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METHODOLOGY FOR IMPLEMENTATION SCENARIOS FOR APPLYING PROTOCOL STEP-NC

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Abstract:*This paper describes methodology for the implementation of scenarios for applying protocol STEP-NC for programming CNC machine tools. Capabilities of the current implementation of the new programming method based on STEP-NC for the available machines, is shown, using software STEP-NC Machine and CAD/CAM system Creo. For a description of the methodology for application protocols STEP-NC were used IDEF0 diagrams. The methodology is verified in two scenarios who are shown (SC1 and SC2). The application of STEP-NC protocols is described by IDEF0 methodology experimentally verified using two examples.*
Key words: *STEP-NC, CAD/CAM, IDEF0*

Metodologija za implmenetaciju scenarija primene protokola STEP-NC. *U ovom radu je opisana metodologija za sprovođenje scenarija primene protokola STEP-NC za programiranja CNC mašina alatki. Pokazane su mogućnosti trenutne primene novog metoda programiranja baziranog na STEP-NC na raspoloživim mašinama pomoću softvera STEP-NC Machine i CAD/CAM sistema Creo. Za opis metodologije primene protokola STEP-NC iskorišćeni su IDEF0 dijagrami. Metodologija je verifikovana za dva pokazana scenarija (SC1 i SC2). Primena STEP-NC protokola opisana IDEF0 metodologijom eksperimentalno je verifikovana koristeći dva primera.*
Ključne reči: *G code, STEP-NC, CAD/CAM, IDEF0*

1. INTRODUCTION

Machine tool programming was based on the G code for more than half a century. The current machine tool programming standard is still ISO6983, also known as G-code [1]. Further developments, however, are being significantly limited by current programming language. Machine tools have evolved from simple machines with controllers that had no memory, driven by punched tape to today's highly sophisticated Computer Numerically Controlled (CNC) machine tools. Machine tool programming using G code is characterized by a low level of information content. These low level of information describes elementary actions and tools trajectories, strongly reducing possibilities at the CNC level [1]. It is necessary to prepare the tool path for each type of CNC machine tools individually using appropriate postprocessor.

Nowadays a new standard, informally known as STEP-NC (Standard for Product Model Data Exchange for Numerical Control) [3,4], is used as the basis for development of the next generation of CNC controller for new generation of machine tools. These new standards are ISO 14649 and ISO 10303 AP 238. The new programming method using standard known as STEP-NC is an open challenge in the field of machine tool programming. The development of a new method of programming is started [1-8], but not completed work.

The STEP-NC is the result of more than a decade long period of international effort to replace G code (ISO6983) with a modern associative language that connects the CAD design data used to determine the machining requirements for an operation with the CAM process data that solve those requirements [8].

The method of programming using the STEP-NC is object-oriented view of programming in terms of manufacturing features, instead of direct coding of sequences of axis motions and tool functions as defined in ISO 6983 [5]. Classical programming is still the most commonly used way of programming and object-oriented programming has not been introduced to the full extent. However, these two methods are simultaneously used as illustrated in Figure 1.

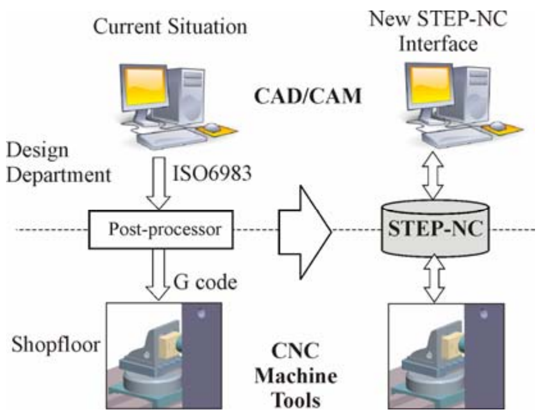


Fig. 1. Current ISO6983 and new interface ISO14649 for programming CNC machine tools [4, 5]

Figure 1 shows the comparison of current G-code programming method (ISO 6983) and new STEP-NC high level programming method (ISO 14649). The STEP-NC provides CNC controller new opportunities to support high level of information from design. It allows bi-directional flow of data between CAD/CAM and CNC Machine Tools without losing information. STEP-NC does not describe the tool trajectories for specific CNC machine tool as G code does, but it provides a feature based data model. A STEP-NC file is not machine tool specific and can be used on various machine tool controllers [1].

The paper structured as follows. Section 2 gives an overview of the scenarios for applying STEP-NC. Section 3 gives a description of the methodology for STEP-NC machining. Section 4 describes program verification and machining experiment.

2. SCENARIOS FOR APPLYING STEP-NC

At the moment, this new method of programming based on STEP-NC can't completely be used, because the resources for its development are owned by several research centers. This paper considers two possible scenarios (SC1, SC2) for indirect application of this method of programming on existing machines and the available software, Figure 2.

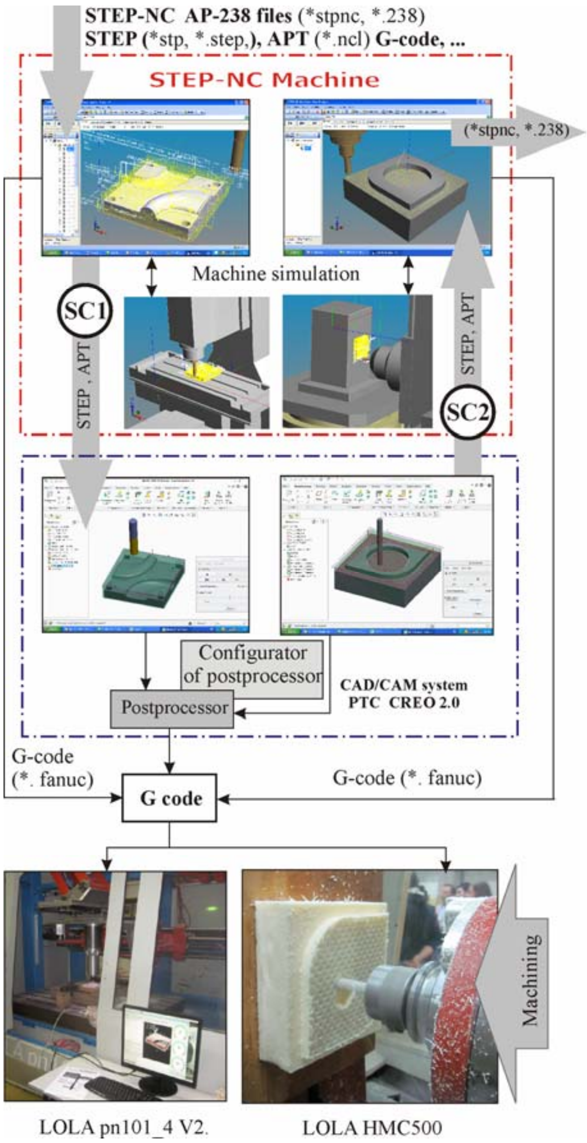


Fig. 2. Current scenarios for the application of STEP-NC programming.

These scenarios are:

- *Scenario SC1* - using the original STEP-NC program, post-processing into G code and executing on the machine tool, and
- *Scenario SC2* - modeling part in the CAD/CAM system, and then exporting in the STEP format; then importing a reference model, workpiece, tools and tool path (CLF) in software STEP-NC Machine [3], where the STEP-NC program is saved in the format Part 28 (XML).

For now, the first scenario is realistic and feasible in two ways. The first way is using of CLF, which is specifically imported into the available CAD/CAM system and post-processed for the selected machine tool. CAD system takes reference model and workpiece in STEP format and CL File. Verification of material removal is done in a CAD/CAM system in the module (NC Check). CAD/CAM system uses configured postprocessor to generate G code for the available CNC machine tools. G code is executed on the available machine tools.

The second way uses an internal application to the direct export of STEP-NC program in G code from the available control units, offered by STEP-NC Machine (Fanuc, Siemens, Okuma, Haas, etc.).

Scenario SC2 involves importing geometry elements of the reference model, workpiece, tool and tool path from common CAD/CAM system into STEP-NC Machine software. The scenario SC2 is performed as follows: (i) CAD models of reference model, workpiece and tool are created in the CAD/CAM system; (ii) technology for machining (roughing and finishing) are planned and implemented; (iii) tool path CL file (*. ncl) is generated; (iv) tool path and material removal simulations (NC Check) is done; (v) the inputs for software STEP-NC Machine are prepared by exporting reference model, workpiece and tool from CAD/CAM System in STEP format; (vi) the reference model, model of the workpiece, model of tool in STEP format, and Cutter Location File (CLF - *.ncl) are loaded in software STEP-NC Machine; (vii) program is saved in the format of STEP-NC AP238 (*. stpnc, * .238); (viii) program is tested by simulations on different machines available in the software STEP-NC Machine; (ix) program for machining is directly translated into Fanuc G code using the Export option of software STEP-NC Machine; (x) workpiece is machined on available CNC machine tools.

3. METHODOLOGY FOR STEP-NC BASED MACHINING

IDEF0 is a method designed to model the decisions, actions, and activities of an organization or system. It is useful in establishing the scope of an analysis, especially for a functional analysis [2]. IDEF0 is used to produce a "function model". A function model is a structured representation of the functions, activities or processes within the modeled system or subject area.

In this paper, functions of STEP-NC based machining, are described by using the IDEF0 diagram. The special case of one box IDEF0 context diagram, containing the toplevel function being modeled with its inputs, controls, outputs and mechanisms, is shown in Figure 3.

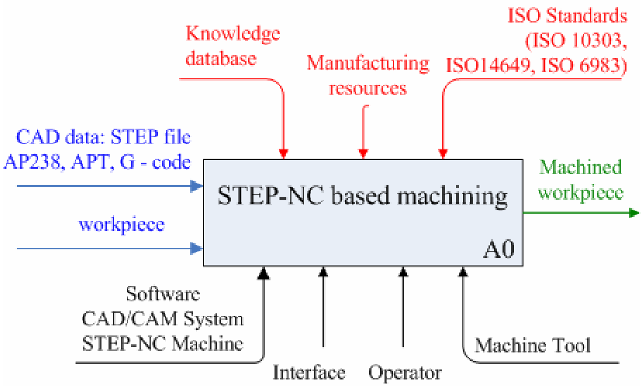


Fig. 3. Top-level IDEF0 diagram for STEP-NC based machining

The single function represented on the top-level context diagram may be decomposed into its major sub-functions by creating its child diagrams. Each child diagram contains the child boxes and arrows that provide additional detail about the parent box. The child diagram that results from the decomposition of a function covers the same scope as the parent box in details.

Top level child diagram A0 describes basic flow of activities and it is illustrated in Figure 4. According to the IDEF0 methodology, by analyzing diagram A0, we get the basic flow of activities shown in Fig. 4 The basic activities are: A1 – Generic STEP files and tool path in CAD/CAM systems, A2 - STEP-NC program generator, A3 – Post-processing programs, A4 – Machining process simulator and A5 - Machining.

The activity A1 is performed in CAD/CAM system. Input into the activity A1 can be CAD models of workpieces, tools in STEP format and programs in the APT format or G code obtained from the software STEP-NC Machine. Output from the activity A1 can be CAD model of the workpiece, tools in STEP format, APT program (CL file), G code or STEP-NC file if CAD/CAM system can generate it. These outputs are inputs for activity A2.

The activity A2 is performed in software STEP-NC Machine. Input into the activity A2 can be an original STEP-NC program in *.stpnc, *.238, *.p21, *.p28 formats. Software STEP-NC Machine implements the activity A3, that allows post-processing of STEP-NC program into G code for machining on the existing CNC machine tools.

G code obtained on this way can be directed to additional verification in the CAD/CAM system or in some of the CNC simulators (activity A4). Some of used simulators are VeriCUT and CNC Simulator. In this activity can be performed machining simulation in software STEP-NC Machine too. After verification of the program in G code, we can pass over to the activity A5 safely, where the machining is realized on CNC machine tools.

The application of this methodology is presented in Section 4. Two examples of machining are used, one for each scenario. CNC machine tools used for machining are Horizontal Machining Center (LOLA HMC500) and vertical milling machine with parallel kinematics (LOLA pn101_4 V.2).

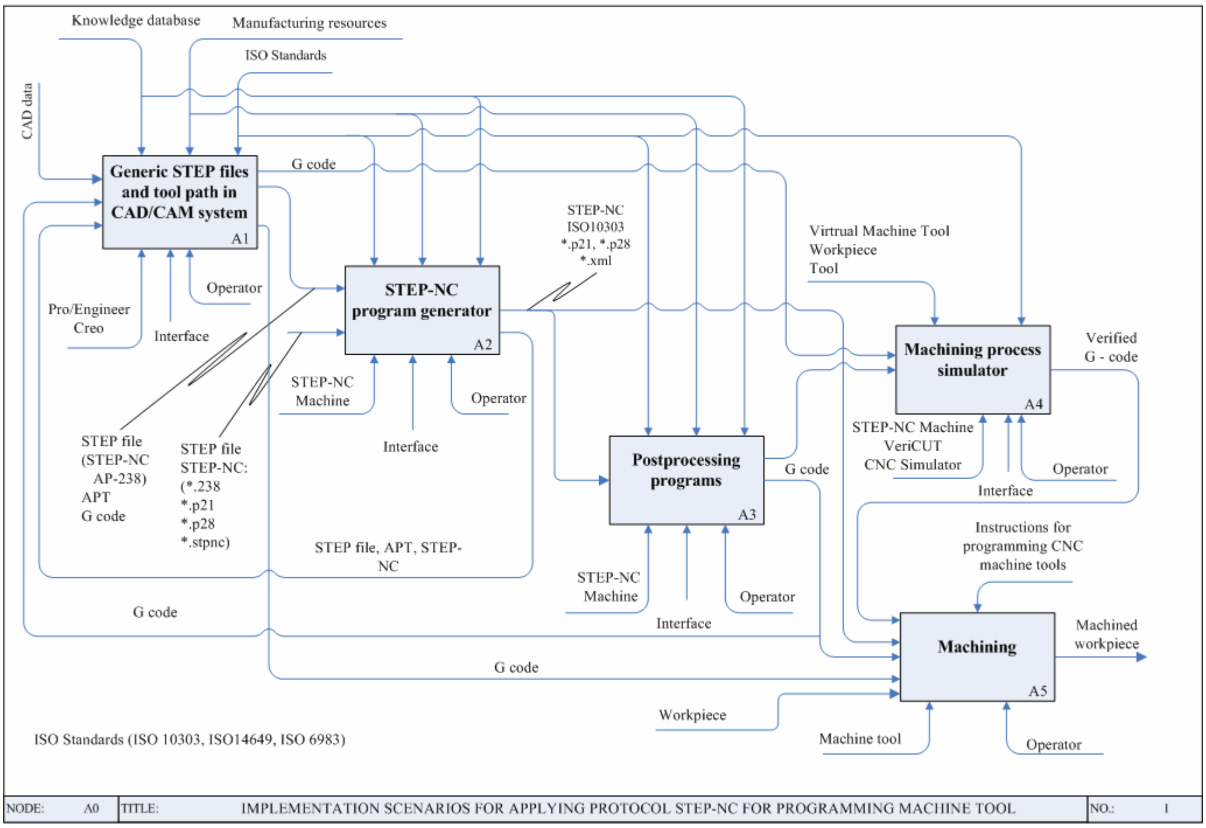
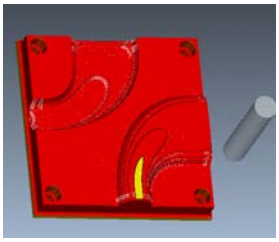


Fig.4. The basic flow of activities for STEP-NC based machining simulations

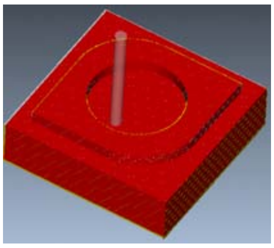
4. PROGRAM VERIFICATION AND MACHINING EXPERIMENT

The application of STEP-NC described by IDEF0 methodology is experimentally verified using two examples. For first scenario SC1 we have used the source program in STEP-NC format for a moldy workpiece [6, 7], Figure 5a,c. "Moldy" workpiece was first machined during a presentation in Renton (Washington, USA) [7]. The second example has been done for scenario SC2, Figure 5b,d.

In the first example, the format of STEP-NC program is translated into APT using the Export option of software STEP-NC Machine. Utilizing APT program, the machining technology is reconstructed in CAD/CAM system PTC Creo. Tool path is verified by simulation of material removal in module NC Check, Figure 5a. Postprocessing into G code has been carried out in the final part of the experimental verification. In the second experiment, the format of STEP-NC program for Moldy workpiece was directly translated into Fanuc G code, using the Export option of software STEP-NC Machine, the activity A3, from Figure 4. The obtained G codes were further verified in the activity A4 – Machining process simulator. Verified G codes were used for the machining on the industrial prototype of 3-axis vertical parallel kinemtic milling machine LOLA pn101_4 V2 [9].

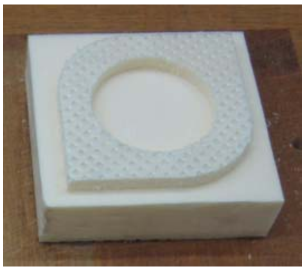


a) material removal simulation for SC1



b) material removal simulation for SC2

c) Roughing machined workpiece moldy, scenario SC1



d) Finish machined workpiece scenario SC2

Fig. .5. Material removal simulation and machined workpieces for each scanario

Scenario SC2 involves importing geometry elements of the reference model, workpiece, tool and tool path from common CAD/CAM system into STEP-NC Machine software, where program is saved in the format Part 28 (XML). Program for machining was directly translated into Fanuc G code using the Export option of software STEP-NC Machine. The final verification is carried out, by machining on Horizontal Machining Center (LOLA HMC500).

5. CONCLUSION

The paper presents possibilities of application of the new method of programming based on ISO14649 and ISO10303 standards, known as STEP-NC. Since there is still not sufficient available CNC machines that can directly interpret the STEP-NC program, preparing for this method of programming is reduced to the translation into G code, which can be realized on the available CNC machine tools.

STEP-NC standard is almost finalized, and we can expect the first shop-floor application of STEP-NC program soon. Existing CNC machine tools will be replaced in the future by machines whose control systems can receive and execute programs in the STEP-NC format.

Our future research will be focused on the building of CNC machine tool with open architecture control system, that can download and directly execute programs in some of the STEP-NC formats.

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