TESTING STEP-NC IMPLEMENTATIONS*

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ABSTRACT

STEP (STandard for the Exchange of Product model data, ISO 10303) data for numerical control, or STEP-NC, is intended to provide full product and process data interoperability between computer-aided manufacturing systems and machine tool controllers. Numerous prototype and several commercial implementations of STEP-NC are currently being developed. Testing is an essential step toward ensuring conformance to a specification and achieving interoperability between different implementations. Test methods and valid test cases that address specific operational scenarios are vital to speed the development process. This paper describes proposed test methods and metrics, validation methods for test data, and test case development.

KEYWORDS: conformance testing, information technology standards, numerical control, STEP, validation, test methods, test cases, process planning, manufacturing features

INTRODUCTION

STEP (STandard for the Exchange of Product model data, ISO 10303) is an international family of standards designed to enable the exchange of product data between heterogeneous computer systems used throughout the product life cycle[1][2]. The parts of STEP that are implemented in software systems are called Application Protocols (APs). The first STEP AP became an ISO standard in 1994 and subsequently most major CAD vendors have implemented STEP data translation. It is estimated that more than one million computer-aided design (CAD) stations now contain STEP data translators[3].

A new AP within this family, ISO 10303-238 *Application interpreted model for computerized numerical controllers* (AP238)[4] henceforth referred to as "STEP-NC,"

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* Commercial equipment and materials are identified in order to describe certain procedures. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

defines a data exchange standard for computerized numerical control machining (milling, turning, and electric discharge machining). STEP-NC will provide full product and process data interoperability between computer-aided manufacturing systems and machine tool controllers. STEP-NC is being developed under the Model-Driven Intelligent Control of Manufacturing (MDICM) project, a three-year Advanced Technology Program (ATP) project awarded to STEP Tools, Inc. by the National Institute of Standards and Technology (NIST)[3][5].

Numerous prototype and several commercial implementations of STEP-NC are currently being developed. Testing is an essential step toward ensuring conformance to a specification and achieving interoperability between different implementations. Test methods and valid test cases that address specific operational scenarios are vital to speed the development and implementation process. A project within the Manufacturing Engineering Laboratory at NIST is focusing on testing the emerging STEP-NC specification.

This paper describes the scope of STEP-NC, proposed test methods and metrics, test case development, and validation methods for test data. The current status of the STEP-NC effort is also reported.

STEP-NC

The STEP data translation capabilities implemented in CAD systems today primarily support geometric models and configuration management as specified in ISO 10303-203 *Configuration-controlled 3D designs of mechanical parts and assemblies* (AP 203)[6] and ISO 10303-214 *Core data for automotive mechanical design processes* (AP 214)[7]. STEP-NC extends STEP into the manufacturing domain by adding data structures that support computer-aided manufacturing (CAM) and computerized numerical controller (CNC) requirements.

The STEP architecture facilitates sharing of common data structures between STEP APs. For instance, a CAD system may output STEP geometry, design feature, and product identification data in AP 214 format. Manufacturing features may be defined in ISO 10303-224 *Mechanical product definition for process planning using machining features* (AP 224)[8] format. A CAM system may then input that data and use it to develop the detailed process data needed to manufacture the part. The CAM system does not need to redefine the geometry and features because these data structures are shared between APs. The CAM system outputs geometry, features, process sequence, and tool requirement data in STEP-NC format. Because STEP-NC data is intended to be processed at run time, specific machine operations (e.g., cutter paths) are left to the machine controller. This offers some advantages over traditional methods:

- A STEP-NC file contains all the data required to produce a part, therefore, manufacturing operations may be adjusted to maximize production efficiency.
- STEP-NC allows for complete safety checking because safety areas for fixtures can be defined as part of the setup.
- Documentation may be easily generated by the CAM or CNC system to show the state of the part before and after each working step.
- STEP-NC is easy to generate; specific tool paths need not be defined in advance.

- A STEP-NC file is not machine-specific; the STEP-NC file can be manufactured on any machine that meets the tooling requirements.

STEP CONFORMANCE TESTING

The STEP architecture includes standardized test methods and a formalized test case structure[2]. All STEP projects are required to produce test cases that reflect industrial demand for the standard. These test cases are intended to facilitate development of STEP implementations and lay a foundation for conformance testing services once the standard is fully implemented.

Test cases combine preprocessor input specifications that provide realistic examples of domain requirements with postprocessor input specifications that include sample STEP exchange data. The preprocessor and postprocessor input specifications are linked as a mirrored pair. Linking the test data pairs enforces the STEP architectural premise that requirements map into data exchange structures. Test cases include verdict criteria that are used to judge output of the system under test.

At this stage of the STEP-NC project, the impetus behind developing test cases is to validate that the emerging specification is complete and unambiguous and to help speed the development of STEP-NC implementations. The process of developing test cases involves acquiring actual production data and translating it into STEP-NC format. The test case development process will quickly demonstrate any inadequacies in the data structures. Once valid test cases exist, they serve as a reference tool for developers to ensure implementations under development are conforming to the specification. This both greatly reduces development costs of implementations and increases acceptance of the standard itself.

Focus on standards development is a result of an increasing movement away from single-vendor engineering software solutions. Designers and manufacturers have found it advantageous to be able to use the best system available for a given situation. Consequently, neutral format standards are gaining acceptance. However, many systems do not interoperate despite vendor claims of standard implementation. For this reason, as STEP-NC is standardized and implemented, the focus for testing will shift toward more formal conformance and interoperability testing.

STEP-NC CONFORMANCE TESTING METHODS AND METRICS

In the overall process, from art to part, STEP-NC provides the data interface between CAM systems and CNC machine tools (see Figure 1). CAM systems output STEP-NC data while

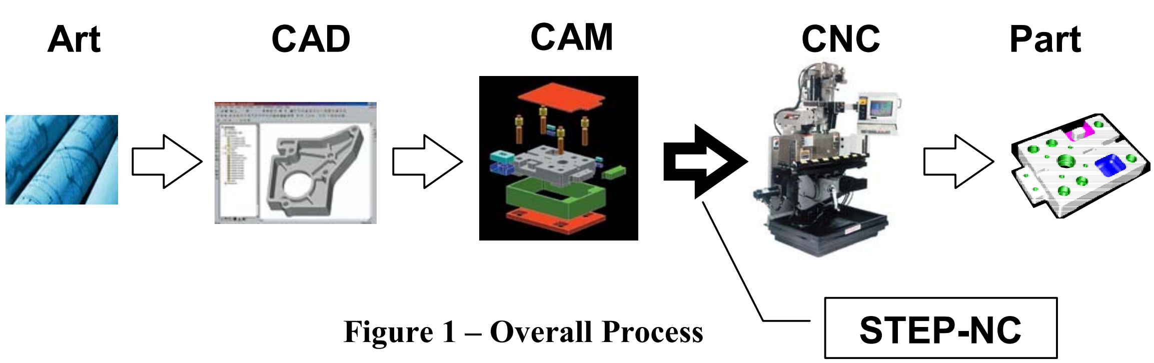

Figure 1 – Overall Process

CNC systems read in STEP-NC data. At present, “data transfer” is accomplished using a physical file in ISO 10303-21 format[9]; data sharing scenarios (i.e., a common database) may be used in the future. Input and output activities must be tested separately.

CAM Testing Methods

CAM is an iterative process most often requiring human interaction. Inputs to the CAM process include part geometry (starting and final), feature information, tooling information, process information, and tolerance requirements. The output of the CAM activity is the STEP-NC data required to process the part.

CAM conformance testing asks the question: is the STEP-NC output correct for the given inputs? In order to make this determination, three things must be evaluated: 1) the syntax of the physical file must conform to the exchange format (e.g., ISO 10303-21); 2) the structure of the physical file must correspond to the structure and constraints (rules) specified in the AP; and 3) the output must be correct for given input. Conformance of STEP-NC output to ISO 10303-21 file format and STEP-NC data models is relatively straightforward to verify with available software.◊ Verification that STEP-NC output is correct (will produce the desired part) for the given design input is much more difficult.

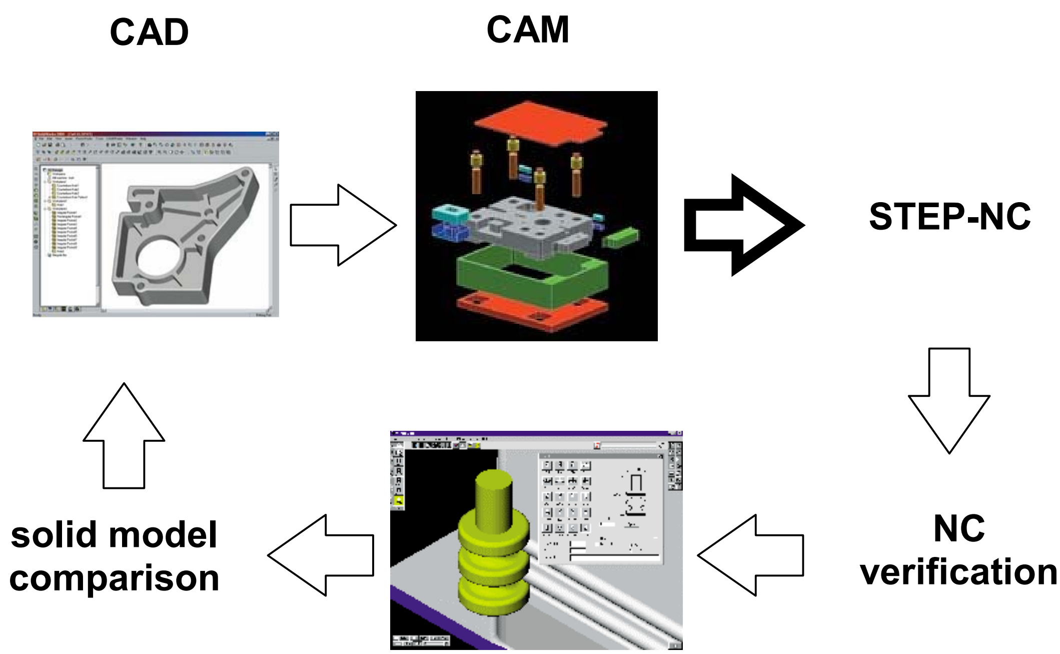

Figure 2 - CAM testing

Verification of output from the CAM process is difficult because there is no unique output for a given input. Independent feature ordering, for example, is arbitrary. Cutter paths may differ, but achieve the same result. Master data sets cannot simply be provided as references

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◊ One such system, Express Engine, originally a NIST-developed tool, is now an open source project. See the Express Engine home page http://sourceforge.net/projects/exp-engine.

– the final result of execution must be evaluated. One proposed solution is solid model NC verification of STEP-NC output against the part design. This strategy compares a solid model generated from a simulated execution of the STEP-NC data with the as-designed solid model (see Figure 2). Model properties, such as surface area, mass, and center of gravity provide a good basis for comparison. Model feature dimensions could also be compared. Comparison of critical feature dimensions to the original design model dimensions would, in a sense provide, a virtual inspection validation of the manufacturing data.

CNC Testing Methods

CNC machining is a more automated process, although tool setting and machine setup (including part fixturing) are manual processes. Inputs are tooling specifications, setup specifications, and processing specifications (STEP-NC). The output of the CNC activity is the machined part.

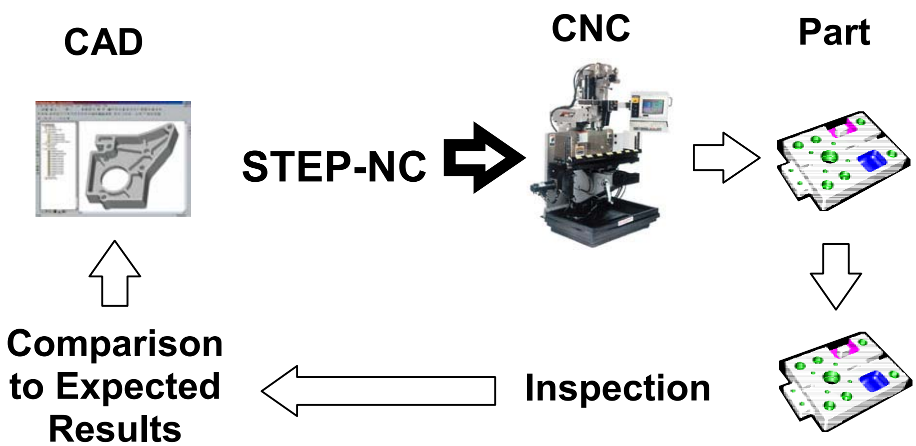

Figure 3 - CNC Testing

CNC conformance testing asks the question: is the part machined correctly for the given STEP-NC input? To verify this, the result of the CNC activity – the part – must be evaluated against the controlling input – the CAD model (see Figure 3). This evaluation may be accomplished by inspecting key features on the part and comparing the inspection results against expected values. Are the features machined as intended? Are the geometry and surface finish within the specified tolerances? Since the accuracy of a machine tool will impact the achievable tolerances, the capabilities of the machine tool used for the test must be taken into account. The test cases for CNC testing will consist of a STEP-NC data set, tooling specifications, and reference data for expected results.

Proper exception handling of the CNC can also be tested. STEP-NC files can be designed that contain exceptions that should be caught by the controller, e.g., syntax errors, STEP-NC data errors, and rule violations. Machine tool controllers that are able to identify data errors can avoid potential damage to the workpiece or tooling.

TEST DATA DEVELOPMENT AND VALIDATION

The quality of test data is critical when building and testing implementations. Application developers are working with NIST to generate STEP-NC test data from pilot implementations of STEP-NC processors. NIST is validating test case data for syntactic and structural correctness against the evolving STEP-NC specification. Semantic constraints declared in the STEP-NC specification can be checked with software and resulting errors are examined by hand to determine the remedy. Errors may indicate flaws in the specification or flaws in the implementation that generated the STEP exchange data. Issues against the specification are being fed back to its authors, and errors introduced into the exchange file by the implementation are reported to the implementers.

STATUS OF STEP-NC EFFORTS

STEP-NC is being standardized within ISO TC 184/SC4 as ISO 10303-238 *Application interpreted model for computerized numerical controllers*. The AP 238 document was delivered to the ISO TC 184/SC4 Secretariat for circulation for a joint New Work Item/Committee Draft ballot late February 2002.

An advanced feature-based CAM system has been implemented by Honeywell. The system was developed under the sponsorship of the Department of Energy and is called FB Mach. Honeywell has enhanced this system under contract to the Super Model project. It can read STEP CAD data (AP 203 or AP 214) and write STEP-NC data. STEP Tools has negotiated a license to market FB Mach as a system called ST-CAM. STEP interpreters for GibbsCAM and Master CAM have recently been developed and will be demonstrated in early 2002. Unigraphics, CATIA and Pro/Engineer CAD systems are all capable of understanding manufacturing features and interfaces to STEP-NC are expected to be included in future versions of these CAD systems.

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