CAM Shapes A Shop From The Start

Two of the most urgent issues in CAD/CAM right now are exchanging data between systems and NC programming of complex surfaces. Here is how one shop built its business around doing both with a personal computer-based CAM system.

By Mark Albert, Executive Editor

CNC Products of Terryville, Connecticut, is a small job shop dedicated solely to machining prototypes and models for large companies that manufacture electrical products of molded plastic components. Its specialty is producing these prototypes and models in very short time.

Fast turnaround on this work is vital. The shop's customers face a highly competitive market for their end products. Success often depends on how quickly a product of superior design gets to market. So the sooner design engineers get these prototypes, the sooner they can test, evaluate, and improve their product design. A sample of these pieces in shown in Figure 1.

CNC Products' ability to create these models in days instead of the usual weeks makes them a key part of this design process. But success depends on how easily and accurately the shop can exchange design data created on a customer's CAD (computer-aided design) system and how quickly and accurately that data can be turned into programs for CNC (computer numerically controlled) machine tools.

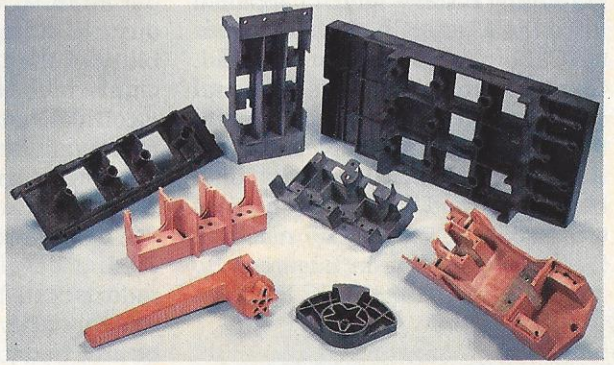
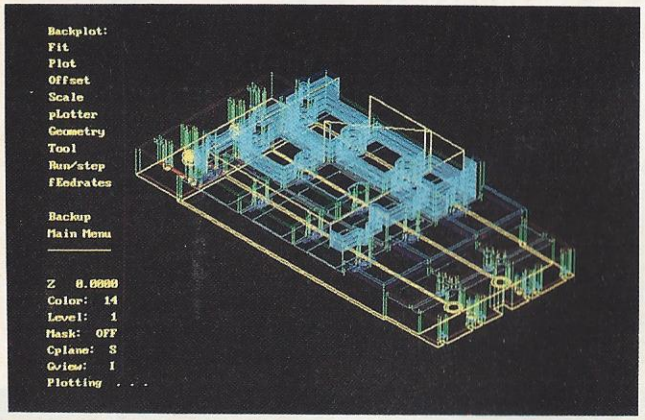
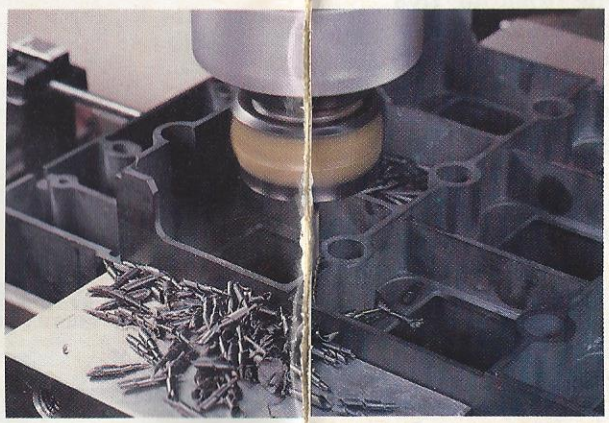


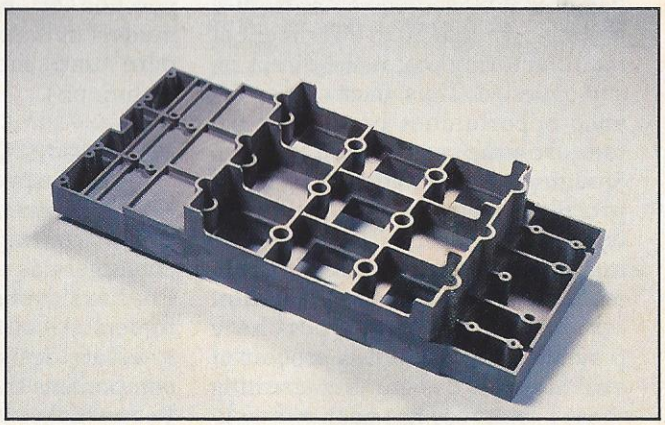
Fig. 1—Prototypes of plastic electrical components, which CNC Products can produce in a few days instead of the weeks it usually takes, help engineers evaluate and improve designs before production begins.

The founder of CNC Products, John Boone, understands this requirement very well. He worked as a prototype engineer for six years before starting his own shop. So from the very beginning, he recognized that a computerized programming system would be essential. However, this programming system had to handle design data from the customer's CAD system and handle the demands of programming for multi-axis machining of complex surfaces.

At his old job, Mr. Boone had the opportunity to evaluate such a pro-







gramming system, which happened to be the MasterCAM system from CNC Software, Inc., of Tolland, Connecticut. Seeing this personal computer-based system in operation convinced him that a prototype shop offering fast turnaround could be built around it. With such a system, and a few four-axis machine tools, he would be in business. So it happened; in 1985, CNC Products was on its way.

Prototypes Still Count

Like many small shops, CNC Products serves a carefully defined niche in the market. It offers only prototype and model machining services to the nation's largest electrical manufacturers. All of these customers are using advanced design tools such as CAD.

For most of these companies, there is tremendous competitive pressure to reduce manufacturing costs and speed the product development cycle. However, studies have shown that 70 to 90 percent of manufacturing cost is the direct result of design. Thus, most cost avoidance opportunities occur long before volume production begins. Studying and evaluating designs, especially in terms of manufacturability, ease of assembly, or fit with mating parts, is essential to finding and exploiting these opportunities.

Traditionally, prototypes have played a key role in this process of evaluating a design. But creating these prototypes has been a drawnout affair. It was usually the arduous and time-consuming responsibility of the most experienced machinist in the shop; and for complex electrical components, a model might take six to ten weeks to create. Engineering changes could add weeks to the development cycle.

If companies want to shorten the product development cycle and still reduce costs by designing for manufacturability, a high priority must be attached to streamlining the production of engineering prototypes.

Because model building requires close work between design engineering and the prototype shop, it seems that it does not lend itself to outsourcing. CNC Products defies this conventional wisdom by setting itself up to work with its customers as closely as a captive model shop would, only with much faster service. Advances in personal computers, combined with software for machining complex surfaces, make it possible to create four to five models in the time required to prepare one model with manual techniques.

Exchanging CAD Data

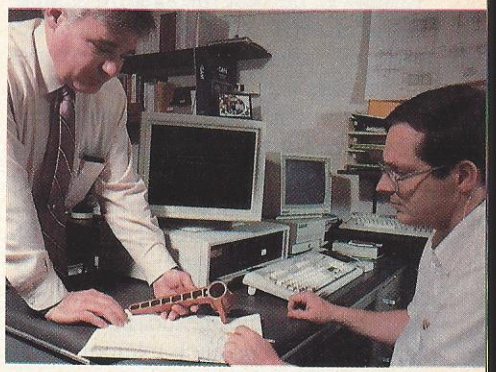
Because speed and accuracy are of the essence in this scheme of things, exchanging design data with customers is a linchpin in CNC Products' relationship with customers. All of them are using CAD to create designs for the electrical components they manufacture. Mr. Boone makes it a policy to use their CAD-generated design files, whenever possible, for NC programming and machining.

Exchanging CAD data, however, can be a difficult matter. CNC Products has customers using a variety of CAD systems and a variety of data formats. Designs created on the customer's systems must be translated into a format that is compatible with the CAM system at CNC Products. Two standard exchange formats have proven very useful, and using both has given the shop flexibility and efficiency. It works like this:

The customers' designers use CAD to translate their wire-frame computer drawings into the IGES (Initial Graphics Exchange Specification) format for transmission to CNC Products. In addition to the wire-frame model, the designers send traditional paper drawings for the part as well as the electronic equivalent of the paper drawings in DXF format. This information can be mailed, or transmitted using communications links across telephone lines.

IGES is a widely-accepted standard for exchanging CAD data between CAD/CAM systems. The development and maintenance of this standard is coordinated by the National Institute of Technology (formerly the National Bureau of Standards) with the support and cooperation of industry. IGES is a very comprehensive standard designed to support the exchange of the most complicated CAD data, including design files in 3D.

DXF, on the other hand, is a translator developed by Autodesk, Inc. (a vendor of widely used CAD software for personal computers), as an interface between AutoCAD, their 2D drawing package, and complementary packages developed by other vendors. Although AutoCAD does not include capabilities for numerical control (NC) programming, several vendors have interfaced their NC software to AutoCAD through DXF. The popularity of AutoCAD and DXF has led many vendors to support this 2D translation format as a simpler, less powerful alternative to the full 3D capability of IGES.



John Boone (left), founder of CNC Products, reviews a project with systems operator Greg LaPlante. Wire-frame drawings lend themselves to translation into standard exchange formats such as IGES yet provide all the information that the CAM system needs for NC programming.

CNC Products finds that DXF is an excellent choice for 2D (flat) file transfers but IGES remains the best choice for moving data representing 3D shapes. Therefore, only the data required by the MasterCAM system for NC machining is exchanged using IGES. CNC Software, the developer of MasterCAM, worked with CNC Products and with its customers to perfect the system's capability to transfer IGES files accurately and completely.

By reserving IGES only for the information needed for machining (the wire-frame model), and passing other explanatory information (dimensions, notes, drawings, and so on) by DXF, the system provides effective and reliable data translation while still allowing CNC Products to generate accurate tool paths. This approach allows each exchange format to be used where they are most efficient and convenient.

Data Accuracy

Within minutes of the arrival of a new project at CNC Products, the geometric data of a part design in wire-frame form can be translated into the MasterCAM 3D system for review. This 3D computer model is checked to ensure that the file is complete (all lines join, and so on); and since it is a true 3D model, the NC programmer can rotate and view it from any angle.

To make sure that there are no discrepancies between the customers' 2D data and the 3D computer model now in the shop's CAM system, the two are compared. MasterCAM's ability to rotate the wire-frame part design on the screen, combined with the ability to enlarge or reduce the display, allows the programmer to align and scale it to correspond to the part views provided on the drawings and in the DXF file. The programmer then "hides" any lines in the wire-frame drawing that should not be visible in that view.

When all "hidden" lines have been masked in that view of the 3D wire-frame display, the programmer then lays the corresponding 2D (DXF) drawing view over the model. The 3D and 2D views are in separate colors. If they match exactly, line for line, the picture on the screen is seen in a third color created by the overlay of the first two. If any of the original colors are visible, there is a discrepancy between the 3D part model and the engineering drawings. Figure 2 shows how such a discrepancy appears to the operator.

Those discrepancies are discussed by telephone with the designer. Discrepancies could indicate an error in the customer's design or an inconsistency introduced when the customer translated his data into one of the exchange formats. When any necessary changes are agreed to, revised data may be sent to CNC Products or each party may independently update their files.

Customers, Mr. Boone has found, are continually impressed by the shop's ability to accept CAD files for processing. This ability was one of the chief reasons that his shop attracted its first customers and could build a reputation for fast, reliable service. It also says something about data exchange formats such as IGES, which are frequently criticized. CNC Products' experience shows that whatever shortcomings may be inherent in IGES, data transfers can be accomplished when both sides want it to work.

Complex Surfaces

When the 3D wire-frame computer model and 2D drawings are consistent, the system can begin creating surfaces and generating tool paths. For CNC Products, one of the chief values of this system is its rapid ability to create "surfaces" for the machine tool to follow during tool path generation. The wire-

Fig. 2—By overlaying two views of the design, one derived from 2D data and the other from 3D data and each in a separate color, the operator can detect discrepancies. Wherever the two views do not match perfectly, the original colors are visible.

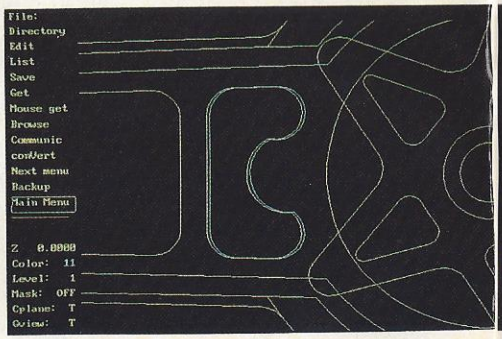


Fig. 3—Certain techniques for creating surfaces lend themselves to different types of complex geometry. A lofted surface such as this one is ideal for defining subtly sculptured contours found in airfoils and some mold work.

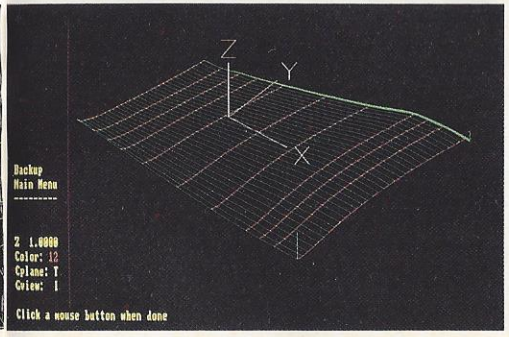
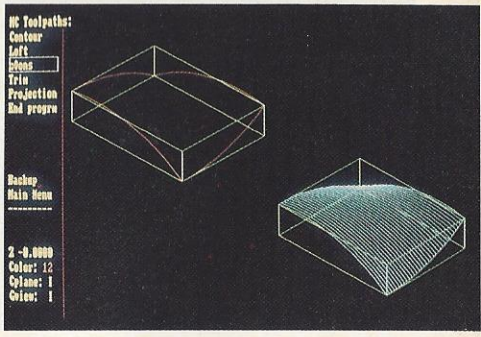


Fig. 4—Coons patches are appropriate for pockets and other features where boundaries or walls intersect but must be machined as one surface. The ability to handle various surfacing techniques greatly enhances a CAM system's usefulness.



frame model imported from a customer's database is not directly usable for machining—a computer system needs a continuous surface for the tool path to trace. A true 3D model provides such a surface. Interestingly, most of the "mainframe" CAD/CAM systems used by CNC Product's customers do not yet support this capability, Mr. Boone reports.

The system first automatically constructs surfaces between each "wire" in the drawing. The user can not only build ruled and swept surfaces and surfaces of revolution but also more powerful lofted surfaces and coons patches as appropriate. Lofted surfaces are used to blend up to 100 different cross sections anywhere in space, making this an ideal function for machining airfoils or molds (Figure 3). Coons patches are used to generate a surface mesh with either three- or four-sided boundaries (Figure 4). Multiple patches may be defined and used as one surface.

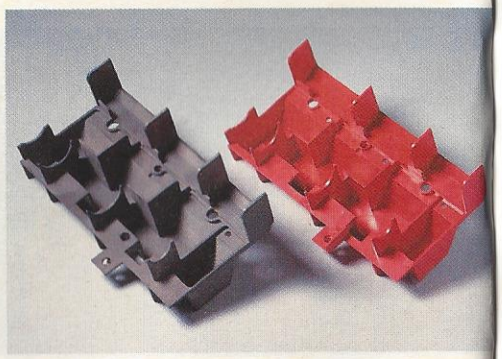
The intersection of these surfaces at the wire boundary may be either angular or they may be filleted. Angular intersections are easily programmed, but a filleted surface can be a programming nightmare if the user does not have a system which can automatically trim and fillet any two complex surfaces with a constant or variable radius fillet. MasterCAM provides this feature.

The surface or "skin" created over the wire-frame skeleton forms an accurate model of the final part. CNC Products routinely machines across the surfaces of the entire model to an accuracy of 0.001 inch.

Dimensional accuracy is only one of the characteristics required of the models this shop produces. Model integrity is important, too. Every cavity, pocket, hole, and surface is accurately created. This means that prototype products can be assembled and accurately tested well before a commitment to manufacturing. Figure 5 shows how exactly similar a model produced by these methods is to the component as mass-produced.

In addition, tool paths can be rotated and viewed from any angle to check for clearances, proper depths in pockets and holes, as well as proper entry and exit trajectories.

Fig. 5—A model or prototype must be exactly like the final component. Otherwise, design engineers cannot evaluate or test it and make confident predictions about how the real thing will perform. Here, a model (left) is compared to the injection molded version that is part of the final product.



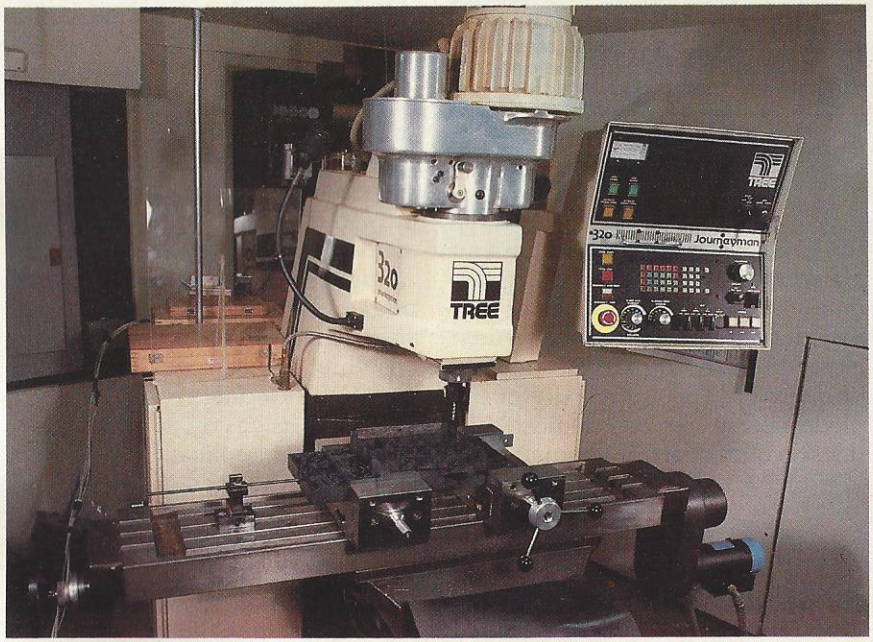
All of this is done on the system's graphics screen before any material is cut. Tool paths are shown with proper tool size and offset for each operation. The tool motion can be previewed from any angle. This verification on screen eliminates dry runs and downtime at the machine tool.

Network For Downloading

Once tool paths have been generated, the completed NC programs are post processed for the two Tree 320 Journeyman CNC machines in the shop (Figure 6). The MasterCAM workstation is linked to each of the control units on the machine tools and the NC part programs are directly "downloaded" to the control unit's memory. For flexibility, each control unit is linked to the other in case one machine is down or a program must be re-directed.

CNC Products has modified the control units on its two machine tools with machine interface devices, or "black boxes" as they are

Fig. 6—Although the inspiration for CNC Products may have been a CAM system, machine tools are certainly not an afterthought. This four-axis Tree 320 Journeyman CNC milling machine is one of an identical pair that is the heart of the shop's ability to produce accurate models and prototypes.



called in the shop, that emulate a behind-the-tape-reader containing 64,000 feet of tape memory (Figure 7). Each control computer is linked to this device with RS-232 connections for direct file transfer.

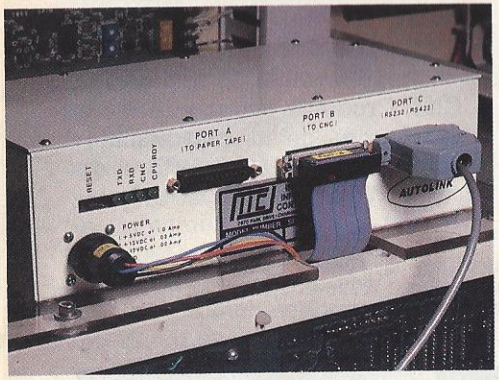


Fig. 7—Complex part designs mean very long NC programs. This interface device at the machine control unit allows program data to be downloaded from the CAM system as needed so that length of an NC program is not a restriction.

Each black box effectively turns the CAM system computer on and off whenever it needs more information and this arrangement lets the machines run programs much larger than those that can be held in memory. The complexity of the models being created is indicated by the size of the part programs, many of which exceed 450,000 bytes.

New Tools, New Opportunities

In the past, many job shops were started by individuals who trusted their own experience as skilled machinists and wanted to offer their services through businesses of their own. All they needed were a few basic machine tools—a milling machine and a grinder—and faith in their own abilities. But today, the traditional skills of the master machinist have been supplanted by the information revolution.

Yet a shop like CNC Products owes its very existence, and its success, to this revolution. John Boone, its founder, was neither machinist nor NC programmer. He did, however, recognize that a business opportunity existed in prototype manufacturing. He also recognized that computers had changed both the tools and the skills required to seize this opportunity and that the cost of entry to this market was dropping rapidly as powerful software for personal computers was developed. Indeed, personal-computer-based CAM systems like MasterCAM incorporate capabilities once available only in systems that cost hundreds of thousands of dollars.

But even the technology and the market opportunity would not be sufficient without commitment to customer support and service. Today, CNC Products serves as an extension of its customer's operations. This kind of application of innovative technology and customer commitment will be necessary in the future if manufacturers are to succeed. **MMS**

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