STEP-NC: Smart Data for Smart Machining

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STEP-NC is a new data standard for CNC machining that combines product and process information. The new standard extends the CAD geometry and tolerance data defined by STEP to include CAM tool path data, process data, cutting tool data and volume removal data [1, 2]. The new data is an enabler for new intelligent applications on the CNC control. In this paper we describe the new standard and its applications.

In order to meet different business cases, the new standard is divided into conformance classes. The lowest conformance class enables tool path interoperability. The second conformance class contains conditional programming constructs for closed loop programming. The third includes CAM process data and enables CAM to CAM data exchange. The fourth includes CAD tolerance information and enables quality control applications on the CNC.

STEP-NC has been extensively tested by industry in pilot projects. In the first round of testing, CNC data was made on four different CAM systems and machined on two different five axis controls: one for a AB tool tilt machine and the other for a five axis BC table tilt machine. In the second round of testing, closed loop machining was demonstrated by having multiple CAM systems create STEP-NC programs for the same CNC and having them executed conditionally depending on the results of a probing operation. In the third round of testing, CAM to CAM data exchange was tested by having one CAM system optimize the speeds and feeds of the tool paths generated by another CAM system. In the latest round of testing, drill holes on a five axis aerospace part were tested using CAD tolerance data before counter sinks were drilled in preparation for the final assembly of a wing component.

Figure 1 gives an outline of the STEP-NC information model as an EXPRESS-G diagram [1, 2]. The root of a STEP-NC part program is a project containing a main work plan. Each work plan contains a series of working steps. Each working step applies a machining operation to a manufacturing feature, for example, a rough milling operation to a pocket. The same machining operation may be used in several working steps and several working steps may be necessary to complete a feature. For example, completion of a pocket may require a roughing operation to be followed by a finishing operation. The diagram does not show the details but work plans may be nested, they may be made conditional on the result of probing operations, and they can be organized to run concurrently on machines with multiple cutting heads.

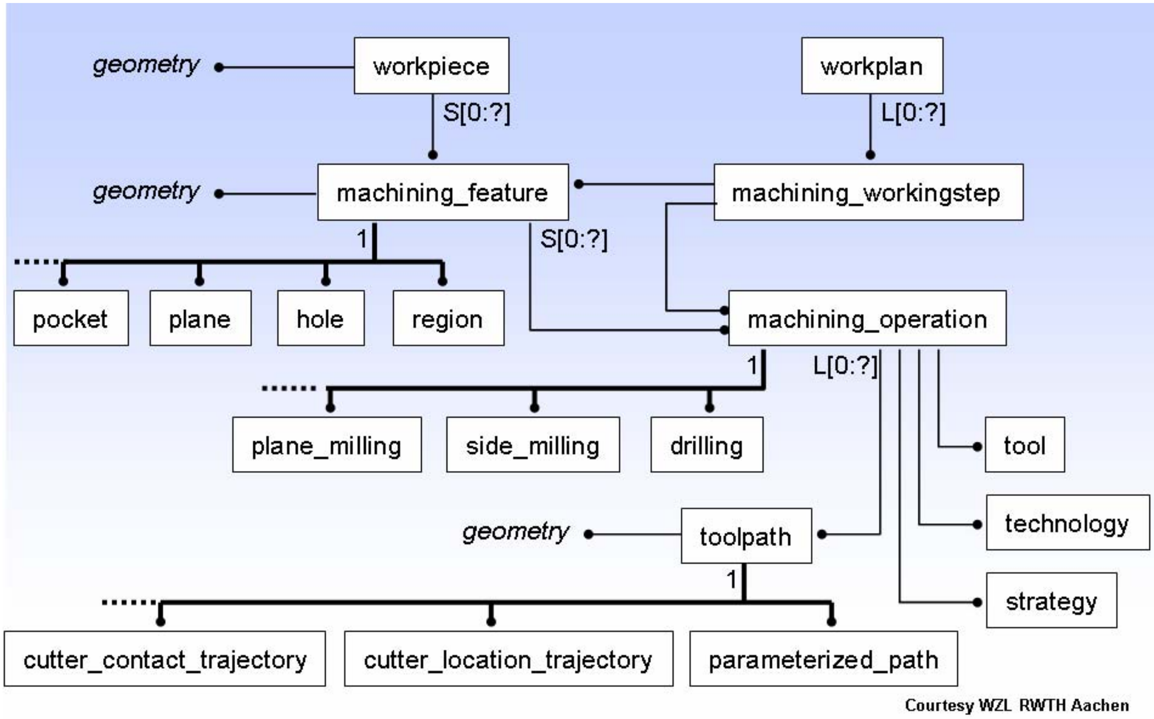

Figure 1. The STEP-NC Information Model

In STEP-NC each operation is linked to all of the other information in the part program by the relationships shown in the diagram. This is one of the key advantages. It means that for any operation an application can find its tooling requirements, the parameters of its feature, the geometry of the feature, the tolerances of the feature and any necessary strategy and technology information. Using this information, algorithms can be written to make CNC machines tool faster to execute and easier to operate.

STEP-NC was started in a joint European and Japanese project. The first model was for the control of CNC milling machines. Other models have been developed for turning, EDM and contour cutting machines, and models are planned for inspection, robotics and composite tape laying. The first developers represented Siemens, the University of Aachen and the University of Stuttgart in Germany, Komatsu and Fanuc in Japan and Heidenhein in Switzerland [3, 4]. The USA joined the project in 2001 and integrated the CNC model with the other STEP standards to enable full data sharing with CAD, CAM, PDM and other types of CAx applications [4].

Figure 2 shows how data is created for a CNC control using traditional methods and the STEP-NC method. In enterprises the job of design is usually performed using a CAD (Computer Aided Design) system, the job of path planning is performed using a CAM (Computer Aided Manufacturing) system, and the job of manufacturing is performed using a CNC (Computerized Numerical Control) system. In many cases the CAD and CAM functions are combined into a single integrated CAD/CAM system but in all cases the CNC function is performed by a separate system.

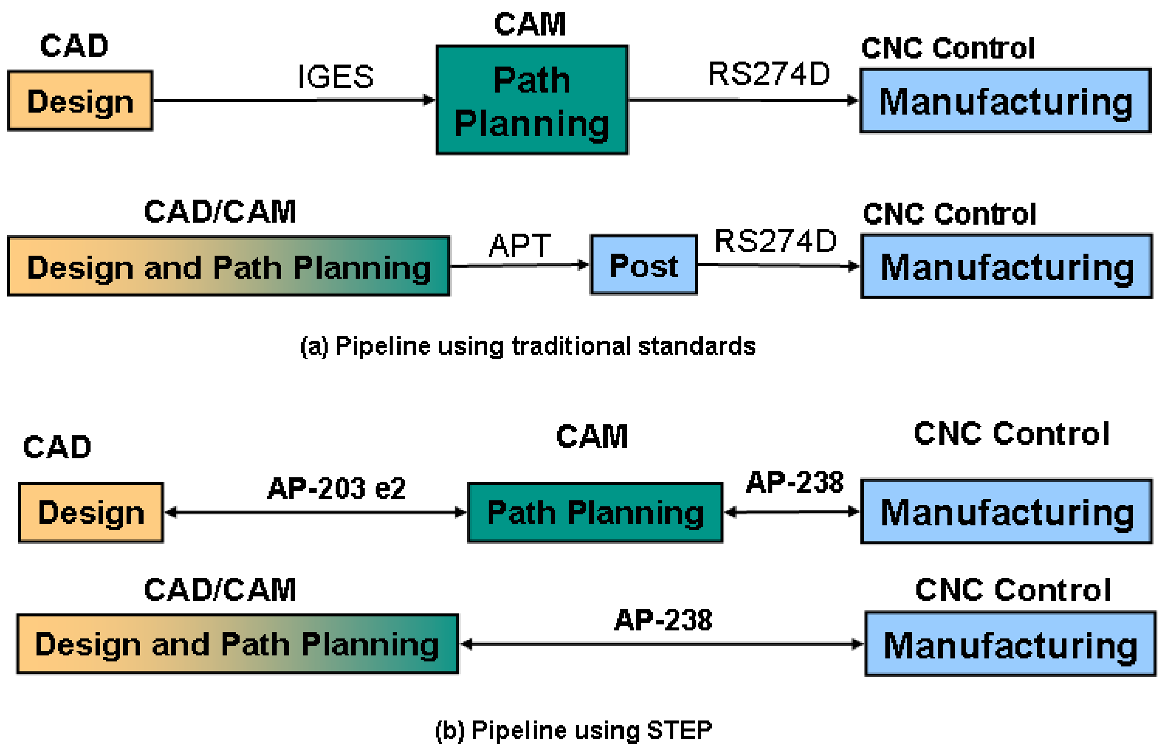

Figure 2. Design to Manufacturing Data Pipelines.

There are many applications that can be made more efficient using STEP-NC. For example, systems such as the Boeing 787 and the Airbus A350 require parts to be machined to higher tolerances with fewer mistakes. Consider the assembly of the structural components for a wing. On the new airframes these components are being made of titanium instead of aluminum. Titanium is stronger so the parts can be smaller and lighter, but this implies that all of the features and tolerances must be smaller if the part is to deliver the same functionality.

Manual checking of the parts by the operators requires a great deal of concentration because every airframe is slightly different. The operator must look at numbers that are in the coordinates of the airframe and detect variances that can be as small as one thousandth of an inch. This is nearly impossible so either a CMM application or a CNC application must be programmed to detect the errors before any assembly operations are started. In an experiment we showed how this could be done on the CNC control if it has STEP-NC data.

Figure 3 shows the architecture of the experiment. As shown the data source was CATIA. Two types of files were exported: an AP-203 edition 2 file containing tolerance data, and an APT-CL file describing the drilling operations. A system was assembled using STEP-NC enabling technology called the STEP-NC DLL. Interfaces in this DLL were used to match the drilling operations in a CNC program that could be RS274D or APT-CL against the cylindrical holes in the AP-203 edition 2 data.

Two STEP-NC programs were generated. The first STEP-NC program tested each hole using a simple touch probe. In the test, four operations were generated for each hole to detect the north, south, east and west boundaries. The second STEP-NC program evaluated the results of the probing. In the test each result was examined to see if the expected value differed from the measured value by more than either the position tolerance or the diameter tolerance. If either tolerance was exceeded then a "code yellow" was generated for this probing operation. If both tolerances were exceeded then a "code red" was generated. If neither was exceeded then the operation was labeled "code green".

The final stage of evaluation was to determine if the holes were correct. In the test a hole was labeled bad ("red") if any of its probing operations were code "red" or if two or more of its probing operations were code "yellow". A more sophisticated algorithm might determine a new location for the hole within the tolerances defined by the AP-203 e2 data. Finally if all the holes were determined to be "code green" then the STEP-NC program proceeded to the next stage and drilled counter sinks for the holes in preparation for final assembly.

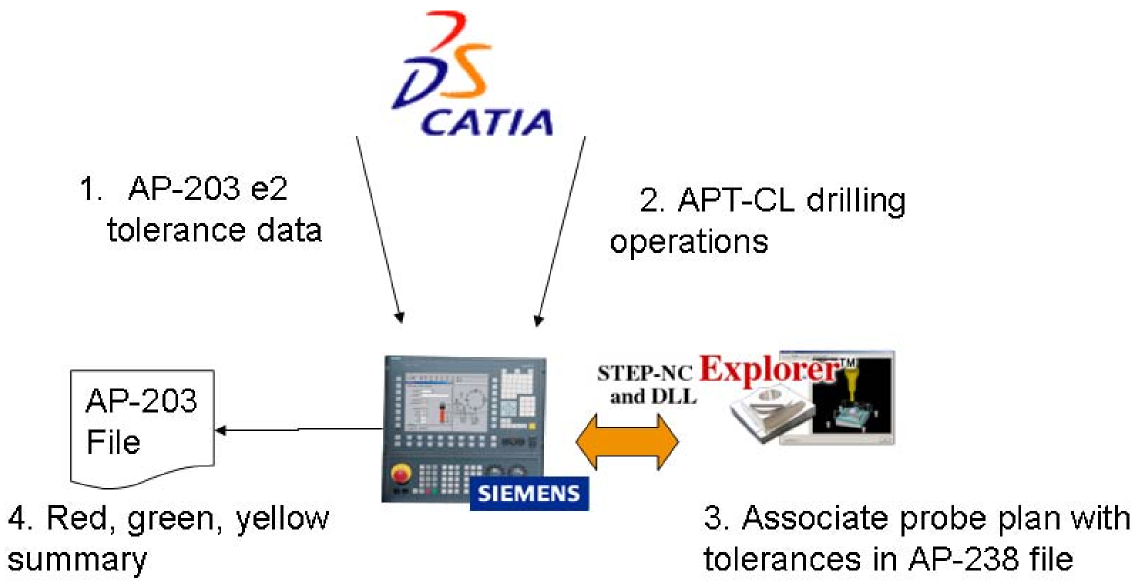

Figure 3. Application to measure tolerances on the CNC using CAD design data.

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[4] M. Hardwick, "On STEP-NC and the complexities of product data integration", ACM/ASME Transactions on Computing and Information Science in Engineering", Vol.4, No1, March 2004.