

APPLICATION OF STEP-NC IN THE INTEGRATION CAx AND CNC SYSTEMS: CASE STUDIES

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Received (05.01.2016); *Revised* (22.02.2016); *Accepted* (24.02.2016)

Abstract: The paper describes possibility of implementation the STEP-NC in process planning for CNC machining, and integration of CAx and CNC systems. Proposed are two variants of possible applying, with verification on example. As software for the realization of CAD/CAM activities were used Pro/E and Catia, while for generate STEP-NC programs and management information to process used software STEP-NC Machine.

Key words: CAD/CAM, STEP-NC, STEP-NC Machine, Process planning, NC program

1. INTRODUCTION

From the beginning of the 19th century under influence of the industrial revolution, it came to major changes in production systems. From the viewpoint of machine tools, the main revolution was the emergence of computer numerical control (CNC). On this way, created path to fulfillment basic goals of numerically controlled production referring to compliant, fast, efficient and automated obtaining NC program [1].

Most of today's CNC machine tools control units is based on the use of G-codes, i.e programming language, which is standardized under ISO 6983 standard, which is not significantly changed since it's inception, more than 50 years. Due to various changes in the production environment, there are significant disadvantages in the implementation of ISO 6983, as well as [2]:

- Programming language is the low level information oriented instruction movement of the cutting tool (CL data), and on/off instructions (M commands),
- Syntax programs have more semantics signification,
- Specific extensions of individual producers control units, which affects on the need for the application of a large number of different postprocessors for specific machine tools,
- Unidirectional flow of information from design to manufacturing, and others.

Consequently, CNC machine tool can only accept the corresponding specific control information which makes it difficult flexibility and interoperability information for production within the framework of a globalized industry [3]. Due to the above mentioned has started development of STEP-NC standard (*Standard for Product Model Data Exchange for Numerical Control*) for exchange information between CAD/CAPP/CAM/CAE systems and CNC control units [4]. STEP-NC standard (which consists of ISO 10303 AP 238 and ISO 14649) is a STEP compliant interface data for numerical control. STEP-NC data model provides a hierarchical data models for CNC machine tools for turning, milling, EDM, etc. [4,5].

In this paper are presented two case studies of application STEP-NC in process planning for CNC machining, namely for integration of CAx and CNC systems for current production conditions of domestic industry.

2. VARIANTS OF APPLYING STEP-NC

Based on previous research in the field of STEP-NC [6,7,8], there are two case studies (I and II). For applying both case studies are essential appropriate softwares and CNC machining systems. At this point, a complete applying programming methods based on STEP-NC data protocol because the resources for it's development are owned by several research centers [8].

The first case study refers to the possibility of applying the native STEP-NC programs that are developed by STEPTools's [9], second case study refers to modeling, process planning, generating NC programs and machining own products or parts, using a commercial CAD/CAM systems and software *STEP-NC Machine*.

2.1. Case study I

In order to implement the first case study, it is necessary to download some of the native STEP-NC files from the website [9]. Available original models, which are located on the website of manufacturer's software STEP-NC Machine and are shown in Figure 1, while the verification in this study used a model 1e.

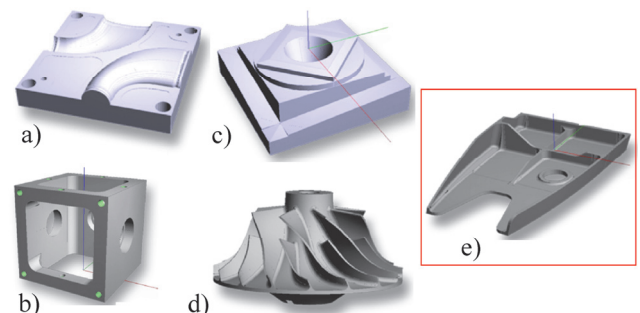


Fig.1. Available native models [9]

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Native STEP-NC program are loaded in software *STEP-NC Machine*, in which are analyzed applied manufacturing technology of observed part. Manufacturing technology includes analysis of the defined rawpiece, processing plan, clamping plan, analysis of applied cutting tools, fixtures, and also simulation of machining on available virtual machine tools, which are available in database of the mentioned software. Within above mentioned software, obtained STEP-NC program can be directly exported and applied to a machine tool with a numerical control unit that supports the STEP-NC program (individual numerical control units of new generation), or can be performed generating NC program in the form of G-codes for numerical controls units for which existed a postprocessor in software database, Figure 2.

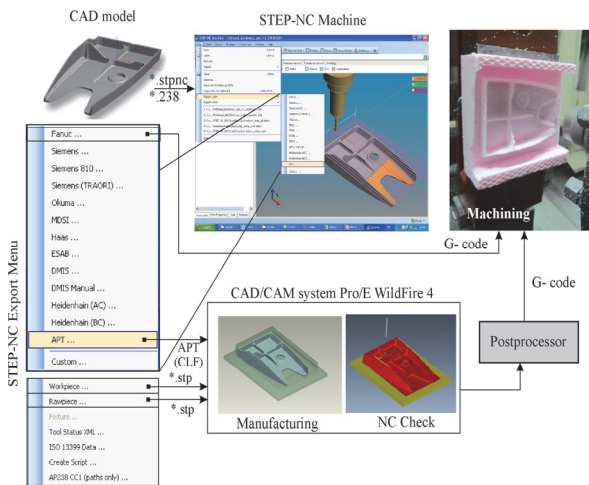


Fig.2. Procedures for the export code in software *STEP-NC Machine* [10]

In case that none of the above conditions is not satisfied, can be executed export program through *APT file*. Obtained APT files (*CLF-Cutter Location File*), can then be loaded into a *CAD/CAM* system (in this case *Pro/ENGINEER Wildfire 4.0*). Also, from the software *STEP-NC Machine* take models of workpiece and rawpiece in **.stp* format, Figure 2. After loading the APT files in *Pro/ENGINEER*, in the module for *manufacturing* can be made simulation of process with defined: rawpiece, workpiece, cutting tools, fixtures, machining strategy, and so on. Within *Pro/ENGINEER* it is also possible execute simulation of removing material by option *NC-check*, in the *VERICUT* software. After simulation and testing, can be carried out post-processing for a specific numerical control unit and obtain the NC program - G-code, by which realizes machining on the specific CNC machine tools [8,10].

2.2. Case study II

The main difference compared to the first case refers to the fact that this variant is applied to generate NC programs for their own products or parts.

The main input data represents product model from an *CAD/CAM* system, after which in the manufacturing module perform process planning, i.e. defines rawpiece, clamping plan and processing plans, cutting tools, parameters and machining strategies. Also it is possible to

execute the simulation manufacturing process and verification, and as well as checking tool path. After complete definition of the process planning and checking tool path, carried out generation *CL files* and storing data (*STEP file*) with the **.stp* extension, in which are the data of the workpiece, rawpiece, cutting tools, fixtures, etc.

The next step is to run the *STEP-NC Machine* software, where is first performs uploads STEP files with data about workpiece, rawpieces, cutting tools, fixtures, and then stored in *CL file*. Next step is carried out testing of program and simulation of manufacturing process into *STEP-NC Machine* software. Upon completion of the testing and simulation of program, can be exported in a variety of formats. Output from the software can be execute in two ways. First, generation output *APT* or *G-code*, after which the program can be forwarded to a particular CNC machine. Second, directly sending program to the numerical control units that support *STEP-NC* information protocol, i.e. numerical control units of new generation. The next section shows the verification of second variants on example.

3. VERIFICATION OF APPLYING

For verification of second variants used the following software: *CATIA*, *STEP-NC Machine*, *CIMCO*, *Siemens Shop-mill*. To manufacturing the selected part was used triaxial machining center *EMCO Concept Mill 450* with numerical control unit *Sinumerik 810/ 840D*.

The first step is related to the modeling prismatic model of product in the software *CATIA*, which is shown in Figure 3. Then the model is preserved in STEP format files with the **.stp* extension.

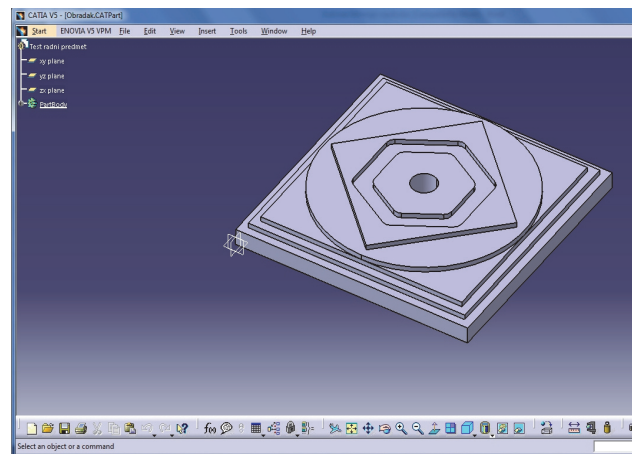


Fig.3. Model of the product

After modeling products, in CAM module of *CATIA* software is carried out defining: rawpiece, coordinate system, machine tools, return plane and then appropriate workingsteps, cutting tools, cutting conditions and machining strategies.

After defining all the elements of process plans, conducted a simulation of machining each individual workingstep within the options *Start Video Simulation using ToolPath*, which represent a simulation of material removal, Figure 4.

The next tasks are realized using *STEP-NC Machine* software. The first step is import the model of the workpiece in software in the form of **.stp*, Figure 5.

The following steps relating to import the model of rawpiece in the software, to define the position of rawpiece and import all workingsteps that were previously saved with the extension *.ncl. It should be noted that for this model in CATIA software, module Machining, defined the following workingsteps: facemilling, machining groove, machining pockets, and machining contour and milling holes. The mentioned processing procedures can be particularly saved, so that every workingstep has an extension *.ncl (e.g. *Facemilling.ncl*), that is unified. The process of loading machining processing into STEP-NC Machine software is shown in Figure 6.

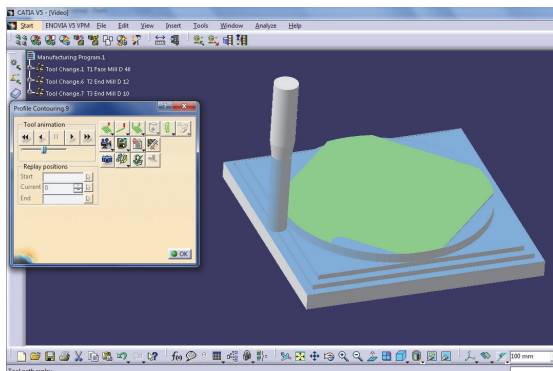


Fig.4. Simulation of machining processes in CATIA software

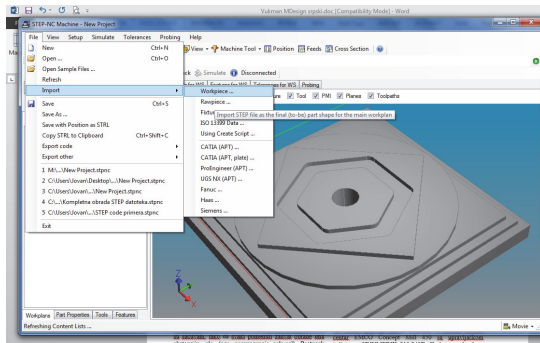


Fig.5. Import model of product (*.stp) in STEP-NC Machine software

Applying STEP-NC Machine software, in this way defined data model with the tool path can be saved as a STEP-NC files (physical file according to ISO 10303-21 standard) whose appearance is shown in Figure 7, which can be used for processing on CNC machine tools new generation

How available machine tools possesses a Siemens numerical control unit, which currently has the ability to directly read the STEP-NC data model was performed exporting code (postprocessing) corresponding to this type of numerical control machine unit, Figure 8.

At the output receives a new data file (G code) that has the extension *.mpf for Siemens 810 numerical control unit, whose derivative is shown in Figure 9.

The next step is a physical machining part on machining center EMCO Concept Mill 450 with numerical control unit SINUMERIK 810/840D. With this machining center axes X, Y and Z are translational. Maximum spindle

speed is 12,000 min⁻¹. Rawpiece for machining was made of aluminum alloy, dimension 150x150x22 mm. For the machining part, the following cutting tools are used: end mill Ø40 mm with tiles of cemented-carbide; end mill Ø12 mm and End mill Ø20 mm, Figure 10.

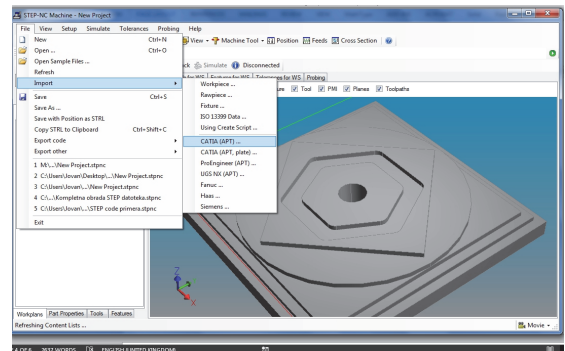


Fig.6. Loading of machining processes in STEP-NC Machine software

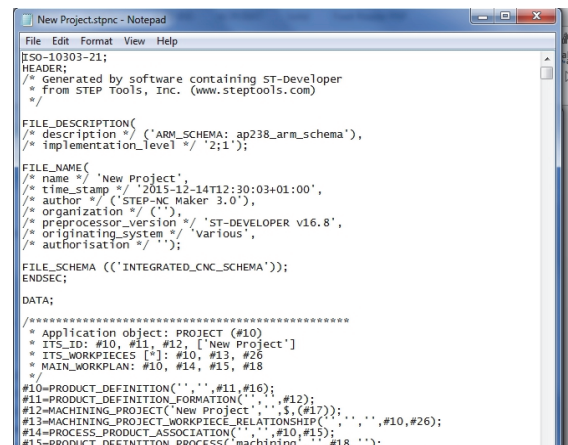


Fig.7. A partial view of STEP-NC physical file in form ISO10303-21

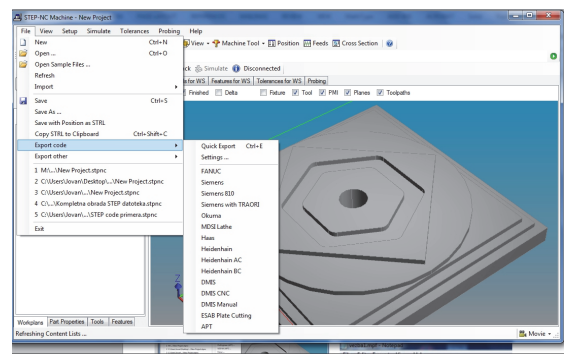


Fig.8. Export NC code for Siemens numerical control unit

After adjusting the machine tools, setup rawpiece and its clamping, defining the zero point and correction tools, started loading the NC program on the machine tool. Before machining, simulations NC program is performed on several software: VERICUT, CIMCO and Siemens ShopMill, which showed the validity of the process planning. After completion of the machining processes access to the measurement process where it is established that the machining performed within the given dimensions. Based on this we can conclude that it is not

occurred problems in the translation process of numerical programs from one software to another, as well as storing model of rawpiece and workpiece in *.stp traction. Figure 11 shown the finished part.

```
Siemens 810 18-11-15.mpf - Notepad
File Edit Format View Help
N100 ; STEP- NC AP-238 PROGRAM
N102 ; STEP- NC File : New Project
N104 ; Generated : 2015-11-18T08 :54:22+01:00
N106 G17 G40 G90
N108 ; work offset : cancel
N110 G53
N112 G71
N114 ; workingstep : line 11 ws 1
N116 ; TOOL CHANGE : TOOL 1
N118 ; diameter : 40mm
N120 ; length : 5mm
N122 ; corner radius : 5mm
N124 ; taper : 0deg
N126 ; tip angle : 0deg
N128 T1 M6
N130 G1 X75 Y75 Z3 F0
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Fig.9. Export NC data file with the *.mpf extension



Fig.10. The applied cutting tools with appropriate tool holders

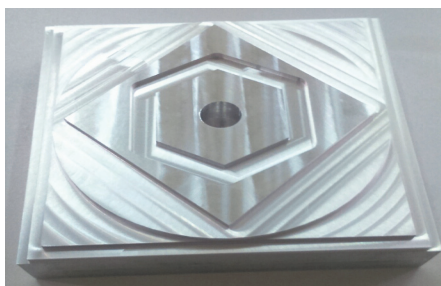


Fig.11. Finished part

4. CONCLUSION

Standard ISO 6983 (G-code), which is still used to define the NC processing information on CNC machine tools and systems, presents obstacle to the full integration of CAx and CNC systems, and total integration of design and manufacturing. The result of efforts to overcome this problem is the development of STEP, or its extension STEP-NC standard.

In this paper are represent the current possibilities of application of STEP-NC in the real conditions of the domestic industry. Also shown a structure of the necessary resources and softwares within the set of variants of application of STEP-NC, as well as their verification on example. These studies are only a small step toward the era of digital production based on the use of STEP and STEP-NC standard. According to current research in this area there are numerous advantages of STEP-NC in relation to ISO 6983, which should be a

guide for further research. Some of these benefits are related to:

- Better information for the production of which is based on the feature technologies,
- Exchange and sharing of geometrical and technological information in the production process without loss,
- Bidirectional flow of data between design and production,
- The need for post processors are lose,
- Possible use of the Internet or the Web-based production (XML) and others.

ACKNOWLEDGEMENT

This paper is part of a research on projects "Modern approaches to the development of special bearings in mechanical engineering and medical prosthetics" - TR 35025 and "Development of a new generation of domestic manufacturing systems" - TR 35022, supported by the Ministry of Education, Science and Technological Development of Republic of Serbia.

REFERENCES

- [1] Rehg, J.A., Kraebber, H.W.: *Computer-Integrated Manufacturing*, 2nd edition, Prentice-Hall, New Jersey, 2001.
- [2] Nassehi A., Newman, S.T., Allen, R.D.: STEP-NC Compliant Process Planning as an Enabled for Adaptive Global Manufacturing, *Robotics and Computer-Integrated Manufacturing*, 2006, Vol. 22, No. 4-5, pp. 456-467, 2006.
- [3] Minhat, M.; Xu, X.; STEPNCMillUoA- A CNC system based on STEP-NC and function block architecture; *Int. J. Mechatronics and Manufacturing Systems*; Vol.2, No1/2; pp. 3 -19, 2009.
- [4] Xu, X.W., He, Q.: Striving for Total Integration CAD, CAPP, CAM and CNC, *Robotics and Computer-Integrated Manufacturing*, Vol. 20, No. 2, pp. 101-109, 2004.
- [5] Xu, X.: *Integrating Advanced Computer-Aided Design, Manufacturing, and Numerical Control - Principles and Implementation*, Information Science Reference, New York, 2009.
- [6] Lukić, D., Todić, V., Milošević, M.: Model of modern technological production preparation, *Journal Proceedings in Manufacturing Systems*, Vol.5, No.1, pp. 15-22, 2010.
- [7] Vukman, J., Lukić, D., Milošević, M., Jovičić, G., Đurđev, M.: The importance of features into STEP standard, *Machine Design*, Vol.7, No.2, pp. 55-60, 2015.
- [8] Glavonjić, M., Živanović, S.: Novi pristup programiranju numerički upravljanih mašina alatki primenom STEP-NC, *38. Jupiter konferencija*, Mašinski fakultet, Beograd, pp. 3.112-3.117, 2012.
- [9] <http://www.steptools.com/products/stepncmachine/samples/>, available on day 02.12.2015.
- [10] Živanović, S., Glavonjić, M.: Methodology for implementation scenarios for applying protocol STEP-NC, *Journal of Production Engineering*, Vol.17, No.1, pp. 71-74, 2014.