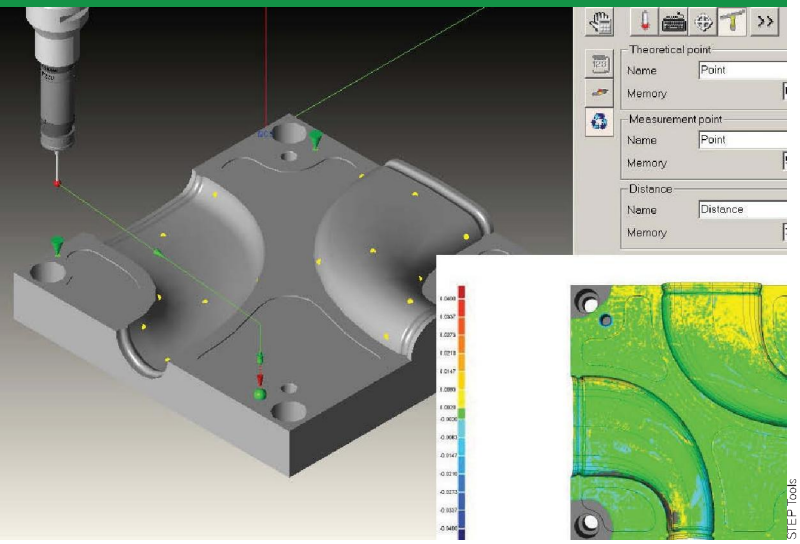
Machine programming investigates a new STEP



STEP Tools

While the machining industry has adapted to the 50-year-old standard for CNC machine language commonly known as G-Code, a community of engineers has worked on a replacement, the STEP AP238 protocol known as STEP-NC. Is the machining world ready for it?

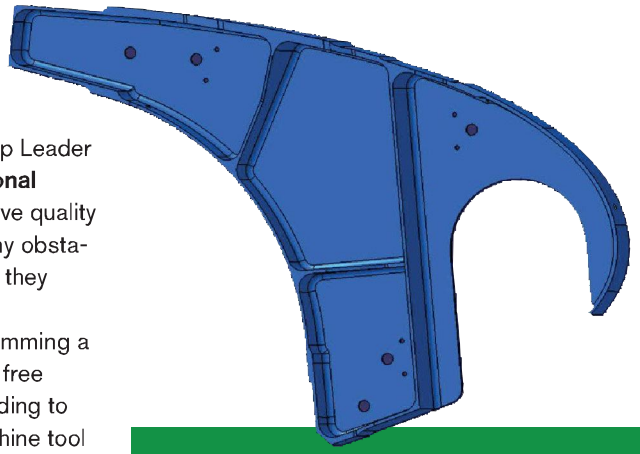
by **Bruce Morey**

"I do not think the U.S. can compete on a low-cost wage basis—innovative products with high quality are how we can be most competitive," said Fred Proctor, Group Leader of the Control Systems Group of the **National Institutes of Standards** (NIST). "To improve quality and drive innovation we need to remove any obstacles manufacturers have in their way when they want to try out new things."

Eliminating the tedious details of programming a dumb machine using an old language will free workers to innovate in faster cycles, according to Proctor. "One goal is to transform the machine tool from an apprentice to an expert, freeing up people to tackle the tough problems rather than watch for the simple ones," said Proctor.

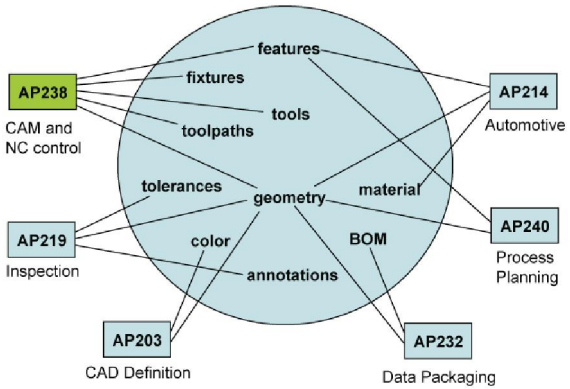
Today, typically CAM programs produce CNC instructions by reading CAD data, and then through a graphical user interface, human interaction, and some automation, a machining process is established. This resulting instruction set for the CNC machine is termed generically G-Code or machine control data. First developed in the 1950s, more recent revisions to the standard date to the 1980s.

"G-Code is a legacy of the paper tape days. It is a primitive description of a tool path" that does not address critical questions such as material removal rate or tolerances among others, according to Proctor. Because it is "dumb," the machine cannot adapt to real-time changes in machine dynamics or tool wear. Portability is another issue. Proctor pointed out that today there is not just one G-Code standard but more than 5000 dialects adapted for each machine, requiring post-processors to convert tool-path data for each machine.



In one experiment on a complicated rib section requiring a five-axis machining process, the AP238 file was comparable in size (~2 MB) to a standard CATIA CL file and only about two to four times larger than a standard NC data file. Processing time on a commonly available 1-GHz Pentium took about 20 s.

Enter STEP-NC. STEP is the Standard for the Exchange of Product model data, also termed the ISO 10303 for computer exchange of product data. The STEP standard has a number of application protocols (APs) of which AP238 (ISO 14649) is designated STEP-NC. It includes the CAD design along with cutter information. Tool paths are now full 3-D bounded curves rather than a simple set of moves or machine axes motion.



An assortment of STEP advanced protocols are intended to aid industry

"The analogy I like to make is that G-Code is like plotter language for the old dot-matrix printers, whereas STEP-NC is like PostScript," said Proctor.

Practicalities

"When I was recruited into this STEP-NC world, I was an optimistic skeptic," said David Odendahl, Information Technology engineer for **Boeing** and a participant in the consortium developing the protocol. He agrees that today's machine control language is not portable, adaptable, or standardized. He has experience with an earlier attempt at a standardized machine language called BCL (RS494).

"I had a built-in opinion that having a customized data set for each individual machine tool did not make any sense. I know that machine neutral paths worked—the Space Shuttle and other aircraft were built with BCL instructions." While sold on the desirability of the result, the skeptic in him was concerned.

- Were the file sizes describing how to machine a part in STEP AP238 practically too large?
- Were crucial elements missing from the standard?
- Are computers and controllers fast enough to process the data?

As the representative of an aerospace OEM, he was not thinking in terms of small or prismatic parts. "Our parts in aerospace are becoming bigger and more complicated. I joke that there must be a straight line on the 787 somewhere, but I have not seen it," said Odendahl. The results of testing were satisfactory. "We proved that there is now an alternative to the 50-year-old data model for CNC machine tools."

The implications of successful implementation of STEP-NC are two-fold for a large aerospace OEM such as Boeing, according to Odendahl. First is the elimination of the complicated and redundant CAD to CAM to CNC software infrastructure. Portability is critical in this—not only from machine to machine but also from supplier to supplier. "If there is a crisis on parts, we want to make it easier to go to another supplier."

The second reason is that with more information available to the controller, including material properties, full geometric dimensioning and tolerancing (GD&T), cutter information, and the CAD geometry itself, the controller could use that information to optimize the process.

History: A long time coming

"We have been working on this for a remarkably long time," said Martin Hardwick, CEO of **STEP Tools.** "Essentially, the whole idea started in Germany [in the late 1990s]. That was when STEP was clearly going to become an option of every CAD system." If STEP was going to be universal, then a standard NC language that combined STEP GD&T data with CAM process data made sense. The development progressed through a number of milestones and procedures, including 11 international demonstrations. The first one demonstrated multi-axis machining at the **Jet Propulsion Laboratory** in 2003. The last one demonstrated machining and measurement of a mold part at Boeing in 2009.

Each demonstration has progressed the standard and knowledge of how to use it. "We showed how to machine and measure. We showed how to modify tool paths while machining and then how to share and reuse data," said Hardwick. The next demonstration will show machining with multiple setups and alternate machining plans for alternate tooling. The demonstration theme is: using STEP-NC reduces tool wear and extends tool life.

"Now we know there are no hidden problems. We have shown that STEP-NC has all the functionality needed to make the most complex parts. The next phase is to focus on the human factors and make sure ordinary engineers can use it, not just the best. Starting in 2010 we will be working on growing the number of systems that support STEP-NC," said Hardwick.

The keys to acceptance?

What is required to make STEP-NC commonly used are controllers that can read the data along with CAM programs that can output the data in AP238 format. Even if today's infrastructure is complex and not overly portable, parts are machined. It does work.

FANUC CNC America supplies CNC controllers. As Rick Shultz, Program Manager for Aerospace and

Mitutoyo

Probe path programming using STEP AP238 and CAD data from AP203.

Aerostructures at FANUC, noted, "with [today's] improvements in processing power, CAD/CAM, and CNC algorithms, the urgency to replace G-code is reduced. If traditional G-code is replaced in the near future, STEP-NC would be a likely candidate."

He also acknowledged that today's built-up infrastructure means expensive-to-develop and maintain post-processing. There are benefits in upgrading CNC programming to a higher-order language. "Eliminating or minimizing the need for a traditional post can result in significant savings, especially when a different post is required for each machine and/or CNC in a facility," he said.

He pointed to improved CAD/CAM and G-Code through advanced capabilities offered by the company. "For example, changing five-axis applications to support tool vector orientation definition makes the generated geometry—with minimal reformatting of the program—machine independent." Traditional posts directly program the rotary axes for the particular machine.

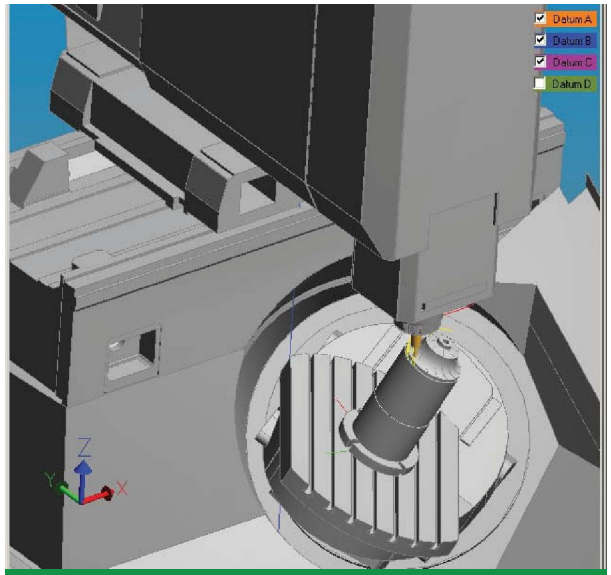
"Directly addressing the rotary axes means the geometry is not portable to another machine without re-posting. By changing the programming method to tool vector representation—sometimes referred to as {i,j,k} programming—the geometry portion of the part program is transferable with minimal modifications."

Shultz noted that a prototype FANUC CNC that accepts STEP-NC is operating in a laboratory at Boeing. Hardwick from STEP Tools also reported two popular CAM packages, **MasterCAM** and **GibbsCAM**, already produce AP238 standard output. "More are needed for the standard to grow in acceptance, and more CNC vendors must join FANUC in processing the data in real time on their controls," said Hardwick.

The bigger picture

While many of the participants in STEP-NC development are looking at process control, process validation is just as important to Shawn Lawrence, Marketing Manager for **Mitutoyo.** Think of process control as adjusting, say, offsets on the machine to compensate for tool wear or variations in material properties. Process validation examines more fundamentally if the process would ever produce the right part. To check that requires a broader view with off-line measurements using coordinate measuring machines and other metrology equipment.

"There is a good reason that the quality department is separate from inline or on-machine measurement. You need a way of finding systemic errors, but a lot of companies today are complaining that their quality department is a bottleneck," said Eric Tingle, Western Regional Sales Manager for Mitutoyo. This is where STEP AP238 can help. Since the



A demonstration of closed-loop machining using STEP AP238. An impeller was machined on a five-axis setup.

STEP AP238 protocol contains within it the fundamental GD&T data, it can also be used to generate measuring programs in the same way as NC machining.

"With our MCOSMOS software, not only can we read in the AP238 specification, but we have a way to check it," said Tingle. "We can verify if the features match the drawing. That allows the QC department to have that separation from manufacturing" while streamlining the process.