

GENERAL ELECTRIC INFORMATION SERVICES

REPRINT OF INTEREST FROM:

AMERICAN MACHINIST

REPRINTED BY PERMISSION OF AMERICAN MACHINIST, MARCH 6, 1972, pp. 73-74

NC machine carves an antenna mold

Effective use of a computer timesharing service holds down the cost of the complex part—thousands of points in the cutter path were derived directly from the design equations



NC machine carves an antenna mold

Effective use of a computer timesharing service holds down the cost of the complex part—thousands of points in the cutter path were derived directly from the design equations

How do you machine a complex, compound-curved mold for a radar antenna—and do it at a reasonable cost—using a standard point-to-point NC milling machine? The elongated dome shape of the mold, derived from the laws of optics and the conservation of energy, doesn't contain a single straight line or circular arc. When a surface is defined by a multifactor exponential equation, it's difficult enough to represent in an ordinary engineering drawing. It's even harder to generate a reliable NC tape.

To accomplish the job, AIL, a Cutler-Hammer division located in Deer Park, N.Y., combined some original thinking with the flexibility of a computer timesharing network to come up with a unique solution. AIL develops aircraft navigation and reconnaissance systems for customers that include the Federal Aviation Administration, three of the U.S. armed forces, and the Swedish Air Force. The company purchases computer time on General Electric's teleprocessing network—accessed through six desk-side terminals—for a variety of data-management and engineering work including the preparation of control tapes for eight of its NC machines.

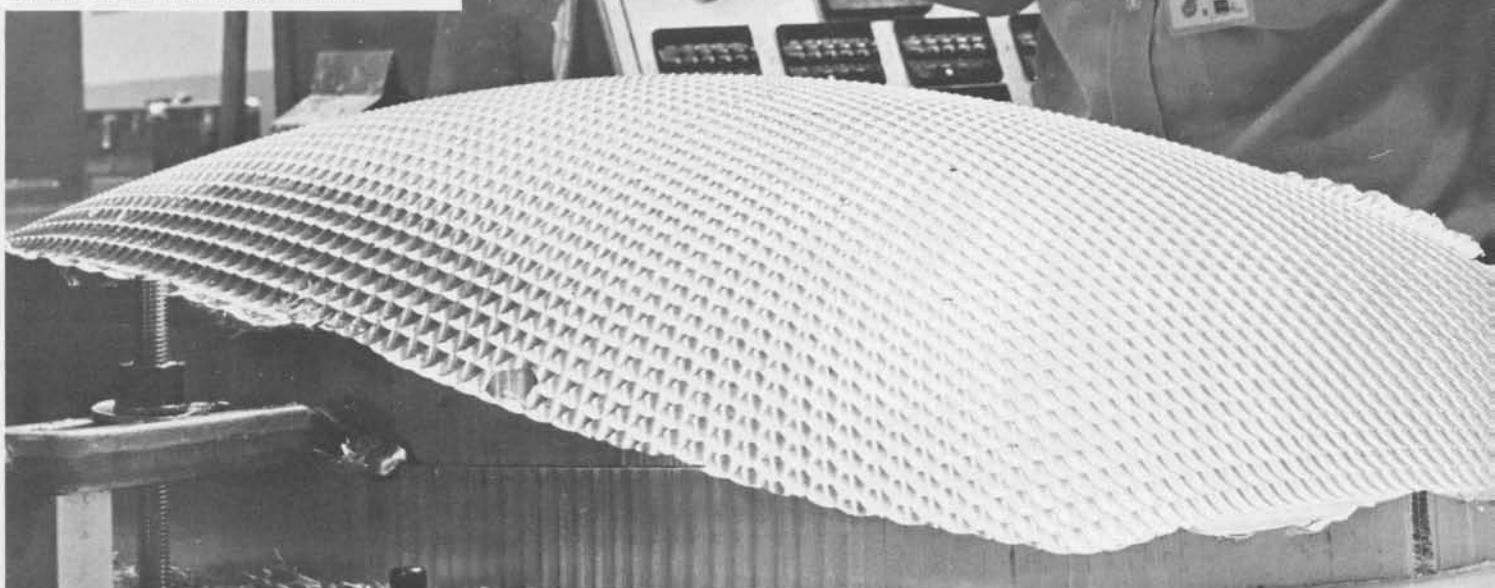
Reflecting-type radar antennas, required for some of AIL's aircraft systems, must be manufactured to extremely close tolerances. The reflector is usually vacuum formed from a sheet of

annealed metal screen or honeycomb. Then the shape is preserved as the metal becomes a layer in a fiberglass-and-epoxy sandwich. Both the vacuum-forming and the fiberglass-layup procedures use the same external mold.

AIL could have spent weeks making

tedious approximations on wooden or plaster mockups. Instead, engineers devised a method that merges computer-aided design with computer-aided NC programming and exploits some of the capabilities of the timeshared computer service at the same time.

Curved surface of mold looks like a honeycomb after shaping by thousands of plunge cuts on point-to-point mill



NC machine carves an antenna mold



Horst Miersch (left) and Steve Pruitt collaborate on details of mold design

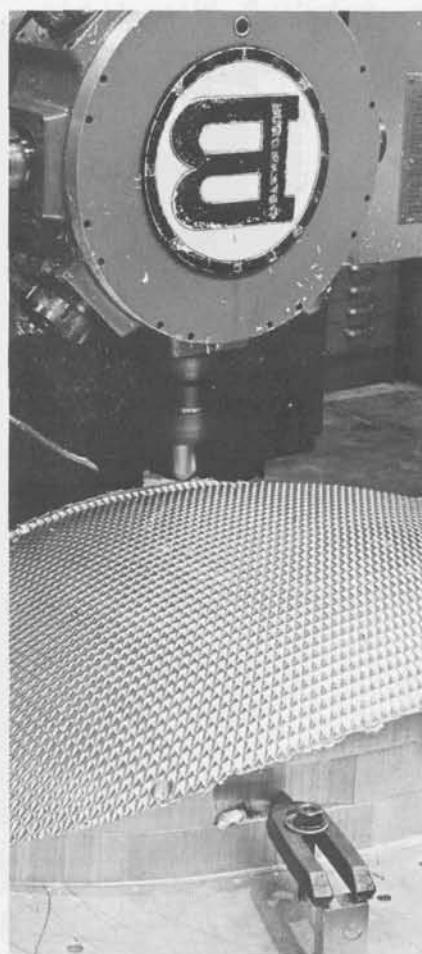


Printout of NC program is checked out by Pruitt. Terminal is tied into timesharing network by phone line

The company's antenna-development engineer, Horst Miersch, was considering the unwelcome production alternatives for his latest antenna concept when he decided to try an unconventional process that bypasses much of the time-consuming hand labor at both the design and production stages of the job. The process included the translation of the design equations for the antenna reflector surface into a cutter path, enabling the reflector mold to be carved out of solid aluminum by a three-axis NC milling machine.

The shape of the reflector was obtained by an iterative mathematical solution based on geometrical optics, the conservation of energy, and differential geometry. Miersch used the engineering FORTRAN language—and the time-shared computer—to compute the solution of the design equation at well over 2000 points on one quadrant of the theoretical surface. Then the data, representing more than 9000 X-Y-Z coordinates, was stored in the files of the timesharing network.

Next, the responsibility for producing the mold passed to the methods section



After machining on the Burgmaster, mold will be ground by hand to smooth off the cusps, then hand-polished

of AIL's manufacturing operations department and Supervisor Richard S. Pruitt. It was Pruitt's job to convert the thousands of three-dimensional coordinates into production tapes for his NC milling machine.

Calling up the data file, Pruitt first checked each row of points for gross errors—detail work that is practical only with a system having immediate response. Then, using GE's NCPPL (NC Parts-Programming Language) and a postprocessing program prepared jointly by AIL and GE, the EIA-coded control tapes were generated for AIL's milling machine, a Burgmaster Model 25 BHTL-SH controlled by a Cutler-Hammer 903 point-to-point NC system.

Data fills 16 files

The control tapes—there were sixteen of them, each 125 ft long—required 16 data files on the timesharing network. "That's a lot of data just to produce a 2 x 4-ft mold," Pruitt admits. Besides the locations of more than 9000 coordinates on a 0.4-in. grid, the files and postprocessor stored information about the Burgmaster and its control system, the

cutting tool, and the rough workpiece.

And, in addition to all this data, the punched tapes contained the necessary statements regarding spindle speeds, feedrates, and tool changes. The amount of NC programming was not as great as one might guess. Eight of the tapes were for roughing, eight were for finishing, and any two of the tapes could define a quadrant of the mold. Redundancy of information, like the solving of polynomial equations, is easily handled by the computer without error or fatigue.

Aluminum billets of alloy 6061-T6 (chosen for its stability during machining) were welded together to fashion the workpiece, which was hollow to save on material and dead weight. With the shell-shaped workpiece clamped to the machine table and a 1-in.-dia ball end mill in the spindle, the roughing tapes were ready to be run.

The first eight tapes directed the tool to make more than 9000 plunge cuts with a maximum depth of about 3 in. Then the set of finishing tapes controlled the removal of the remaining 0.100-in. envelope of material. The result was a curved surface with the appearance of a giant honeycomb.

The operations leading to completion of the reflector mold included painting the entire surface with blue die and grinding to remove the cusps between the thousands of dimples. Hand grinding was continued until the blue in the depressions just began to be worn away. Then the whole mold surface was hand-polished to a finish of about 20 to 30 microinches.

Better accuracy than hand work

Engineer Miersch says, "We achieved more accuracy than we ever could have with the only other method available to us for this compound-curved mold—hand work." According to AIL, the start-to-finish cost of producing the radar-antenna mold was about \$600, including the mathematical calculations on the timesharing network, data storage, and use of the program library.

"It just couldn't be done for twice the time or cost any other way," Steve Pruitt says. "The computer calculated the coordinates with complete precision so that we ended up with thousands of exact points on a permanent mold instead of hundreds of hand-approximated points. We didn't even need the usual handwritten manuscript for the lengthy NC program."

"You can see that the process isn't that difficult with the proper know-how. But the step that really saved us time and money was going right from the design equations to the actual production tapes using the timesharing service." ■

GENERAL  **ELECTRIC**
INFORMATION SERVICES

7735 OLD GEORGETOWN ROAD | BETHESDA, MARYLAND 20014 | PHONE (301) 654-9360