Abrasive Technology Aerospace, Inc

CAD/CAM Technology Advances Superabrasive Grinding

In 1995, a highly efficient grinding process called superabrasive grinding was beginning to be used by manufacturers in the automotive and industrial sectors. Superabrasive grinding, which uses tools such as the electroplated superabrasive grinding wheel, removes material faster and achieves more exacting dimensional tolerances than traditional grinding. The grinding wheel that is used is a metal hub with a single layer of superabrasive material, such as diamond, plated to a machine rim. Although it was underutilized in the United States, especially when compared with Europe or Japan, its use was expected to grow as manufacturers increasingly adopted difficult-to-machine materials, such as ceramics and superalloys. However, the initial cost of developing the wheels used in the process was high, turnaround time was slow, and producing the wheels was labor intensive.

Abrasive Technology Aerospace, Inc., the world's largest U.S.-owned manufacturer of cubic-boron-nitride-plated and diamond-plated tools, proposed to develop an integrated computer-aided design/computer-aided manufacturing (CAD/CAM) approach to apply superabrasive coatings to the complex surfaces of electroplated superabrasive grinding wheels. This was a high-risk endeavor, as it involved computer-based predictive design, which was a new concept at the time. However, the company also anticipated that a CAD/CAM approach would result in a 90-percent reduction in order turnaround time and a significant reduction in cost. In 1995, after unsuccessful attempts to secure funding from the private sector and other government sources, Abrasive Technology applied for cost-shared funding through the Advanced Technology Program's (ATP) focused program, “Motor Vehicle Manufacturing Technology”.

By the end of the ATP project in 1998, Abrasive Technology had successfully reached its goal of developing an advanced high-precision grinding wheel technology and had reduced turnaround time from several weeks to three days. Since 1998, the company has continued to manufacture more complex, higher tolerance grinding wheels and has increased its sales of the wheels to a variety of industries, including automotive and aerospace.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

* *

Research and data for Status Report 95-02-0053 were collected during January 2003.

NCMS Recommends Development of Superabrasive Grinding

Grinding is a major material-removal process in manufacturing. In 1994, the National Center for Manufacturing Sciences (NCMS) completed a study on the importance of grinding in the United States, "US Grinding Partnership - 2000." The study recommended the development of high-speed grinding using grinding wheels plated with superabrasive cubic boron nitride (CBN) or diamond, which were the two hardest known materials.

Superabrasive grinding combines grinding at high wheel speeds with deep-cut, creep-feed grinding (a process in which a formed grinding wheel is plunged into the workpiece, slowly producing a finished part in a single pass). With superabrasive grinding, it is possible to achieve both high dimensional tolerances and high surface-finish tolerances at less cost and in less time than through conventional grinding.

By 1995, superabrasive grinding was an emerging yet underutilized technology in the United States. The initial application development cost of plated wheels was high, turnaround time for the product was slow, and the process to produce the wheels was labor intensive. Also, U.S. manufacturers had little knowledge of the high-speed grinding process, and wheel builders did not have significant experience building low-cost plated wheels for this process.

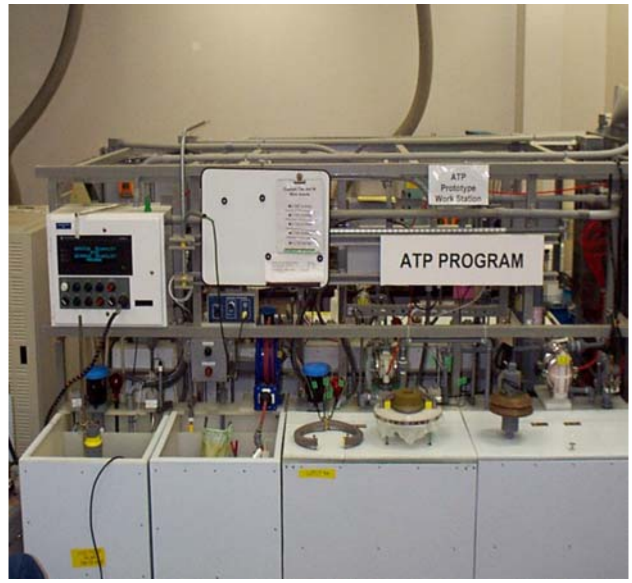
Abrasive Technology Proposes CAD/CAM System

Abrasive Technology Aerospace, Inc. agreed with the conclusions of the NCMS study. The company's goal was to develop an innovative computer-aided design and computer-aided manufacturing (CAD/CAM) system for the rapid design and manufacturing of plated superabrasive grinding wheels. This new system would reduce the time it took to design, fabricate, and electroplate a new wheel design from three to eight weeks to three days, as well as significantly reduce the cost. If successful, Abrasive Technology would establish a new standard for the rapid, low-cost manufacture of high-precision plated superabrasive grinding wheels.

By 1995, superabrasive grinding was an emerging yet underutilized technology in the United States.

The CAD/CAM technology would consist of a predictive design system, based on existing software, as the technology engine for an electrodeposition CAD station; a CAM station for the electrodeposition of plated grinding wheels; and the integration and validation of the resulting software and hardware into a working prototype system. The technology would enable the full integration of a grinding tool request, from the time an order was entered until it was tested and shipped.

Abrasive Technology realized that the development of the CAD/CAM technology was a high-risk endeavor. This was because the concept of a computer-modeling tool that could accurately predict the best



A prototype of a CAM plating workstation incorporates features that could be refined and specified from the CAD system.

manufacturing conditions to produce acceptable thickness distributions on a plated part was new. At the time, only one software package, Cell Design, was capable of simulating an existing plating process at the request of a user. This two-dimensional software, which was owned by L-Chem, Inc., a subcontractor to the project, had no predictive design capabilities. However, the anticipated benefits encouraged Abrasive Technology to pursue this project. At the time, funds for research and development were limited, and Abrasive Technology estimated it would take 10 years to complete the project. By that time, business would have shifted to foreign suppliers. Abrasive Technology predicted that with ATP support, it could complete the project in three years, and so, in 1995, the company submitted a proposal to ATP for funding within the “Motor Vehicle Manufacturing Technology” focused program.

Broad-Based Benefits Could Expand Nation's Competitive Position

Abrasive Technology believed that using an integrated CAD/CAM technology to design, fabricate, and electroplate new wheel designs would significantly increase the rate at which plated complex-form wheels were produced, resulting in substantial cost savings. Manufacturing advances in applying close-tolerance superabrasive coatings to complex surfaces that used 100-percent electrodeposition technology would improve the quality and reliability of the wheels.

The company anticipated a 50-percent increase in plated form wheel usage. Because of the significant cost savings that would accrue in producing wheels for superabrasive grinding, manufacturers using more traditional grinding methods would be able to cost-effectively convert to this more efficient grinding process. Using this new process would provide immediate benefits: the manufacturers could remove material faster, use fewer steps to form various complex parts made from new materials to final dimension, and reach finished tolerances more quickly and at less cost.

New CAD/CAM System Is Successfully Developed

Abrasive Technology began its development of the CAD/CAM technology by conducting short focused studies of the entrapment of superabrasives in the plating process. Although electroplating and electroless plating had been studied in the past, these processes had not been associated with the bonding of precision conformal coatings of abrasive particles over complex part geometries. Much of the work in studying this relationship was performed at Case Western Reserve University.

Abrasive Technology would establish a new standard for the rapid, low-cost manufacture of high-precision plated superabrasive grinding wheels.

One of the major challenges that Abrasive Technology faced was how to improve the CAD process so that the company could rapidly analyze the manufacturing process parameters of a customer's request. It could then determine the feasibility of the parameters in terms of coating placement, thickness, abrasive concentration, and allowable process variation. To successfully apply plated diamond and CBN to abrasive-coated parts and tooling, several computer-based modeling techniques for feasibility assessment, process design, process operation, and process prediction had to be developed. The new software had to be integrated into drafting software similar to AutoCAD. A portion of this CAD modeling development work, which involved modifying Cell Design, was performed by L-Chem, Inc..

Next, Abrasive Technology began to develop a prototype of a CAM plating workstation, which incorporated features that could be refined and specified from the CAD system. The workstation was designed to permit fabrication to close tolerances specified by a mathematical model. The central part of the prototype plating station, a high-precision plating-cell fixture, was then engineered and constructed according to the features and specifications generated from the CAD system.

The new software has been used to produce grinding wheels for a variety of industries, including automotive and aerospace.

Abrasive Technology attempted to automate the process for applying abrasive to plated complex-form wheels. The company believed that automating this process was necessary to achieve consistency, reduce manual labor, and minimize bare spot fill during plating. With the new system, a metering device would dispense the abrasive on the area to be coated. Automation of the abrasive application, however, turned out to be very difficult to implement, so this activity was abandoned in the first year of the project.

Abrasive Technology also developed a test prototype control system. This control system was central to automating the routine manual steps in the plating process. Data from the research and modeling phases of the project were used to predict optimal control parameters for applied current, voltage, and time to minimize plating time and produce the highest quality plated product. Simultaneous monitoring and control of applied current and voltage were expected to produce a good part the first time. The major features of the control system were:

- Control for process actuators and pumps
- Control for process chemistry (pH, temperature, and concentration)
- Data logging for test, evaluation, and quality control

Finally, the integrity between the output from the computer-based manufacturing tools and the prototype plating workstation was validated to test modeling and plating station performance across a variety of complex forms. The goal was to demonstrate an actual physical plating station that would perform according to the predictive model and produce a product correctly the first time.

Prototype Is Constructed and Tested

By the end of the project, Abrasive Technology had collected experimental data on plating solution chemistries, and kinetic parameters had been successfully quantified. The software that was integrated with the AutoCAD interface was working well, resulting in a faster and more efficient design process. However, extension of the software to incorporate three-dimensional surface solutions (for nontraditional machining) was only partially achieved. Overall, though, the functionality of Cell Design was greatly improved over the 1995 MS-DOS demonstration model.

The prototype CAM plating workstation was successfully constructed and testing of it continued. Development of the high-precision plating-cell fixture, the central part of the plating workstation, proved to be a great success. Abrasive Technology was able to cost effectively apply the new design/engineering technology to increasingly more difficult and high-precision wheel geometries. The prototype control system was also completed and testing was expected to continue for at least two years.

Abrasive Technology then integrated the CAD system with a new technology database and the manufacturing process workstation. (The database was created to join together critical parts of the CAD/CAM system.) The systems integration and testing proved successful. Afterward, an integration team at the company used the new technology on a trial basis. Abrasive Technology produced parts while receiving prototype production orders for field testing and customer acceptance evaluations. At the same time, a cross-company integration team for "rapid technology transfer" met on a regular basis.

Superabrasive Grinding Wheel Market Increases

In 1998, at the end of the ATP project, Abrasive Technology began to look into superabrasive grinding wheels for gas turbines as a potential market for the CAD/CAM technology. The new technology could be used to create automobile parts, stationary power generators, and turbo chargers. Also, the automotive industry had shown strong interest in using superabrasive grinding wheels for the production of parts for co-generation power plants, facilities that burn fossil fuel to produce both steam and electricity. Another potential opportunity was through the Department of Energy, which was expected to use superabrasive grinding tools in a major initiative for a ceramic turbine engine hybrid power plant within the automotive industry. Abrasive Technology also participated in exploratory meetings with the University of Massachusetts at Amherst and the University of Toledo to discuss the longer range application of high-precision ceramics grinding.

Between 2000 and 2001, Abrasive Technology earned $600,000 from the sale of complex, close-tolerance electroplated superabrasive grinding wheels and anticipated that revenue from these products would exceed $1 million by 2003. In response to interview questions in 2003, the company stated that, as a result of the ATP-funded project, it is now producing more complex, higher tolerance grinding wheels with increased repeatability. Moreover, since the project ended, sales of the wheels have increased. The new software has been used to produce grinding wheels for a variety of industries, including automotive and aerospace.

The newer grinding wheels allow designers in the automotive industry to specify parts with closer tolerances and finer surface finishes that are made from a greater variety of materials. In the aerospace industry, use of the wheels for superabrasive grinding has resulted in increased productivity and significant reductions in engine production costs, enabling companies to remain competitive with overseas manufacturers.

According to Loyal Peterman, the President of Abrasive Technology, "The computer-aided design and manufacturing process is now part of our technology base for wheel production."

Conclusion

By the end of the ATP-funded project, Abrasive Technology had successfully reached its goal of developing an advanced high-precision grinding wheel technology through an integrated computer-aided design/computer-aided manufacturing (CAD/CAM) approach involving predictive design. The new technology reduced order turnaround time from several weeks to three days. Since 1998, the company has consistently manufactured more complex, higher tolerance grinding wheels and has increased its sales of the wheels. It has used the new CAD/CAM technology to produce grinding wheels for a variety of industries.

PROJECT HIGHLIGHTS
Abrasive Technology Aerospace, Inc.

Project Title: CAD/CAM Technology Advances Superabrasive Grinding (Advanced Computer-Aided Design and Manufacturing Technology for Rapid Fabrication of Superabrasive Grinding Tools)

Project: To develop innovative computer-aided design/computer-aided manufacturing (CAD/CAM) technology for the rapid design and precision manufacturing of electroplated superabrasive grinding wheels.

Duration: 9/15/1995-9/14/1998
ATP Number: 95-02-0053

Funding (in thousands):

ATP Final Cost	$ 1,996	66%
Participant Final Cost	1,038	34%
Total	$3,034	

Accomplishments: During this three-year project, Abrasive Technology successfully developed an integrated CAD/CAM approach to applying superabrasive coatings to complex surfaces of electroplated superabrasive grinding wheels. The company achieved the following:

- Developed advanced computer-aided design software and product prediction simulation
- Developed production workstation hardware and modeling techniques

In October 1997, Abrasive Technology presented the following paper at the Advanced Technology Program Motor Vehicle Manufacturing Technology Public Workshop:

- "Computerized Modeling of Electrodeposition Between Conducting Boundaries Having Variable Geometries."

Commercialization Status: In 2000, Abrasive Technology began to market and sell electroplated superabrasive grinding wheels using the CAD/CAM technology it developed during the ATP-funded project, and still continues to do so. The company has used the new technology to produce grinding wheels for a variety of industries, including automotive and aerospace.

Outlook: Since the ATP-funded project ended in 1998, Abrasive Technology has consistently manufactured grinding wheels that are more complex and have a higher tolerance than those it manufactured prior to the project. The company has also increased its sales of the wheels.

Composite Performance Score: * *

Focused Program: Motor Vehicle Manufacturing Technology, 1995

Company:
Abrasive Technology Aerospace, Inc.
8400 Green Meadows Drive
Lewis Center, OH 43035

Contact: Loyal Peterman, President
Phone: (740) 548-4100

Subcontractors:

- Case Western Reserve University
  10900 Euclid Avenue
  Cleveland, OH 44106
- L-Chem, Inc.
  13909 Larchmere Blvd.
  Shaker Heights, OH 44120

Research and data for Status Report 95-02-0053 were collected during January 2003.