

STEP-NC demonstration at Boeing, Mitutoyo

The latest developments in STEP (Standard for Exchange of Product Data-Numerical Control) were demonstrated recently at an event held jointly at Boeing's main assembly facility at Renton, WA, and at Micro Encoder Inc., Kirkland, WA, a wholly owned Research and Development subsidiary of Mitutoyo America.

The two-day session held May 14 and 15, 2009 reviewed the current state of STEP-NC, an extension of existing STEP standards widely used in computer-aided design (CAD). This scenario demonstrated that a STEP-NC machining plan could support a variety of parallel machining processes that were in turn validated by a STEP-NC measurement plan run on a CMM.

Background

By the time a finished part has been realized in actual material, many systems have been used to manage the technical data required to design, manufacture and verify the piece. Generally, each system has its own data formats – requiring the same information to be entered multiple times into multiple systems. This duplication results in lost productivity and the opportunity for introduction of error, misunderstandings among the parties involved, and ultimately, higher manufacturing costs.

Over time, many solutions have been considered to reduce or eliminate this redundancy. The most effective approaches have focused on data exchange standards, eliciting many proposed solutions from around the world.

To sort things out, beginning in 1999, a unifying initiative was undertaken by the International Standards Organization (ISO) to develop an international standard covering all aspects of technical product manufacturing data. The result was STEP.

A NIST (National Institute of Standards and Technology) project to integrate GD&T (Geometric Dimensioning and Tolerancing) as well as the manufacturing plan and the measurement plan into STEP was led by STEP Tools, Inc. in collaboration with an industrial review board (IRB) consisting of major manufacturers, CAD/CAM software developers, machine tool manufacturers and job shop and other industry experts. This effort yielded ISO 10303-238 published in 2007 as STEP-NC AP238.

Currently, nearly every major CAD/CAM system includes modules capable of reading and writing data defined by one or more of the STEP applications for CAD, CAM, CNC or CAE (Computer Aided Engineering Analysis). As a result of AP238, information about the product being machined and sent to a machining center's CNC controller can now include:

- toolpath descriptions that are portable and independent of machine geometry;
- a visual process to show the toolpath in the context of the machine and workpiece and to eliminate drawings;
- on-machine simulation to check for machine interference and other undesired behavior;
- inspection information with linked tolerances, cross section information and sensor data, and
- associativity so feedback can be sent from manufacturing back to design.

Machining demonstration

The May 14 - 15 STEP Manufacturing Team (ISO TC184 SC4 WG3 T24) meeting was attended by representatives of the following: STEP Tools, Inc.; Boeing Company; Mitutoyo America; Micro Encoder, Inc.; KTH (Royal Institute of Technology, Sweden); NIST; CCAT (Connecticut Center for Advanced Technology); Puget Sound Naval Shipyard; Helical Solutions Group; Application Specialties; University of Bath, UK; Al's Rod Shop; Sandvik Coromant; Scania and GE Fanuc.

The meeting's key goal was to demonstrate how multiple discrete sites, each equipped differently, can manufacture the same, high-surface-finish part, in parallel, from the same AP238 program files. Ensuing performance issues were the subject of roundtable discussions.

The samples to be scrutinized consisted of mating sets of male and female mold forms. Rough and finished milling was performed prior to the meeting. The resulting samples were delivered from diverse global locations to the session by the participants. A scheme to introduce a variety of CAM programs, machine tools, cutting tools and operators into the test was implemented: Five mold sets – each consisting of a male and female half – were produced using five different “pairs” of facilities. To begin with, NIST, Sandvik, Boeing, CCAT and KTH each received identical high-level, “generic” AP238 files defining the mold halves in terms of CAD, GD&T, a workplan and a measurement plan. The AP238 files were loaded to the various machine tools for their low-level controllers to demonstrate the ability to generate both rough and finish milling routines.

Each participant then rough milled a mold set; next, each transferred their rough milled set to a different “partner” for finish milling. (NIST handed over their rough mold set to KTH for finish milling; Sandvik to NIST; Boeing to Sandvik; CCAT to Boeing and KTH to CCAT. *See Fig. 1.*) An additional mold set was “live machined” during the meeting at Boeing's machining lab.

Verification and issues

On the first day of the meeting, each of the male mold halves was fit-checked against each of the female halves – all passed. A more rigorous proof-of-performance was conducted on the second day when the parts were verified on a CMM operated by Eric Tingle, Western Regional Sales Manager, Mitutoyo. The CMM, a Mitutoyo Crysta Apex C776, fitted with a touch probe and capable of a resolution of 0.1µm, provided a different perspective.

Larry Maggiano, Mitutoyo Senior Systems Analyst, explains, “Currently,

AP238 enables vectored CMM measurement using touch trigger probes. The demo showed that a Crysta Apex equipped with an appropriate probe could readily be driven from STEP. Inspection of mold parts did identify significant part-to-part differences, attributable among other factors, to the choice of roughing tools. In one case, the rough milling working step called for a $\frac{3}{4}$ " rougher; but some facilities had used a smaller ($\frac{1}{2}$ ") rougher with a different chip load since the machine tool did not have enough horsepower or parameters for a $\frac{3}{4}$ " tool. Also, we found the reamer specified by Boeing did not have a common metric equivalent so was difficult for the European partners to duplicate." Tingle adds, "The departures from nominal tool usage raised awareness about enabling AP238 to accommodate workarounds to account for facility-to-facility differences in tools as well as in equipment, English vs. metric units, etc."

Maggiano says similar concerns were voiced regarding the ability of AP238 to accommodate a variety of CMM probe technologies. He comments, "Just as you want to choose a cutting tool, you want to be able to select laser scanning or other types of CMM sensors, depending on workpiece characteristics. As a matter of fact, for this demo, we chose two different CMM sensors to compare the part to the AP238 file. Measurements were made by inspecting discrete points defined on the CAD model using a Renishaw TP-200 touch probe. We also measured the same parts using a laser line scanner (Metris LC-50) to collect a dense point cloud for comparison to points in the STEP model which was achieved by overlapping the two sets of points using Geomagic[®]. The results were then compared."

Specifying discrete touch probe points on the model is normally accepted in today's manufacturing plans but laser line scanners provide more information by collecting almost 18,000 points per second. The ability of touch probes to measure smaller characteristics is limited by stylus size: the smallest diameter stylus available from Renishaw being 0.012" (0.3mm). Laser line scanners can capture points in sharp, shallow areas under 0.012" and can also collect a dense set of points from small curvatures. The disadvantages of laser line scanners are

less accuracy and the phenomena whereby shiny surfaces can over-saturate the laser line causing spikes or outliers.

Beyond AP238 accommodating unique machines and tools, another perhaps larger issue arose: that of the discretionary decisions that might be made regarding execution of the machining and measurement plans. Tingle explains, “Let’s say that a contractor receives an RFP from a customer, and, due to experience, sees an opportunity to modify the AP238-defined working plan – maybe to execute in three instead of five operations. How does STEP address the matter of sharing insights with the customer and confidentiality? And how might the contractor be rewarded? These are the kinds of business issues to be considered even as the technical aspects of STEP are refined.”

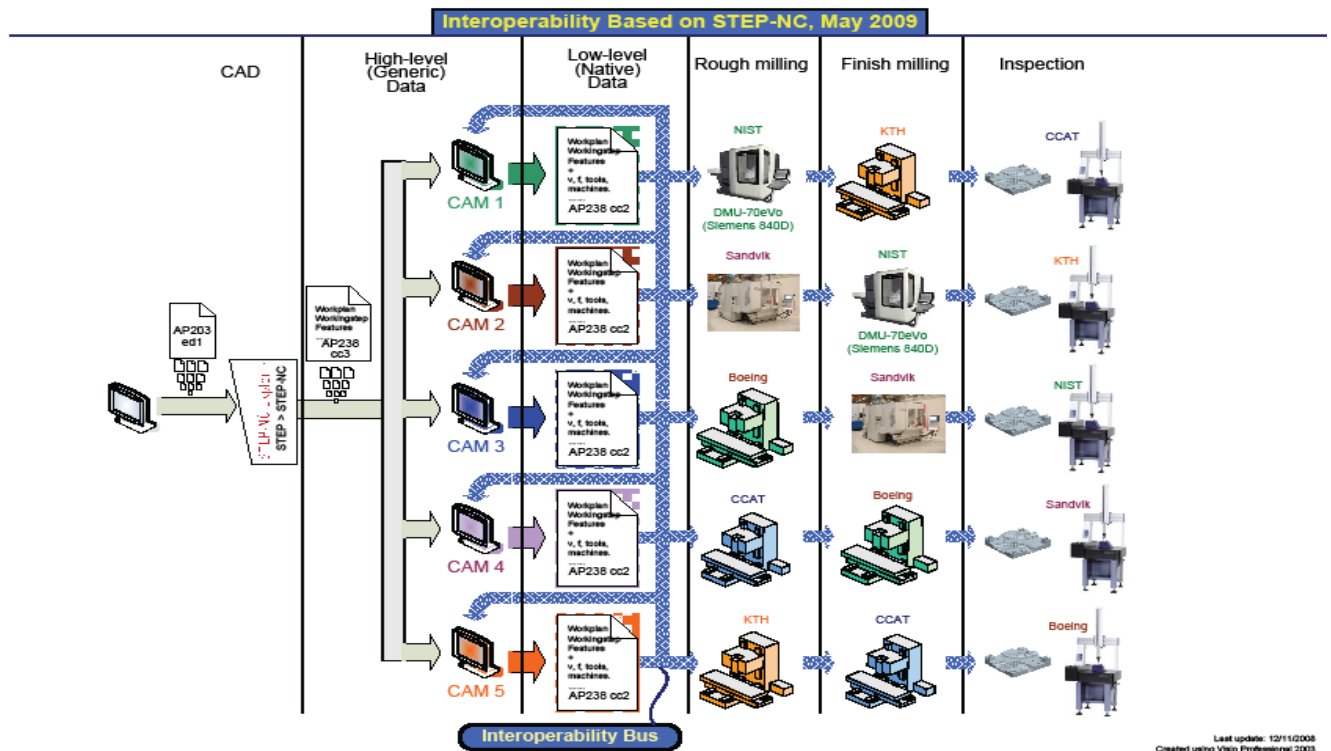
Conclusion

The meeting confirmed that programs authored in both CATIA and Mastercam 9 and saved as STEP-NC AP238 would implement with little problem on GE Fanuc controls as well as on a CMM running under Mitutoyo’s MCOSMOS. Exceptions included instances requiring manual edits to account for Helical tooling, feed-and-speed and to code for tool changes. However, in many cases, AP238 tolerance definitions and working steps can translate and run exactly as written to speed up the process of planning, inspection and manufacturing.

Expressing enthusiasm, Tingle concludes, “AP238 should improve the viability of all types of machining operations – and especially for smaller shops. AP238’s virtual tool-paths, speeds & feeds and inspection plan can reduce or eliminate time that used to be spent to create working steps by reviewing prints and annotations. This will make it much easier and quicker to respond to RFPs and to place bids. Machine manufacturers such as Fanuc, Mitutoyo and others understand that AP238 will provide companies like Boeing with time savings, reduced scrap and lower total costs to help sustain a competitive position in today’s global market.”

Putting the May 14 -15 STEP-NC demonstration into context, Dr. Martin Hardwick, President, STEP Tools, Inc., observes, "We are very pleased with the progress of STEP-NC. The past three years have seen a series of progressively more complex demonstrations at Airbus in Toulouse in June 2006, in Japan in June 2007, at Sandvik Tooling in Sweden in April 2008, at the Connecticut Center for Advanced Technology on the Pratt and Whitney campus in October 2008, and now at Boeing and Mitutoyo in May 2009. These demonstrations show that STEP-NC can be used to machine and measure a wide range of parts. At this latest demonstration, we were able to show that many different sites can take a STEP-NC file and use it to machine a part on different machines with different configurations and tooling." Looking ahead, Hardwick adds, "At our next meeting at the University of Bath in the UK we expect even more sites will be machining the part to show how we have used the lessons learned at Boeing and Mitutoyo to make the data even more portable."

Fig. 1



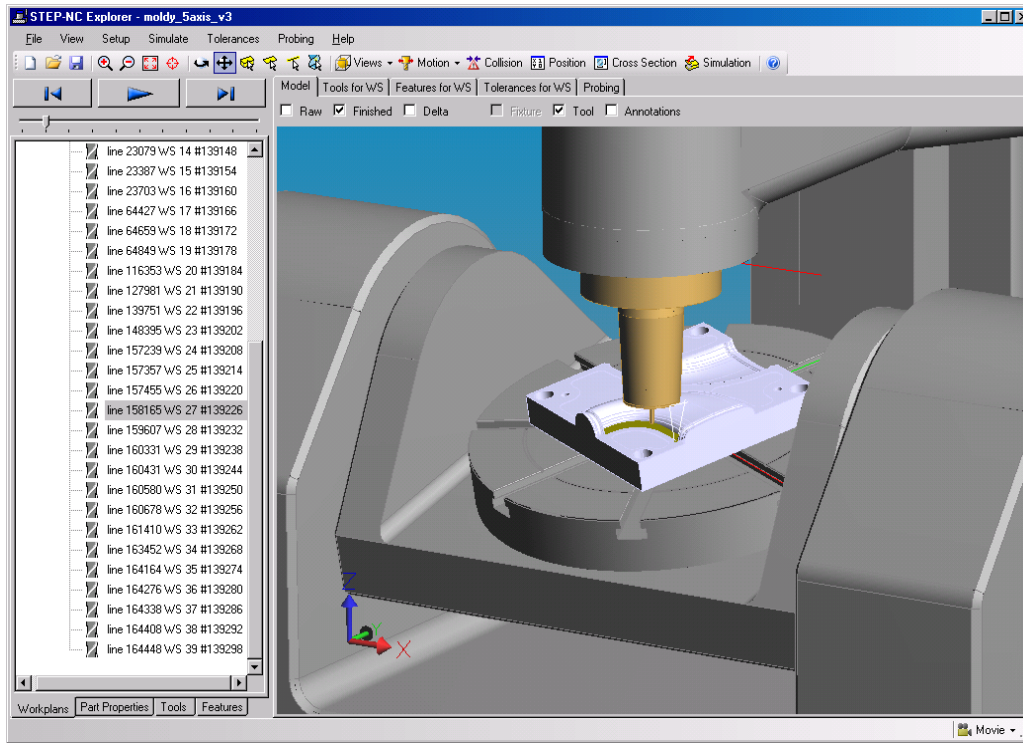


Fig. 2 Subject mold part imaged in STEP-NC Explorer

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