product definition database is the basis for all analysis and manufacturing functions, resulting in a 50% to 70% reduction in engineering changes.
Concurrent engineering is an after-the fact design review process, resulting in four or more drawing iterations per part.	Concurrent engineering is a team design environment, not a review process, resulting in one drawing cycle per part.
Analysis and manufacturing automation is neutralized by the large amount of data preparation required (Paul, p.2).	Analysis and manufacturing use the design database directly for all process planning operations (Paul, p.3).

Table 1. Comparison of Impact on Product Life Cycle Between Use of Multiple Databases and a Common Database.

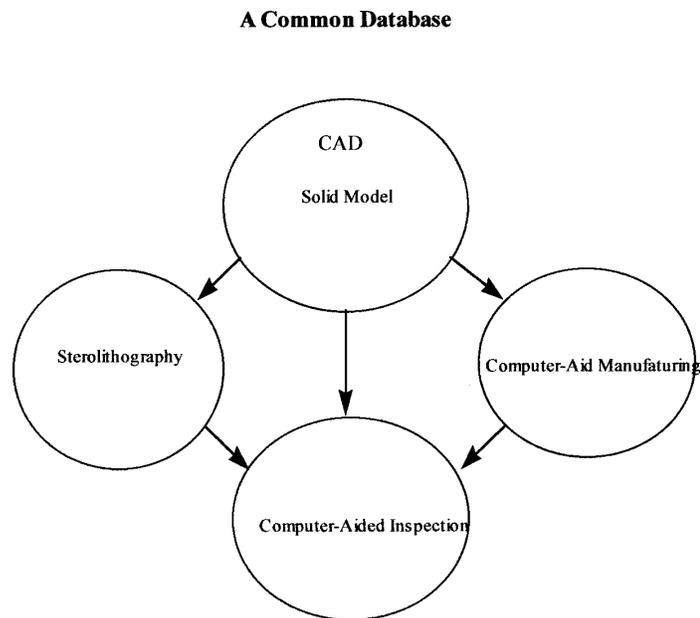


Figure 1. Create the design once and use it throughout the manufacturing process.

change, and have “intelligence” (Paul, 1995).

Conclusion

The applications cited will be a focus of the Department of Manufacturing Systems program. Preparing students and faculty members for the real world of manufacturing means giving them the right tools to succeed. Competition in the world marketplace requires quick response time. Using a common database and parametric features for as many applications as possible will decrease some of our manufacturing problems and our response time. The manufacturing of high quality products is clearly related to the way we design, prototype, and inspect parts.

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