TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
MECHANICS | MECHANIKA
1-M/2013

JANUSZ POBOŻNIAK*

THE USE OF STEP-NC (ISO 14649) FOR THE INTEGRATION OF CAD/CAM/CNC CHAIN

ZASTOSOWANIE STANDARDU STEP-NC (ISO 14649) W INTEGRACJI ŁAŃCUCHA CAD/CAM/CNC

A b s t r a c t

The paper presents the information flow between CAD/CAM/CNC systems when using the CNC machine tool programming language based on ISO 6983. Next, the data structure of the new programming standard STEP-NC, defined in ISO 14649, is presented. The information flow for this new standard is also discussed. The results of analysis show how this standard can be used for the increase of the automation of CNC machine tool programming.

Keywords: *STEP*, *STEP-NC*, *process planning*, *CAD/CAPP/CAM/CNC*

S t r e s z c z e n i e

W artykule przeanalizowano przepływ informacji pomiędzy systemami CAD/CAM/CNC przy korzystaniu z języka programowania obrabiarek CNC opartego na normie ISO 6983. Następnie scharakteryzowano strukturę danych w nowym standardzie programowania OSN STEP-NC, zdefiniowanym w normie ISO 14649 i również przeprowadzono dla tego standardu analizę przepływu informacji. Uzyskane wyniki analizy wskazują, w jaki sposób można wykorzystać ten standard do dalszej automatyzacji programowania obrabiarek sterowanych numerycznie.

Słowa kluczowe: *STEP*, *STEP-NC*, *projektowanie procesów*, *CAD/CAPP/CAM/CNC*

* PhD. Janusz Pobożniak, Production Engineering Institute, Faculty of Mechanical Engineering, Cracow University of Technology.

1. Information flow in the CAD/CAM/CNC for machine tool programming language based on ISO 6983

CNC machine tool programming language defined in ISO 6983 [6] is still widely used despite the fact, the it was not fundamentally changed since more than 50 years. Generally speaking, the ISO 6983 control program contains (only) three basic groups of information:
– data about the required position of the tool relative to the machined part (for example G00 – linear interpolation in rapid travel, G02 – clockwise circular interpolation),
– data about the relation between the tool and part during the material removal (for example S960 – cutting speed of 960 m/min, F160 – feedrate of 160 mm/min),
– data controlling the auxiliary functions (like M03 – spindle clockwise rotation, M08 – coolant flow on).

The main purpose of ISO 6983 language is to describe the tool trajectory and not the machining tasks for the part. Now, the model created in CAD system is usually used by the CAM system for machining tool programming. The nowadays CAM systems are very advanced [8, 10]. They analyse the part not on the level of the basic geometric primitives like points and lines, but on the level of the elements useful from the manufacturing point of view, i.e. machining features [7]. Slot, open pocket, closed pocket or counterbored hole can be given as examples. CAM systems are able to automatically select the appropriate machining cycles for the automatically recognised manufacturing features. During the CNC program development, the manufacturing engineer can use the sophisticated databases of the cutting tools. Before execution of the program on the real machine tool, it can be simulated using the model of this machine tool. Unfortunately, the ISO 6983 program, containing mainly G and M functions does not include all the information about the machined part, manufacturing features, defined machining cycles or the manufacturing recourses. All machining cycles, as for example deep hole drilling cycle or pocket milling cycles are transformed into the series of elementary motions. It is not possible to make the reverse transformation, i.e. to convert the elementary motions into the machining cycles. As the results, ISO 6983 program does not include the structure created in CAM system and it is not possible to make any changes, even the simplest one, as the change of the cutting depth. So, the decision taken during the program development can not be later changed on the stage of the program trial runs, because the high-level information is transformed into the elementary movement of the controlled axes.

All the part information modelled in CAD system, and then enhanced by the manufacturing data describing the machining processes and the manufacturing equipment are significantly reduced when sending to CNC system (Fig. 1).

Also the information about the cutting tools selected for the machining is lost. CAM systems allow to select tool bodies, cutting inserts as well as tool holders. Not only geometric parameters can be defined, but also 3D models can be used. Very often, the cutting tool manufactures offers such 3D models, as for example Sandvik Coromant. These exact models allow to exactly check the amount of materials still remaining on the part, the amount of material removed due to programming errors or the find all collisions between the tools and part. In ISO 6983 program, the tool is represented only by number. The machine tool operator must have the additional documentation to start the production. This proofs once again the lack of information in ISO 6983 programs. The program processed by postprocessor is tailored for the given combination of machine tool/CNC control system and thus looses its flexibility. This is due to the fact, the modern machine tools have a lot of functions not covered by ISO 6983. To use the full functionality of the machine tools, the manufactures introduce own addresses as well as preparatory and auxiliary functions. Although such solution is efficient, it blocks the flexibility and restricts the area of the use of the program.

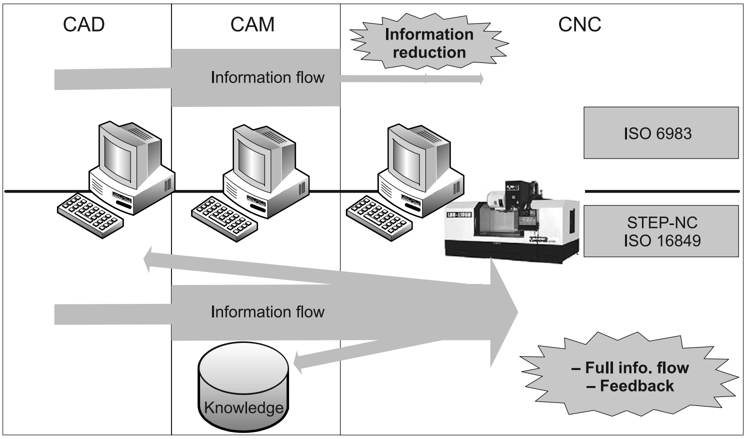

Fig. 1. Comparison of CNC machine tool programming with ISO 6983 and STEP-NC

Rys. 1. Porównanie programowania OSN wg normy ISO 6983 i normy STEP-NC

The other problem is the number of postprocessor, resulting from the rich set of CNC control systems available on the market. The primary concern of every persons starting the work with new CAM system is to find the appropriate postprocessor. The modification of ISO 6983 language introduced by CNC control system manufactures resulted in the hundreds of its dialects. Because the CAM system producers can not deliver the postprocessors to all control systems, the postprocessors are created on its own using CAM system tools or delivered on demand by specialized companies. One thing is sure, it does not simplify the operation of the manufacturing department.

Summarizing, the main disadvantage of ISO 6983 control program is the reduction of information available in CAM system, lack of cooperation with CAD/CAM and unidirectional flow of information. Usually, it is not possible to change the destination of the ISO 6983 program developed for the particular machine tool. ISO 6983 program is definitively the link breaking the CAD/CAM/CNC chain.

2. ISO 14649 standard (STEP-NC)

STEP, the Standard for the Exchange of Product Model Data (ISO 10303) is a complete and the unambiguous product data description throughout its life cycle [1]. STEP-NC is the application of STEP into the CNC machine tool programming. Unlike the ISO 6983 standard describing the tool motions relative to the part and informing "how to make" that part, STEP--NC standard informs "what to do", describes the sequence of machining cycles, tool path style, the required accuracy and the tools. The STEP-NC concept uses the manufacturing features.

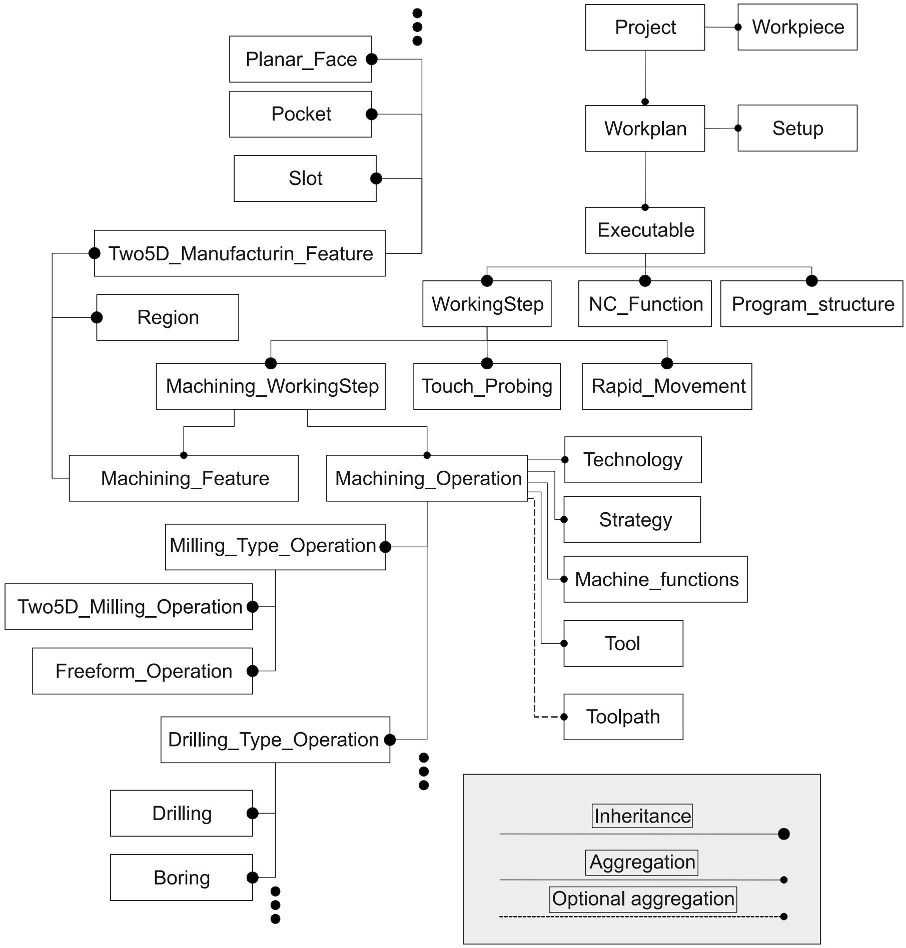

Fig. 2. The simplified view of STEP-NC data structure

Rys. 2. Poglądowy model danych standardu STEP-NC

Fig. 2. presents the simplified, object data model of STEP-NC. The inheritance, aggregation and optional aggregation relations should be noted on this scheme. The top element is Project object. This object has assigned the data about the project owner, versions, status and machined part information. Apart from the basic information like material or tolerance class, also the complete B-Rep representation of the machine part can be optionally stored. This is the option, as the part is described using manufacturing features. The Workplan is assigned to

Project. Then the Setup is assigned to Workplan. The list of so called Executables representing the machine tool activities is also assigned to the workplan. The inheritance relations distinguish three types of executables, namely working steps (WorkingStep), auxiliary NC functions (NC_Function, activity of machine tool does not moving the interpolated axis, as conditional stop, program stop, etc.) and control structure (Program_structure) deciding about the execution of executables based on the state of given conditions. Program_structure object allows for example to run executables in parallel. This is important in case of multipath machine tools. The WorkingStep blocks are the basic elements of STEP-NC standards. They describe the actions using the numerical controlled axes of machine tools. The can represent rapid linear movement (Rapid_Movement), measuring cycles (Touch_Probing) or machining blocks (Machining_WorkingStep) removing the material from the part. In the later case, WorkingStep define the relations between manufacturing feature (Machining_Feature) and its machining cycle (Machining_Operation). If the particular machining feature requires more than one machining cycle, the workplan has appropriate number of machining blocks (one for each machining cycle).

Each machining cycle has assigned the objects representing cutting parameters (Technology), machining strategy (Strategy), the state of the auxiliary machine tool functions (Machine_functions) and the optional toolpath (Toolpath). Technology object can represent such information like feed, cutting speed, spindle rotational speed, spindle synchronization, disable of feed and speed override, etc. Strategy object can represent such information like feed reduction on the beginning of the cutting movement, selection of conventional/climbing milling, distance between paths, etc. Machine_functions object is used to turn on the coolant, set the cooling fluid pressure system, start the chip removal, etc.

Object representing the tool contains the information about the tool holder, the list of cutting inserts, the total length of tool assembly, etc. The information about the material and the tool life management data are assigned to cutting insert objects. Despite this information, it seems that the B-Rep representation of the tool, with the categorization into cutting and non-cutting parts is missing. Of course, such B-Rep models can be created but will be stored outside of the STEP-NC file. This will increase the self documentary advantages of this format. The optional toolpath can be assigned to Machinining_operation object. The program send to CNC control system does not include the toolpath, it is generated by the procedures of CNC control system, based on the information about the machining tasks included in this STEP-NC file. Nevertheless, in the interim period, to facilitate the introduction of this new standard, CAM system can store the explicit tool path. This releases CNC from its generation.

The objects representing the machining cycles are categorized based on the machining method. Each machining method is the subject of the separate STEP-NC standard part. Now the standard parts for milling [4] and turning [5] are available. Within the milling, the milling and drilling cycles are distinguished. Milling cycles are divided into the 2.5D machining cycles requiring the simultaneous interpolation of two numerical controlled axes and the surface milling cycles requiring the simultaneous interpolation of at least 3 axes.

Manufacturing feature is assigned to each Machining_WorkingStep. Two groups of features were distinguished. The first is related to the freeform surfaces (Region), while the second to 2.5D machining features. The representation of the manufacturing feature is similar to common solutions [9].

3. Information flow in the CAD/CAM/CNC chain for machine tool programming language based on STEP-NC

Because STEP-NC does not describe "how to do" (as ISO 6983 programming language), but "what to do", CNC control systems can intelligently optimize the control program. They decide alone how to convert machining task into the movement of the numerical controlled axes. The way of machining can be changed "online" by the CNC control system, using the real-time feedback information. The introduced changes can be sent back to CAM system and stored in the library of standard machining processes for further reuse. This creates the mechanism for update and expansion of the manufacturing knowledge used by CAM system. Bidirectional communication with STEP-NC does not break the continuity of CAM/CNC chain. Furthermore, the same mechanism can be used to sent back the changes introduced by the machine tool operator (Fig. 1).

STEP-NC includes the full description of the machining task. There is a lot of information about the cutting tool available, not only the short mysterious word like T0101. The file contains also the description of the machined part. This includes not only the geometry definition, but also all manufacturing information like shape and location tolerances or the material hardness. Optional, also the definition of the raw material can be added, depending on the conformance class. STEP-NC program taken from the repository after several months can by analyzed (of course using software) and no additional documentation is needed.

The complete part description in STEP-NC standard is one of the most important attributes of this solution as it allows to further automate CNC machine tool programming. The lack of such description in computer readable form was one of the reasons blocking the entrance to the next level of CAM system automation. Having such information, CAM system can offer additional, new functions, releasing the time of the manufacturing engineers. The use of manufacturing feature oriented product data representation can be given as the example. Based on such feature representation of product data, including the non-geometry information like tolerances and material properties, advanced CAM systems can automatically select the appropriate machining cycles and establish their order. They can use the manufacturing knowledge databases also based on these features. Additionally, the experiences gathered during the actual machining, as the received surface quality, can be directly stored in the manufacturing knowledge database, for example as facts in the form "machining parameters – machining cycle – feature geometry". These facts can be used during the generation of the next CNC machining programs. This guarantees the direct integration of CAM/CNC systems.

Summarizing, STEP-NC integrates CAD/CAM/CNC chain and allows to create the feedback loop to upstream systems.

4. Conclusions

There is a number of obstacles blocking the implementation of STEP-NC in industry: the costs of the investment in this new technology, lack of commercial CNC systems based on STEP-NC and proved in industry environment, as well as reluctance of the people used to employ the traditional approaches. Nevertheless, taking into the account the functionality of STEP-NC, especially related to CAD/CAM/CNC integration, no reduction of information to downstream systems as well as feedback loop, it seems that this is the solution of the future. The complete set of information about the CNC machine tool programming task and the working environment, including the feature based part description and the tool database can be used for the further automation of CNC machine tool programming. The author used the presented analysis of STEP-NC and its functionality as the base for the continuation of works related to the automation of manufacturing production preparation, using the STEP-NC as one of the basic elements.

References

[1] ISO 10303-1:1994 Industrial automation systems and integration – Product data representation and exchange – Part 1: Overview and fundamental principles, 1994.

[2] ISO 10303-203:2011 Industrial automation systems and integration – Product data representation and exchange – Part 203: Application protocol: Configuration controlled 3D design of mechanical parts and assemblies, 2011.

[3] ISO 14649-10. 2004. Industrial automation systems and integration – Physical device control – Data model for computerized numerical controllers – Part 10: General process data, 2004.

[4] ISO 14649-11:2004 Industrial automation systems and integration – Physical device control – Data model for computerized numerical controllers – Part 11: Process data for milling, 2004.

[5] ISO 14649-12:2005 Industrial automation systems and integration – Physical device control – Data model for computerized numerical controllers – Part 12: Process data for turning, 2005.

[6] ISO 6983-1:2009 Numerical Control of Machines – Program Format and Definition of Address Words – Part 1: Data Format for Positioning, Line Motion and Contouring Control Systems, 2009.

[7] Nikiel G., *Wymiana danych geometrycznych w komputerowo wspomaganym projektowaniu i wytwarzaniu*, Mechanik, No. 2/2010, 2010, 125-127.

[8] Pobożniak J., *Programowanie obrabiarek sterowanych numerycznie w systemie CAD/CAM Catia*, Helion, 2013 (w przygotowaniu do druku).

[9] Pobożniak J., *Two stage approach to feature recognition for Computer Aided Process Planning*, Advances in Manufacturing and Science Technology, Vol. 29, No. 4, 2005, 33-43.

[10] Stryczek R., Pytlak B., *Elastyczne programowanie obrabiarek*, Wydawnictwo Naukowe PWN, Warszawa 2011.