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ROBOT MACHINING SIMULATION IN STEP-NC MACHINE ENVIRONMENT

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Summary: *This paper presents an approach for applying new programming method based on STEP-NC standard in machining operations by using industrial robots. The paper discusses about programming and simulation of industrial robots for machining using software STEP-NC Machine. Programming verification has been realized by simulation in STEP-NC Machine using available and configured virtual robots in STEP-NC Machine environment through several examples.*
Key words: robot for machining, STEP-NC, programming, machining simulation

1. INTRODUCTION

It is widely recognized that poor accuracy, stiffness, and complexity of programming are the most important limiting factors for wider adoption of robotic machining in machine shops. Nowadays, the major field of interest for robotic machining is the solving problem of programming.

The reason for the complexity of robot programming in machining application is in that each robot manufacturer uses, for the most part, its own proprietary robot programming language, because no industry standard exists. This fact was a strong motivation for both researchers and leading world robot and CAD/CAM software manufactures to develop versatile software solutions, such as G-code translators, specific postprocessor solutions, etc. to make the robot programming close to the programming efficiency of CNC machine tools [1].

Today a new standard, informally known as STEP-NC (Standard for Product Model Data Exchange for Numerical Control) [2,3], is used as the basis for development of the next generation of CNC controller for new machine tools and robots. These new standards are ISO 14649 and ISO 10303-238. However, industrial robots are getting

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more and more capable of taking onto machining operations [4] and it is necessary to couple the robot for machining towards the new standard.

Examples of the applications of robots programming for machining operations based on STEP-NC standard can be found in papers [5,6]. The STEP-NC based Robot CAM module for industrial robot machining operations is introduced in [5]. As stated in [6], the unified data models of industrial robots under the STEP standard, to exchange information between different CAx and robot off-line programming systems, will not only benefit the robot simulation systems, but also for the improvement of traditional industrial robot controllers.

The paper considers the possibility of programming and robot machining simulation based on a new method of programming by the STEP-NC protocol [2]. Virtual machining simulation is very important in modern manufacturing. This paper presents the results in the robot machining simulation, based on STEP-NC programs in STEP-NC Machine environment.

2. STEP-NC MACHINE

The STEP-NC AP238 standard is the result of a more than 15 year international effort to replace the RS274D (ISO 6983) M and G code standard 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 solves those requirements. STEP-NC is a modern, associative communications protocol that connects computer numerical controlled (CNC) process data to a product description of the part being machined. Integration of the CNC model into STEP to produce ISO 10303-238 was done in the United States, under the NIST ATP Model Driven Intelligent Control of Manufacturing project, led by STEP Tools, Inc. with an industrial review board (IRB) consisting of Fortune 500 companies, CAD and CAM software developers, machine tool manufacturers, job shops and industry experts. STEP-NC AP238 was published in 2007 [2].

STEP-NC Machine uses a new ISO standard to create machining programs that can be shared between many organizations and reused on many different machines and robots for machining. With STEP-NC Machine, the execution of a STEP-NC program can be simulated on a new machine or robots for machining, to make sure it will execute correctly using adequate modelled tooling and fixturing.

STEP-NC Machine integrates CAD design requirement data with CAM process data so it can be:

- seen machine programs in context with the raw and finished part;
- assembled STEP-NC machine programs from many sources;
- exchanged machine programs across organizations or machines or robots for machining;
- simulated tool motion (Fig.1a) with virtual machine tool and robots for machining (Fig1d);
- exported programs in G-code for different control units (Fig.1b);
- exported programs in Cutter location file (CLF);
- seen material removal simulation (Fig1c);
- adapted programs to match machine or robots for machining, tool, and production constraints and
- executed STEP-NC programs on your arbitrary CNC machine tool or robot

control.

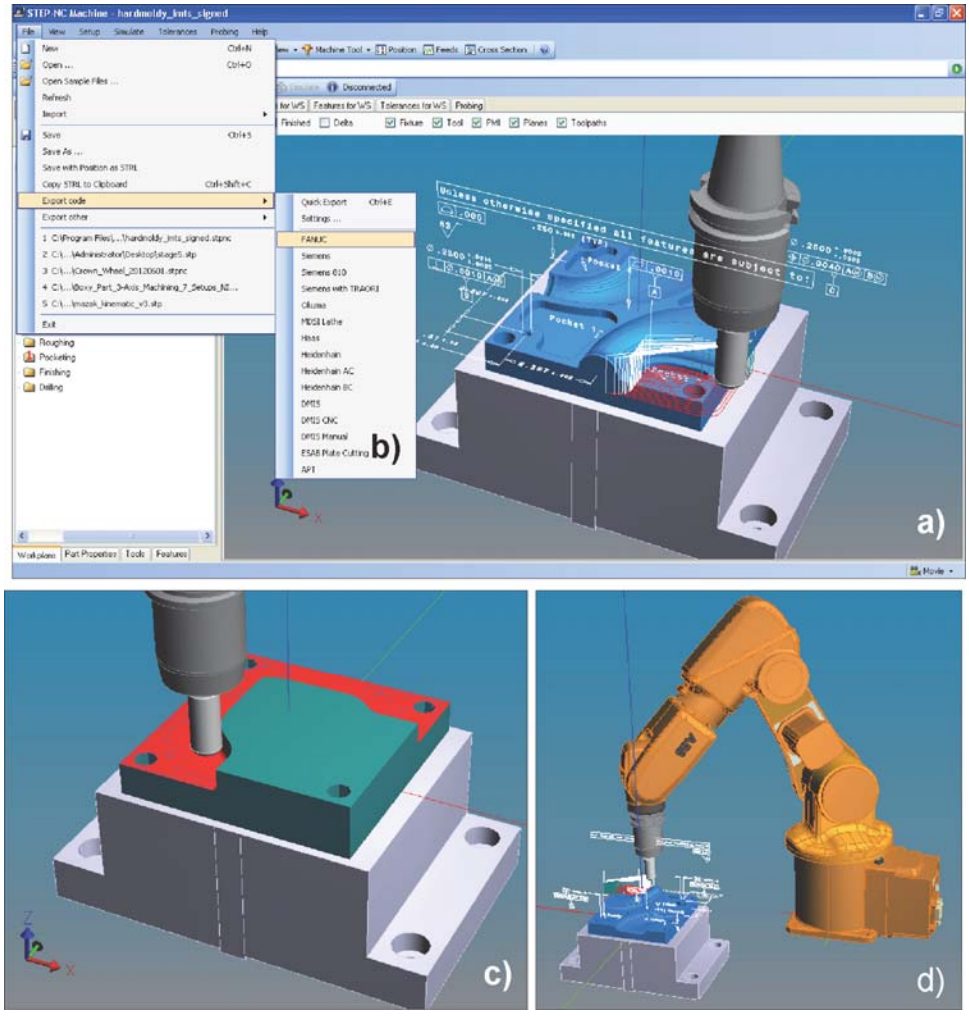

Fig. 1 *STEP-NC Machine*

3. ROBOT MACHINING BASED ON STEP-NC

The method of programming using the STEP-NC is an object-oriented view concept of programming in terms of manufacturing features, instead of direct coding of sequences of the interpolated axis motions and tool functions as defined in ISO 6983 [7]. 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 Fig. 2.

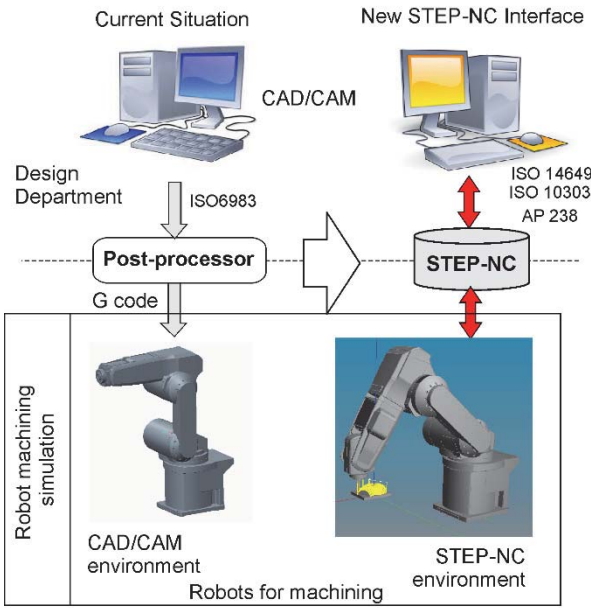

Fig. 2 *Current and new STEP-NC interfaces for programming the robot for machining*

Figure 2 shows the comparison of current G-code programming method (ISO 6983) and new STEP-NC high level programming method (ISO 14649 and ISO10303). The STEP-NC provides for CNC controller a set of new opportunities to support high level of information from design. It allows bi-directional flow of data between CAD/CAM and CNC machine tools or robots for machining 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 [8]. A STEP-NC program can be used on various robots for machining, which have control unit that support the new method of programming, or using export option software STEP-NC Machine into G-code. Robot machining simulation of the machining process presented in this paper includes the simulation of machine operation based on the program generated in CAD/CAM system and in software STEP-NC Machine.

4. VIRTUAL ROBOT FOR MACHINING SIMULATION IN STEP-NC MACHINE

For STEP-NC standard-based robot programming, models of the workpiece, pre-machined stock and tools in STEP format in CAD/CAM environment, as well as toolpath trajectory (Cutter Location File – CLF), were prepared. Thus prepared input is loaded in the STEP-NC Machine software, where STEP-NC program is generated. Verification of obtained programs is realized on a virtual robot that is able to execute programs in STEP-NC format in STEP-NC Machine environment, Fig. 3. After a successful verification of machining, the program can be safely executed on the real robot.

Virtual machining simulation is very important in modern manufacturing before its execution on real machinine. Robot machining simulation includes the simulation of available or configured robot in software STEP-NC Machine based on STEP-NC program, Fig.4. Robot machining simulation is important because it: (i) prevents robot collisions during machining, (ii) gives a good insight for robot operators what to expect from new programs, (iii) increases robot machining safety, (iv) enhances presentations and documentation with AVI simulations, and (v) provides training and education without using production time (or risking a crash of the real robots).

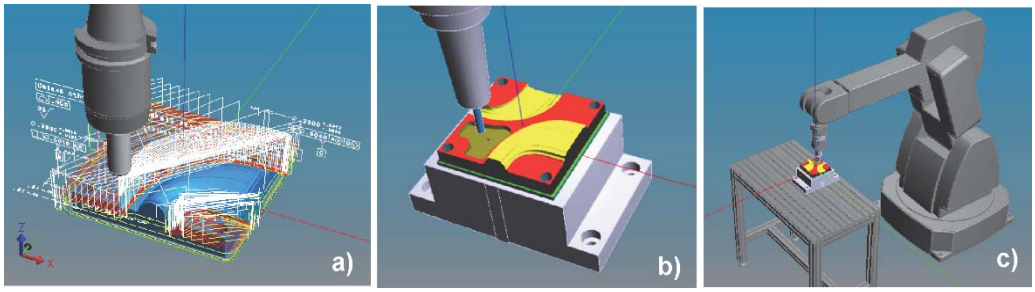

Fig. 3 *Three types of machining simulation in STEP-NC Machine*

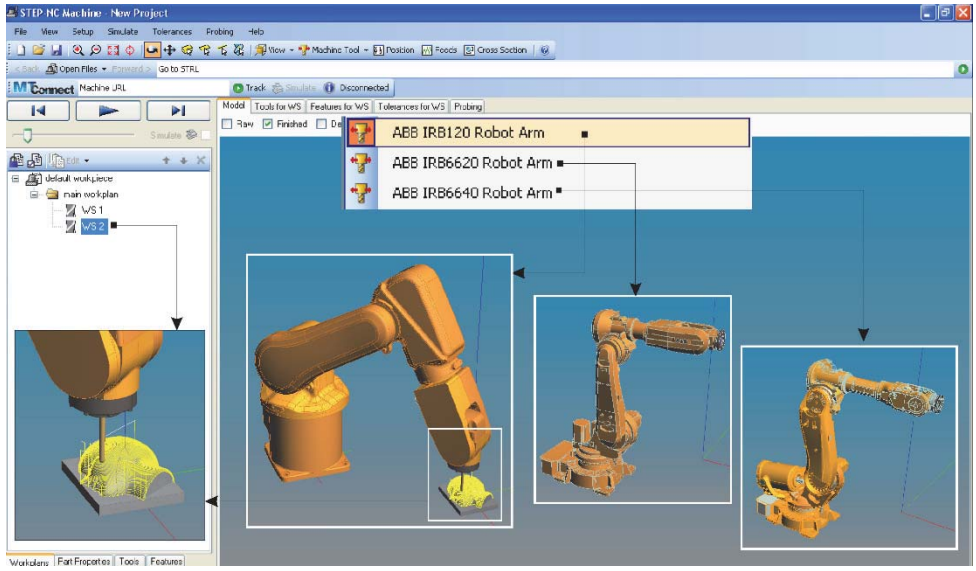

Fig. 4 *Virtual robots in STEP-NC Machine*

Virtual robots have a possibility to interpret the STEP-NC program in the software STEP-NC Machine. To load the robot in the STEP-NC environment, it is necessary to follow next procedure: (1): Prepare a CAD model of the robot, (2) Export model of the robot in the STEP format by the protocol AP203 or AP214, (3) Configure kinematic chain of robot in XML format, (4) Integrate STEP and XML in STEP-NC Machine, (5) Execute robot machining simulations based on STEP-NC program.

The most important activity includes configuring the XML file that requires the following information: (i) robot's name, (ii) control algorithm, (iii) name of the robot STEP file, (iv) description of the robot base structure, which is stationary, (v) description of tool side structure, (vi) defining of placement location for tool, (vii) description of workpiece side structure, (viii) defining of placement location for workpiece, and (ix) description of robot axes and their constraints. An example of the XML file description for Mitsubishi robot, with comments and illustrations of STEP model is given in Fig. 5.

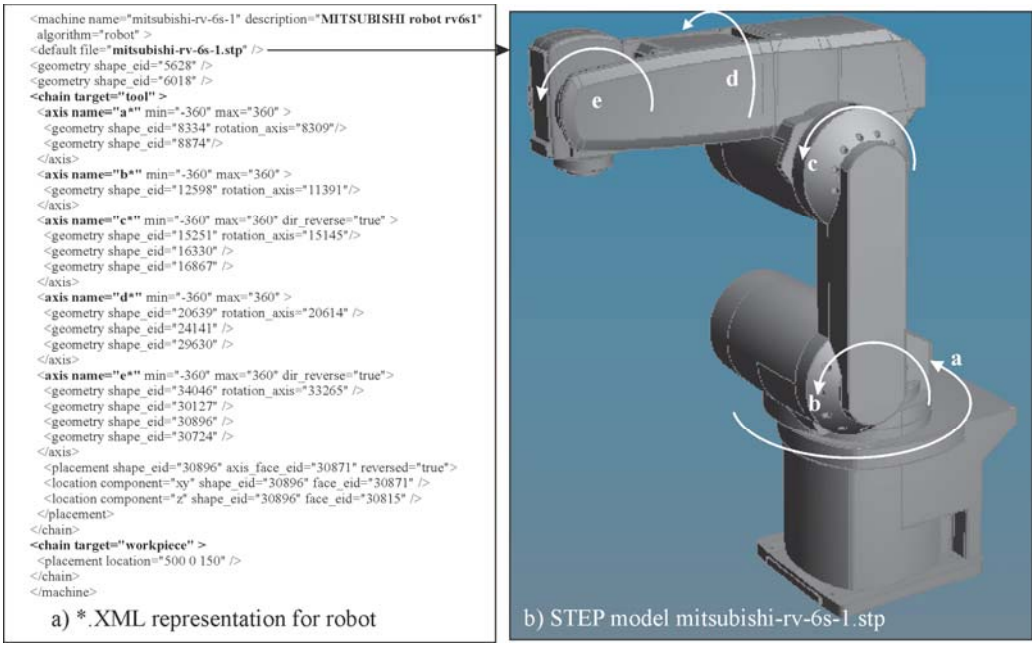

Fig. 5 *XML file structure and the robot model in STEP format*

In order to correctly create the XML file structure and the description of the assembly components, the robot model in STEP format, Fig. 5b, is loaded in the software ST Viewer which is used to define geometry shape_eid for each part and face_eid for corresponding surfaces. Three elementary entities can be in a structure: robot stationary components (base, working table), chain target tool and chain target workpiece. All movable rotational joints are placed here on the side of the tool. For each axis the elements that have to be defined are: name (a, b, c, d, e), constraints, mutual position, as well as the sequence of rotary axes. Placement location for workpiece is defined with respect to a specified coordinate system of the robot. Using this procedure three configured virtual robots are presented: LOLA50 (Fig. 6e), Mitsubishi robot (Fig.6f) and Fanuc LR Mate 200ic (Fig. 6g).

For example, the machining of the human head model is shown by machining simulation for pre-machining (Fig. 6b) and finishing (Fig. 6c) in STEP-NC Machine (Fig. 6a). Thus prepared virtual robots can be loaded in the STEP-NC Machine environment, where they will appear as new machines in a dropdown menu of Machine Tool, Fig. 6d. After selecting the machine from the menu, it is loaded in the STEP-NC Machine environment and STEP-NC programs can be executed. This is of great importance for training in a new method of programming, because it is possible now to check STEP-NC programs by simulating operation on virtual robots.

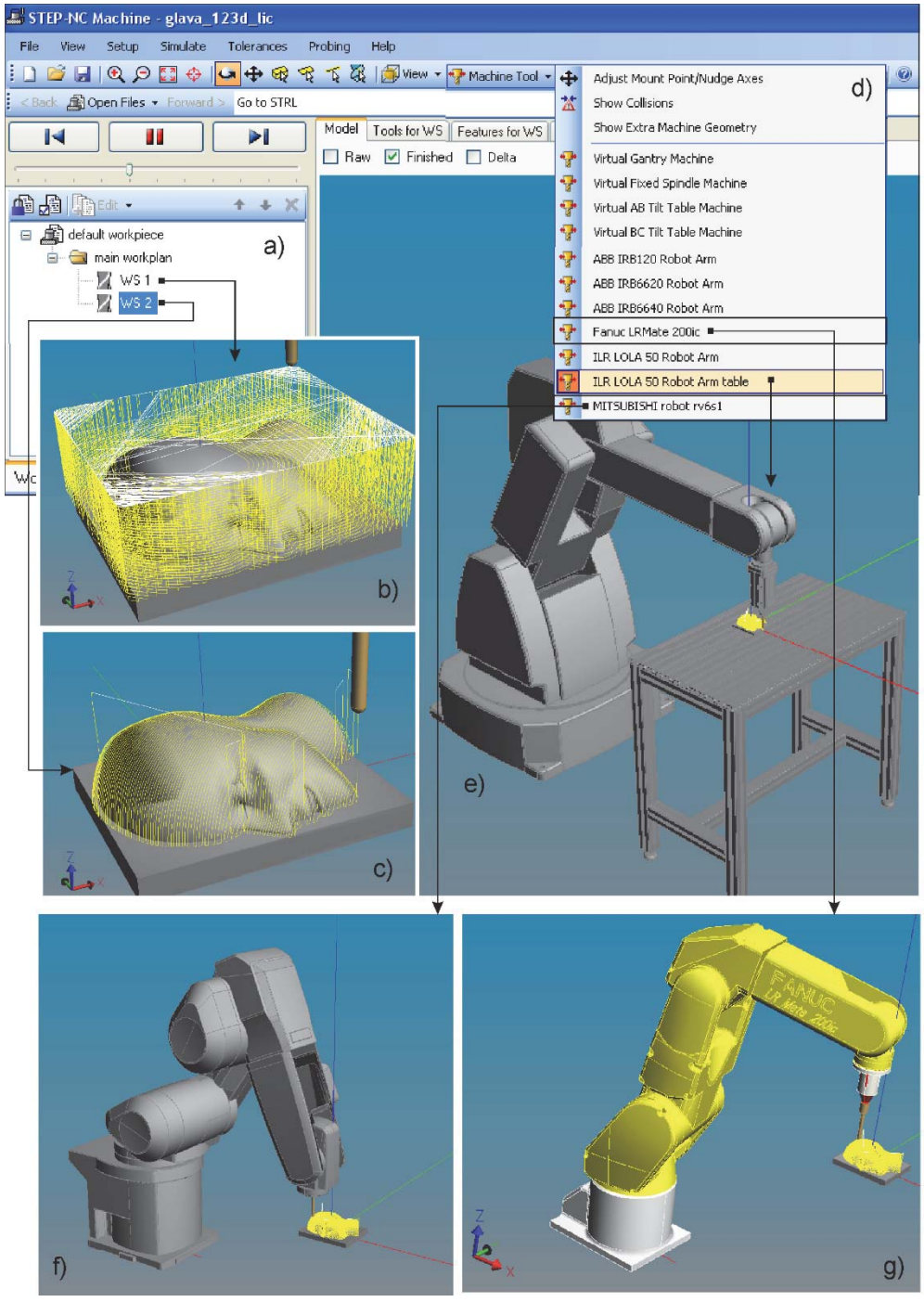

Fig. 6 *Robot machining simulation based on STEP-NC program for three different robots*

5. CONCLUSION

The major field of interest for robotic machining is solving the problem of complexity of programming. STEP-NC standard is almost finalized, and we can expect the first shop-floor application of STEP-NC program in robot machining operation.

This paper described the possibility of programming and robot machining simulation based on a new method of programming by the protocol STEP-NC. This paper presented the results in the robot machining simulation, based on STEP-NC programs, on existing or configured robots in STEP NC Machine environment.

Our future research will be focused on development of module for translation of STEP-NC program into robot programming language. This module will enable use of existing robots in shop-floor for machining applications.

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