World Engineering Congress 2010, 2nd – 5th August 2010, Kuching, Sarawak, Malaysia
Conference on Manufacturing Technology and Management

CMTM86
THE NEW STANDARD (ISO 14649) TO ADDRESS PROCESS PLANNING AND MACHINING

Yusri Yusof, Nurul Zakiah Zamri Tan, Noordiana Kassim and Mohd Fahrurazi Mohd Nor
Faculty of Mechanical and Manufacturing Engineering
University Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Johor, MALAYSIA
Email: yusri@uthm.edu.my

ABSTRACT
Literatures show that the current CNC is difficult to manage, modify and verify NC data easily. ISO 14649 referred to as STEP-NC is the result of an international effort to achieve full interoperability and bidirectional information exchange throughout the manufacturing network. STEP-NC has been designed in such a way that information remains in its context and without reducing to primitive instructions such as G&M code. This research will explore ISO 6983 (G&M Code) together with ISO 14649 (STEP-NC) and utilize STEP-NC in overcoming the problems of G&M code at the same time take advantage of current advances in computing and controllers. A new STEP NC Code Generator which focuses on the milling process that are able to generate STEP-NC codes based on Example 1 in ISO 14649 Part 12 will be developed. The advantages of the proposed Code Generator program will be verified and evaluated. The Code Generator can understand and generates STEP-NC codes through a STEP-NC compliant interface and will give industries and academician more in-depth of understanding and confidence to switch from G&M code to STEP-NC.

Keywords: *CNC machine, ISO 6983 G&M code, ISO 14649 STEP-NC..*

INTRODUCTION
To stay competitive in today's manufacturing environment, many companies have introduced advanced technologies, and particularly computer based applications, into their business. This is motivated by the belief that advanced technologies such as computer aided design, manufacturing and engineering (CAD/CAM/CAE) combined with effective resources management and improved work force training and education can greatly improve a company's competitiveness and profitability [1]. When we refer to the CNC for the new generation; portability, interoperability and adaptability are the objectives of the system. These objectives can be achieved if the CNC manufacturing "pool" has one open system to utilise CAD, CAPP and CAM software tools to enable CNC manufacturing resources repeatable produce the turn/mill components. Since CNC machines were introduced more than 50 years ago G&M codes have been the common programming language for both in-line and off-line programming but with the advances in computer hardware and software, that programming is becoming the bottleneck for today's global manufacturing [2].

STEP-NC is a new model of data transferred between CAD/CAM systems and CNC machines which replaces G&M codes by specifying machining processes using the object-oriented concept of workingsteps. STEP-NC provides a comprehensive model of the manufacturing process based on an object and feature orientation and describes the machining operations executed on the workpiece, by commands that are not dependent on machine axis motions [3]. STEP-NC will be expected to run on different machine tools or controllers. This compatibility will spare all data adaptations by postprocessors, if the new data model is implemented on the NC controllers. Figure 1 illustrates a global manufacturing pool, and how STEP-NC is envisaged to be used within this approach with different machine tools and localities [4]. STEP-NC contains the required functional information, such as workingstep, machining feature, machining operation, machining tool, machining strategy, machine function and workpiece [5]. In other words, STEP-NC includes much richer information set including "what-to-make" (geometry) and "how-to-make" (process plan). However, G & M code data structure contains only axis movement, some machine and special features. Based on the data model, the STEP-NC part program is represented as a physical file according to ISO 10303 Part 21 [6] Clear Text Encoding Rule. The data section includes all the information about the manufacturing such as process sequence, manufacturing feature, operation type, machining strategy, machining technology, machine function, workpiece and geometry [7]. The reason of STEP-NC establishment is because of the limitation of G & M code.

RELATED WORKS

Xu et al (2004) overview the STEP-NC and ISO 14649 approach to be replace the G & M code [8]. The authors summarize the benefits, potentials, challenges and opportunities that can be achieve from utilization of ISO 14649. Xu et al highlight the frailty of G code which they agree that G & M code is low level data that make data transferability is limited. Xu et al also visualize CAD/CAM scenario in data transfer where user use DFX, IGES and PDES commonly [8, 9]. STEP is use for three reasons which are for data exchange, data sharing and internet collaboration. They also stress standard that has been published and the basic structure of STEP-NC. They agreed that STEP-NC is convincing to enhance process of data transfer, adaptability and overcoming the frailty of G & M code. The authors emphasize three countries are to be the active country with STEP-NC study. The authors pictures the collaboration between end users, controller manufacturer, CAM manufacturer, research institute and other association that those countries made to boost the development of STEP-NC. Challenge issues that pointed out are development of database for STEP-NC supported process, securities issues when data is transfer via internet, resistance from manufacturing industry as G & M code has been used for a long time. It is very advantageous to whom that implemented STEP-NC but will surely excel CAD and Cam vendor can increase their competitiveness by investing in supplying machine tool with STEP-NC. The best point of Xu is by applying STEP-NC is not only reshaping CNC but it is also reshaping the manufacturing industry [10]. Suh et al also agreed that G & M code is low level language without intelligence to machining. It is black box style proprietary that disable user fully access [11]. STEP-NC will be an information highway for e-manufacturing encompassing CAD, CAM and CNC [12]. Xu et al explains the background history of STEP-NC and the structure of it content. With the new breed of technology, STEP-NC will impact the CAD-CAM-CNC supply chain. From the perspective of CNC, the new data model is very significant, providing CNC with all information about "what to make" and "how to make" in the machine tool [13].

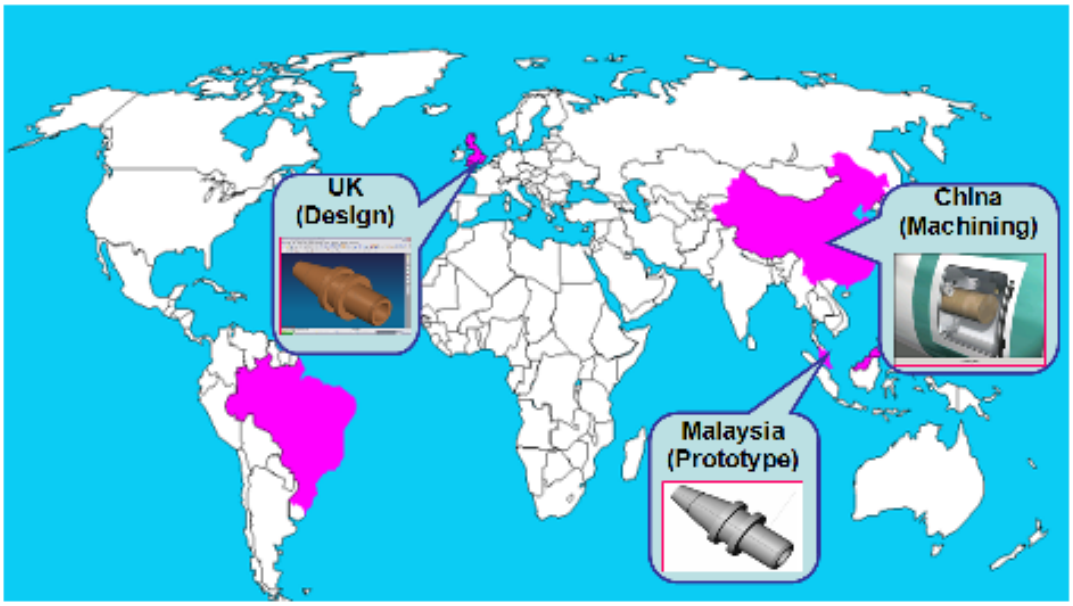

Figure 1: Manufacturing pool with different machine tools and locality

STEP-NC shows some advantages in managing information within supply chain. STEP-NC allows internal and external supply chains to use the same data format and reduces the time needed to do rework in transferring data. The data format contains all information needed to plan manufacturing process and can be optimized in every function in supply chain. STEP-NC makes manufacturing set-up faster and more flexible because there is no need to specify specific machine tools in CAM system. By using information and communication technology, e-collaboration and the e-manufacturing can be easily performed. As a result, the time to market can be shortened, the quality of manufactured product produced using the STEP-NC will be increased, and the cost of manufactured product will be reduced because optimization of the product and the process can be done in every function in supply chain.

In basic production flow, it is started with idea and the design will present in CAD. It then will undergo the CAPP process and analyze using CAM software to generate code and production is run to develop the output. Without using STEP-NC, data transfers is using many standards to change data format, but using STEP-NC data will be only transfer using Protocol AP within STEP framework. Basically without STEP-NC, at each stage operator/programmer have to set or calculate the machining path and data cannot be correct directly. If error

occurs data has to be redesign and generated again. The concept of using STEP-NC is simpler. STEP-NC allows a complete database of machining information to be built around the digital product model [14, 15].
Most of the researchers agreed that STEP-NC gives benefit in term of producing profit to the manufacturing industry. It gives benefit to time and cost when STEP-NC data can be shared and transferred globally through the internet without missing data. STEP-NC is believed to be intelligent manufacturing system with smart data machining. Xu (2005) stressed that STEP-NC provides a complete and structured data model linked with geometrical and technological information [14]. No information is lost between the different stages of the product development process. Its data elements are adequate enough to describe task oriented NC data. The data model is extendable to further technologies and scalable with conformance classes to match the abilities of a specific CAM, SFP or NC. Machining time for small to medium sized job can be reduced a lot because intelligent optimisation can be built into the STEP-NC controllers. Post-processor mechanism will be eliminated, as the interface does not require machine-specific information. Machine tools are safer and more adaptable because STEP-NC is independent from machine tool vendors. Modification at the shop- floor can be saved and fed back to the design department hence bi-directional information flow from CAD/CAM to CNC machines can be achieved. XML files can be used as an information carrier hence enables Web-based distributed manufacturing [16].

DEVELOPMENT OF CODE GENERATOR

This research is important in order to bring a new situation of machining in manufacturing industry especially in Malaysia. As STEP-NC can bring ease and agile data transfer, it is opportunities to develop a system that may compete the old system thus it make variety in manufacturing industry. Other significant of this research is to promote the advantages of STEP-NC. This will open an opportunity to hold cooperation between researcher in university with manufacturing industry, users and CNC maker. Consequently, this research is to bring understand to ISO 14649 fundamental and concept behind it as the standard is the brain to the key in developing software to generate STEP-NC code. To such an extent will bring STEP-NC research in Malaysia to higher level of its knowledge when creating STEP-NC code for other features machining process. Further development of STEP-NC by researchers from academia and industry have focused on the use of complete machining on a single machine for both sides of a turned workpiece without change of clamping tool, turning with milling and eccentric drilling capability, integration of several techniques with complex tools and other procedures parallel processing and synchronization [2]. At UTHM the development of a STEP compliant manufacturing model to support the process planning activity for turn/mill machining was started by Rosso Jr. [17] and continues to be developed by the authors [18]. It refers to elements of ISO 14649 Part 10, 12 and 121 [5, 19, 20] to maximise interoperable information. The overall framework is illustrated in figure 2 and based on the Java programming language. The prototype has been developed using Visual Basic to provide a suite of integrated development tools related to STEP standards. This concept has been used to generate classes from the EXPRESS schema and to handle the STEP Part 21 physical file format [21].

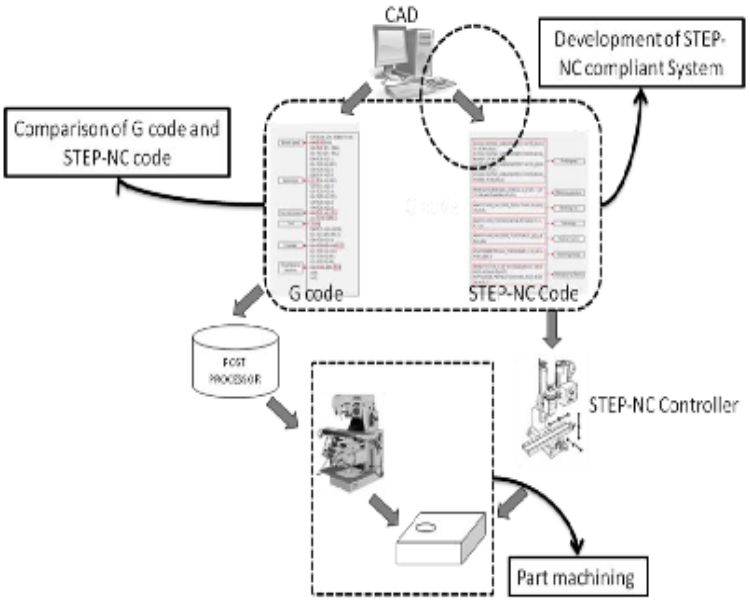

Figure 2: The overall STEP-NC Compliant CAD/CAPP/CAM System

Today complex turn/mill components can be produced on a wide range of turning centre configurations with multi axes, twin spindles and dual turrets. Due to the complexity of programming there is a need to model their process capability to improve the interoperable manufacturing capability on machines such as turning centres. The aim for this work is to address the process planning and machining of turn/mill discrete components and to propose a STEP Compliant NC structure for generation of ISO 14649 code which can be used for interoperable turn/mill component manufacture. A STEP-NC compliant CAD/CAPP/CAM prototype system for turn/mill operations is being developed to consider the complexity of turning centre configurations and is based on the STEP-NC turning features. According to the tasks, the functions of these system are divided to i) workpiece definition, ii) manufacturing feature, iii) turn/mill operation, iv) project & set-up, v) functional/technology, vi) strategies, vii) placements/lengths and viii) tools.

GRAPHIC USER INTERFACE

The GUI (graphical user interface) is the interface between the user and software. The new menu is created with the user interface style, which can be launched. Each case has an appropriate button. The use-cases are launched by the buttons, Create Feature and Write Stepfile. Further use-cases handled in this project are editing and delete feature, handling of technological attributes, reading STEP files and exiting the STEP Turn/Mill system environment. Each button of the menus is connected to a call back-function, which is automatically called when the user executes the associated button. The source code files with these call back functions are created automatically by the user interface. The connection between this procedure-oriented structure and the object-oriented structure of the STEP Turn/Mill system software is materialised by an object of the class, which is known by the callback-functions. Each callback-function calls an appropriate method in this object. In this research, extensive tests with developed software were accomplished. In further transverses through the development cycle the results of the tests were considered, and thereby the structures were optimized and the functionality extended until the requirements were fulfilled. The value of this research work is highlighted by the use of the case study, with the STEP-NC data representation of a standard turning component. The example shown has been designed and based on ISO 14649 Part 12 having 7 machining features. This model forms the basis for further work on a STEP-NC compliant information structure to support both turning and milling operations on NC turning centres. Figure 3, represents the input screen interface that was developed for the prototype system. After studying the STEP-NC code for round hole that are listed in Example 1 ISO 14649 Part 12, the required inputs are classified and categorized into for main groups, which are the main section, round hole section, drilling section and reaming section. For the initial prototype, lots of inputs were required from the user side.

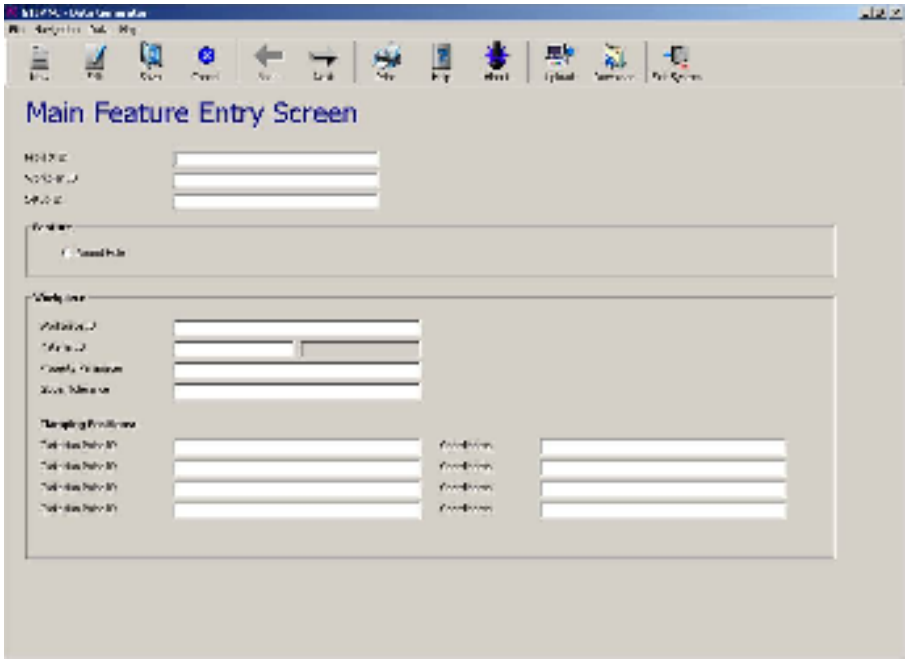

Figure 3: Input from the Prototype System

Based on the inputs provided, a prototype system that can manipulate the inputs to form a full STEP-NC code for round hole, identical to the one provided by Example 1 ISO 14649 Part 12 will be developed. The coding structure that points one entity to another in a recursive way will be structured.

SUMMARY

This paper summarized the current CAPP and CAM systems related to STEP-NC that have been created by other researchers and the development of a STEP-NC compliant CAD/CAPP/CAM system that is currently being implemented by the authors. STEP-NC forms a possible basis to satisfy the latest requirements and demands with respect to a bi-directional CAx process chain for machining. ISO 6983 or G&M Code has been used in manufacturing industries more than long enough that it lacks the capabilities to integrate and assimilate with the advancement of current development and technology. ISO 14649 or STEP-NC is the solution that was developed by the ISO community to overcome the drawbacks of G&M Code. The advantages of the proposed Code Generator that can understand and generates STEP-NC codes through a STEP-NC compliant interface and hopefully will give industries and academician more in-depth of understanding and confidence to switch from G&M code to STEP-NC. In addition its development as a future manufacturing platform to enable different process models to be integrated for the adaptable integration of CAD/CAPP/CAM and CNC will be a major avenue of research for years to come.

ACKNOWLEDGEMENT

This research is supported under Graduate Incentive Grant (GIS), University Tun Hussein Onn Malaysia (UTHM) and Ministry of Science, Technology & Innovation, Malaysia under Sciencefund Grant. Malaysia. Thanks to all team members for every support provided.

REFERENCES

[1] NIST Manufacturing Systems Environment project report http://www.mel.nist.gov/msidlibrary/doc/sima-study/bakstud1.htm Dated accessed 20th April, 2006.,

[2] Newman, S.T., A. Nassehi, X.W. Xu, R.S.U. Rosso Jr, L. Wang, Y. Yusof, L. Ali, R. Liu, L.Y. Zheng, S. Kumar, P. Vichare, and V. Dhokia, Strategic advantages of interoperability for global manufacturing using CNC technology. Robotics and Computer-Integrated Manufacturing, 2008. 24(6): p. 699-708.

[3] Xu, X.W. and S.T. Newman, Making CNC machine tools more open, interoperable and intelligent--a review of the technologies. Computers in Industry, 2006. 57(2): p. 141-152.

[4] Yusof, Y., S.T. Newman, and K. Case. Machining of rotational asymmetric components with a single turning centre. in Proceedings of the 8th Biennial ASME Conference on Engineering Systems Design and Analysis, ESDA2006. 2006. Torino, Italy.1-9.

[5] ISO, International Standard 14649-10: Part 10 : Industrial automation system and integration - Physical device control - Data model for computerised numerical controllers - Part 10 : General process data. 2004.

[6] ISO, International Organization for Standardisation - ISO 10303-Part 21 Industrial automation systems and integration - Product data representation and exchange - Part 21: Implementation methods: Clear text encoding of the exchange structure. 2002.

[7] Heusinger, S., R.S.U. Rosso-Jr, P. Klemm, S.T. Newman, and S. Rahimifard, Integrating the CAx Process Chain for STEP-Compliant NC Manufacturing of Asymmetric Parts. International Journal of Computer Integrated Manufacturing, 2006. 19(6): p. 533-545.

[8] Xu, X.W. and Q. He, Striving for a total integration of CAD, CAPP, CAM and CNC. Robotics and Computer-Integrated Manufacturing, 2004. 20(2): p. 101-109.

[9] Xu, X.W., Realization of STEP-NC enabled machining. Robotics and Computer-Integrated Manufacturing, 2006. 22(2): p. 144-153.

[10] Xu, X.W., L. Wang, and Y. Rong, STEP-NC and function blocks for interoperable manufacturing. IEEE Transactions on Automation Science and Engineering, 2006. 3(July): p. 297-308.

[11] Suh, S.H., B.E. Lee, D.H. Chung, and S.U. Cheon, Architecture and implementation of a shop-floor programming system for STEP-compliant CNC. Computer-Aided Design, 2003. 35(12): p. 1069-1083.

[12] Suh, S.-H. and B.E. Lee. STEP-Manufacturing roadmap. in Proceedings of the 2004 Society of CAD/CAM Engineers. 2004. Kangwon, Korea.

[13] Xu, X.W., P. Klemm, F.M. Proctor, and S.H. Suh, STEP-Compliant Process Planning and Manufacturing. International Journal of Computer Integrated Manufacturing, 2006. 19(6): p. 491-494.

[14] Xu, X.W., H. Wang, J. Mao, S.T. Newman, T.R. Kramer, F.M. Proctor, and J.L. Michaloski, STEP-Compliant NC Research: The search for Intelligent CAD/CAPP/CAM/CNC Integration. International Journal of Production Research, 2005. 43(17): p. 3703-3743.

[15] Newman, S.T., A. Nassehi, X.W. Xu, R.S.U. Rosso-Jr, L. Wang, Y. Yusof, L. Ali, R. Liu, L. Zheng, S. Kumar, P. Vichare, and V. Dhokia. Interoperable CNC for Global Manufacturing (Keynote paper). in Flexible Automation and Intelligent Manufacturing, FAIM2007. 2007. Philadelphia, USA.1-13.

[16] Qiu, X. and X. Xu, Information Sharing in Digital Manufacturing Based on STEP and XML, in Collaborative Design and Planning for Digital Manufacturing. 2009. p. 293-316.

[17] Rosso-Jr, R.S.U., STEP Compliant CAD/CAPP/CAM System For Rotational Asymmetric Parts, in Wolfson School of Mechanical and Manufacturing Engineering. 2005, Loughborough: Loughborough, UK. p. 176.

[18] Yusof, Y., S.T. Newman, A. Nassehi, and K. Case. Interoperable CNC System for Turning Operations. in Proceedings of World Academy of Science, Engineering and Technology. 2009. Dubai, UAE.941-947.

[19] ISO, International Standard 14649-12: Part 12 : Industrial automation system and integration - Physical device control - Data model for computerised numerical controllers - Part 12 : Process data for turning. 2005.

[20] ISO, International Standard 14649-121: Part 121 : Industrial automation system and integration - Physical device control - Data model for computerised numerical controllers -Part 121: Tools for Turning Machines. 2005.

[21] Yusof, Y., K. Case, S.T. Newman, and X.W. Xu. A STEP Compliant System for Turning Operations. in 17th International Conference on Flexible Automation and Intelligent Manufacturing (2007 FAIM). 2007. Philadelphia, USA.140-147.