CREATION OF SOFTWARE FOR THE TRANSFORMATION OF STEP-NC DATA

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Abstract: *Standard for the Exchange of Product data compliant Numerical Control (STEP-NC) is a new model of data transfer between CAD/CAM systems and CNC machines. The paper is focused on explaining of design and creation of software for transformation of STEP-NC data. Created TERMINAL STEP NC software processes STEP-NC control program and sends motion control commands based on the designed communication protocol to the lathe control unit. Utilization of this software verifies the possibility of using ISO 14649 as a new model for data exchange between CAD/CAM systems and CNC machines and also the possibility of implementing a new standard into the older types of CNC machines.*
Key words: *STEP-NC, CNC machine, transformation, data, software.*

1. INTRODUCTION

Recently, there are a lot of CAD systems, which may be combined by CAM systems. Each of CAD/CAM system has their own data format with its advantages and disadvantages. Because each system must be able to be utilized together with other systems, all CAD/CAM systems mostly provide a function to exchange their data format to some neutral data formats, which can be accessed by all CAD/CAM systems. *The data flow during the manufacturing of parts today can be divided into several steps:*

- Primary information about a product is imported into the CAM system. Usually 3D CAD model is imported.
- In mechanical engineering CAM is used to calculate toolpaths to cut material. The CNC programmer just specifies the machining operations and the CAM system creates the toolpath, usually written in CL data (Cutter Location data) file.
- Calculated toolpath is imported to the postprocessor which converts the CL data to the NC program - the specific machine codes that are required to operate numerically controlled machine tools. Machine codes vary by machine tool. The output from a postprocessor should be usable in the controller without further modification.
- NC program written in a notation called G-code is exported to the NC machine and the manufacturing process can begin.

Digital product data must contain sufficient information to cover a product's entire life cycle, spanning design, analysis, manufacture, quality control testing, inspection and product support functions. The present situation in production data flow is show on Fig.1. (Monková et al., 2006).

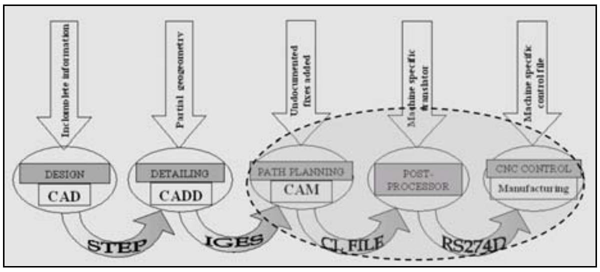


Fig.1. Current NC Programming Interface

A new model of data transfer between CAD/CAM systems and CNC machines is *STEP-NC - Standard for the Exchange of Product data compliant Numerical Control*. STEP-NC provides an object oriented data model for CNC with detailed and structured data interface that incorporates feature based programming where there is a range of information such as the feature to be machined, type of tools used, the operations to perform, and work plan. This paper presents design and creation of software for transformation of STEP-NC data and shows implementation of a new standard into the older types of CNC machines. Created software program processes the STEP-NC control program and sends motion control commands based on the designed communication protocol to the lathe control unit.

2. STANDARD STEP and STEP-NC

STEP is the international standard that specifies a neutral data format for digital information about a product. STEP allows this data to be shared and exchanged among different and otherwise incompatible computer platforms. (ISO 10303-11, 2004). ***STEP-NC*** is a machine tool control language that extends the ***ISO 10303*** STEP standards with the machining model in ***ISO 14649*** (ISO 14649-1, 2003), adding geometric dimension and tolerance data for inspection, and the STEP PDM model for integration into the wider enterprise. STEP-NC standardizes how information about CNC machining can be added to parts represented in the STEP product model. The combined result has been standardized as ***ISO 10303-238*** (ISO 10303-238, 2007), also known as AP238. STEP-NC was designed to replace *ISO 6983/RS274D* G-codes with a modern associative communications protocol that connects computer numerical controlled (CNC) process data to a product description of the part being machined. In the new method enterprises can continue to use their existing systems for CAD, CADD and CAM, but the end result is sent to the CNC as a STEP-NC AP-238 file instead of an RS274D file. Fig. 2 shows the modified data flow with the using of STEP-NC. (Monková et al., 2006).

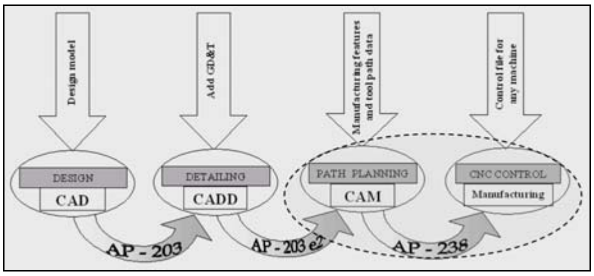


Fig.2. Data flow with the using of STEP-NC

2.1. Development of STEP-NC standard

Today, STEP-NC or ISO 14649 is under development in USA, Europe, and Asia. STEP-NC is being developed concurrently under two different subcommittees of **ISO Technical Committee 184** (Industrial automation systems and integration), as two different standards - *ISO 14649* (*Data model for computerized numerical controllers*) and *ISO 10303-238* (*Application interpreted model for computer numeric controllers*). Both of them can be represented in 10303-21 (ISO 10303-21, 2002). As mentioned above, STEP-NC is being developed to provide a data model for a new breed of intelligent CNC controllers. The ARM of STEP-NC, i.e. ISO 14649 is made up of several Parts. The general title for STEP-NC is *Data Model for Computerized Numerical Controllers* representing a common standard specifically aimed at NC programming, making the goal of a standardized CNC controller and NC code generation facility a reality. In 2004, the first set of Parts of ISO 14649 became International Standards. Several Parts of ISO 14649 were also adopted as conceptual models by the ISO team developing AIM of STEP-NC, i.e. ISO 10303-238 (or STEP AP238) in the early 2000s, and AP238 was published in 2007. Development of both ISO 14649 and STEP Part 238 continues today. Both of them are commonly known as “STEP-NC”.

2.2 Structure of STEP-NC

The concept with the using of STEP-NC is simple. It enables a product model database to serve as direct input to a CNC machine tool. No separate files of tool paths. No G&M codes. No postprocessors. This is a radically different approach to CNC programming (ISO 10303-11, 2004). Standard STEP-NC generates “*workingsteps”*, which contain information about geometry, tool requirement, and feature definition. With this information, CNC machine tools can receive a file with STEP-NC data, knows what it means, and proceed manufacturing the work piece without any more instruction.

A comparison between programming with use of G&M codes and STEP-NC using is described at Fig.3. STEP-NC allows a complete database of machining information to be built around the digital product model and ultimately makes it possible for this enhanced product model to serve as machine tool input. This database is structured such that part features are linked to specific "workingsteps," generic descriptions of various machining operations.

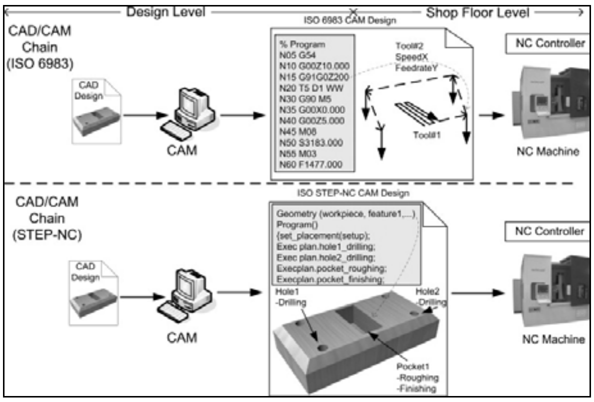


Fig.3. Comparison between programming with G&M codes and STEP-NC (Campos J.G. & Miguez,L.R., 2011)

STEP-NC workingsteps are roughly equivalent to machining commands formatted as traditional M and G codes. With the concept of "workingsteps" in place, the manufacturing process becomes streamlined (Xun .H. & Nee Y.C. (2009).

Effectively, STEP-NC defines a data input standard for CNC systems. As STEP-NC is an extension of STEP to handling NC processes, it strictly follows the STEP standard. Like other STEP applications, a STEP-NC file also conforms to ISO 10303-21. That is, the file contains two sections marked by the keywords *Header* and *Data* respectively (Fig.4).

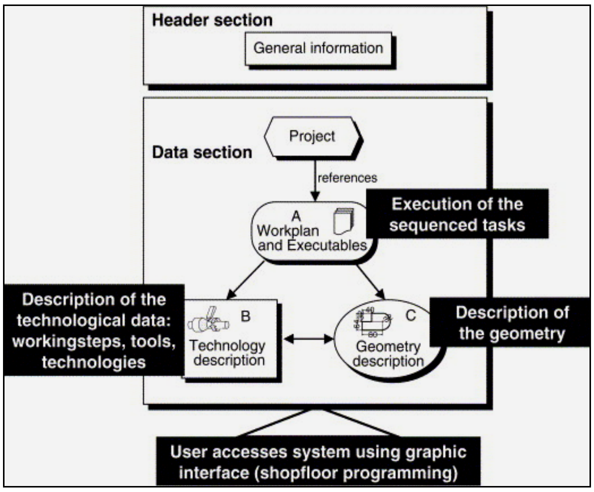


Fig.4. Structure of the STEP-NC data model (Xu, X.W. 2006)

In the *Header* section, some general information and comments concerning the part program are included. These are, for example, filename, author, date and organization. The *Data* section is the main part of the program, containing all the information about manufacturing tasks and geometries. This section also includes a *Project* entity that is an explicit reference for the starting point of the manufacturing tasks.

The *Project* entity contains a main *Workplan* that contains sequenced executable manufacturing tasks -*Workingstep* (ISO 14649 - 1 2003). Details of each *Workingstep* are given in two parts, Technology description and Geometry description. The **Technology description** contains a detailed and complete definition of all *Workingsteps* in a *Workplan* (Fig.5).

```
/* ********************************************************* */
/* ***** Workpiece definition ***** */
#1=WORKPIECE('SIMPLE WORKPIECE',#2,0.010,$,$,$,());
#2=MATERIAL('DIN EN 10027-1','E 295',(#3));
#3=NUMERIC_PARAMETER('ELASTIC MODULUS',2.E11,'pa');

/* ********************************************************* */
/* ***** Manufacturing features ***** */
#10=REVOLVED_FLAT('END FACE',#1,(#20,#21),#70,#80,0.000,#91);
#11=OUTER_DIAMETER('CONE',#1,(#22,#23),#76,#83,#93,#95);
#12=OUTER_DIAMETER('CYLINDER',#1,(#22,#23),#78,#72,#74,$);

/* ********************************************************* */
/* ***** Turning operations ***** */
#20=FACING_ROUGH($,$,'ROUGH END FACE',$,$,#100,#41,#40,#52,#53,#50,0.500);
#21=FACING_FINISH($,$,'FINISH END FACE',$,$,#110,#42,#40,#52,#53,#51,0.000);
#22=CONTOURING_ROUGH($,$,'ROUGH CONTOUR',$,$,#100,#43,#40,#56,#56,#54,0.500)
#23=CONTOURING_FINISH($,$,'FINISH CONTOUR',$,$,#110,#44,#40,#56,#56,#55,0.000);

/* ********************************************************* */
/* ***** Project ***** */
#29=PROJECT('TURNING EXAMPLE 1',#30,(#1),$,$,$);
#30=WORKPLAN('MAIN WORKPLAN',(#31,#32,#33,#34),$,#37,$);
#31=MACHINING_WORKINGSTEP('WS ROUGH END FACE',#63,#10,#20,$);
#32=MACHINING_WORKINGSTEP('WS FINISH END FACE',#63,#10,#21,$);
#33=TURNING_WORKINGSTEP('WS ROUGH CONTOUR',#63,(#11,#12),#22,$);
#34=TURNING_WORKINGSTEP('WS FINISH CONTOUR',#63,(#11,#12),#23,$);
#37=SETUP('SETUP FOR TURNING EXAMPLE 1',$,#63,(#38));
#38=WORKPIECE_SETUP(#1,#64,$,$,());
```

Fig.5. Sample of STEP-NC program structure

This may include *tool data* (dimensions, tool type, conditions and usage of the tool), *machine functions, machining strategies, other process data and a workpiece definition* (surfaces, regions and features of the finished part).

The **Geometry description**, which is of ISO 10303 data format, provides the geometrical information for *workpieces*, *set-ups* and *manufacturing features.* At the lowest level, the operations can also contain an explicit and exact description of the tool-path if this is required by a CAM system or an NC controller. The hierarchy of a STEP-NC program can be depicted by the diagram shown in Fig.6, (ISO 14649-10, 2002).

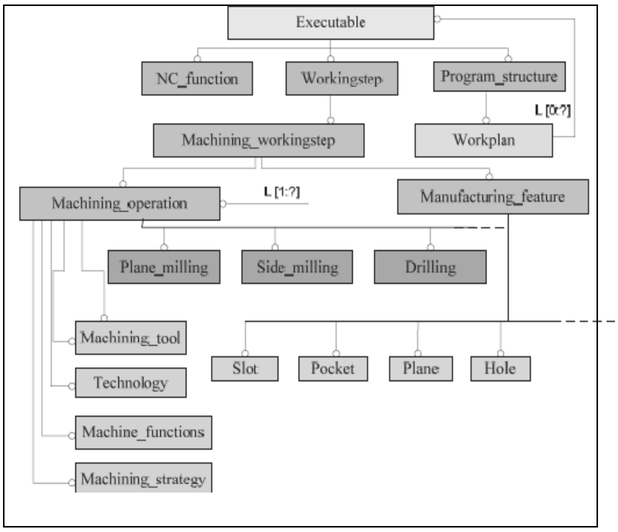


Fig.6. Hierarchy of STEP-NC program

3. DESIGN AND IMPLEMENTATION OF SOFTWARE TERMINAL STEP-NC

Department of Automation and Production Systems (DAPS) at the Faculty of Mechanical Engineering, University of Žilina focuses on the issues of computer support and automation in the engineering industry with an emphasis on programming NC and CNC production machines and industrial robots, working with CAD systems, CAD / CAM, CAM, CAPP and CAQ, solving technical production using CAx systems and technologies, and the application of microelectronics and microcomputers in engineering practice. Within research tasks was solved at DAPS analyzing, specifying and the possibilities of using standard STEP-NC. At the department was created software program for the transformation of STEP-NC data *TERMINAL STEP-NC*. The software allows processing control STEP-NC program, and based on the proposed communication protocol, sends commands to the motion control lathe controller via the serial interface USB. Created software so verify the possibility of using ISO 14649 as a new model for data exchange between CAD / CAM systems and CNC machines and also verifies the possibility of implementing a new standard to the older types of CNC machines.

3.1. Algorithmization and software creation

For solving of selected issue - the creation of software *TERMINAL STEP-NC*, was chosen programming language Visual Basic, specific environment Visual Basic 6.0. The proposed principle of processing the input file STEP-NC is composed of five basic steps (Fig.7).

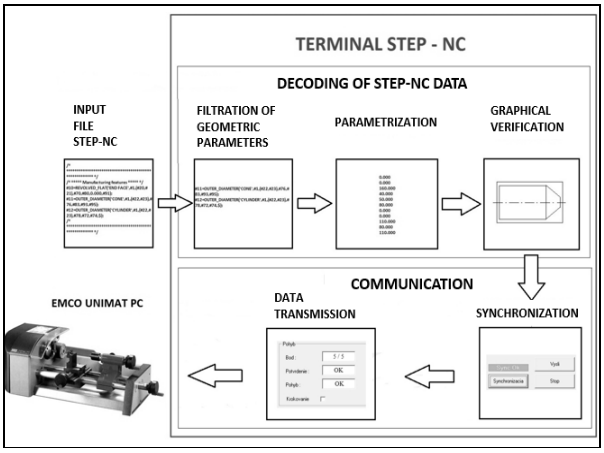
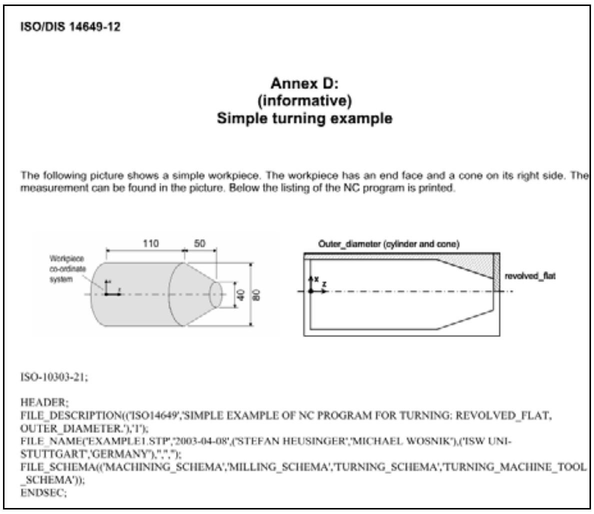


Fig.7. Working principle of software - TERMINAL STEP-NC

Decoding the STEP-NC data is formed, by filtration geometric parameters, parameterization and verification of graphics. Communication consists of synchronization and data by sending.

Entry for the program is a text file STEP-NC, which is processed by the program, so that it can be sent by asynchronous transmission over via serial line to the controller lathe Emco Unimat PC. Research also followed the creation and programming of the control unit of the machine.

Entry for the software TERMINAL STEP-NC is a control program STEP-NC (Fig.5). The software processes the source control program (.txt). Therefore the original format of the control program STEP-NC is necessary to converted to format ".txt" before the loading. Created software program TERMINAL STEP-NC was tested on STEP-NC program used from Standard - ISO 14649-12, where the program referred to under the heading "SIMPLE TURNING EXAMPLE " (Fig. 8, Fig.5).


ISO/DIS 14649-12

Annex D:
(informative)
Simple turning example

The following picture shows a simple workpiece. The workpiece has an end face and a cone on its right side. The measurement can be found in the picture. Below the listing of the NC program is printed.


```
ISO-10303-21;

HEADER;
FILE_DESCRIPTION(('ISO14649','SIMPLE EXAMPLE OF NC PROGRAM FOR TURNING: REVOLVED_FLAT,
OUTER_DIAMETER.'),'1');
FILE_NAME('EXAMPLE1.STP','2003-04-08',('STEFAN HEUSINGER','MICHAEL WOSNIK'),('ISW UNI-
STUTTGART','GERMANY'),'','','');
FILE_SCHEMA(('MACHINING_SCHEMA','MILLING_SCHEMA','TURNING_SCHEMA','TURNING_MACHINE_TOOL
_SCHEMA'));
ENDSEC;
```

Fig.8. List of control program for turning example from Standard - ISO 14649-12

Description of the structure of one program line (line 11-Fig.5) is displayed in Fig.9.

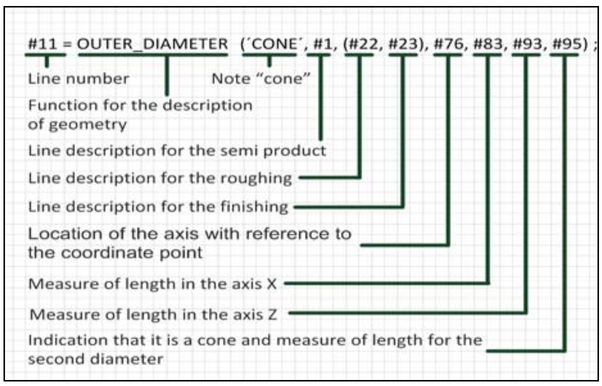


Fig.9. Structure description of one program line

Data decoded from the input file STEP-NC with this proposed procedure, are then allocated to a geometric object and transform to the necessary form for the expression of tool paths. This gives a set of discrete points describing the contour of the rotary components. In the next step, by the values of these points, will be fill the proposed structure of the communications protocol and use it's the data will be transmitted to the control system lathe (Fig.7). The process of decoding input STEP-NC program is based on the format of STEP-NC and the proposal of method describes the flowchart - Fig.10 A.

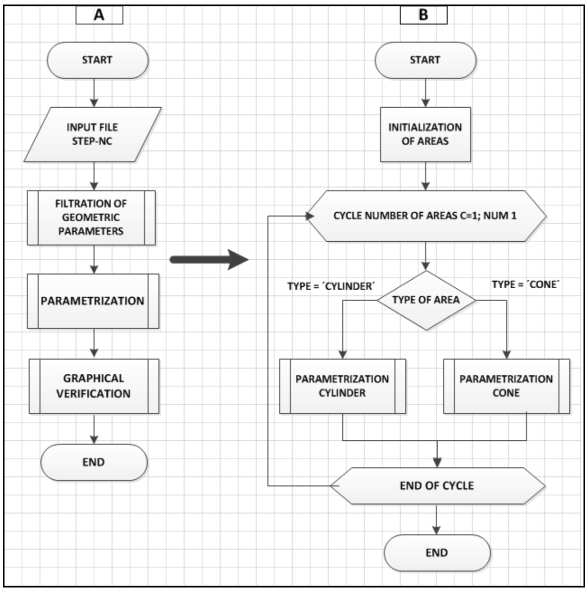


Fig.10. A: Flowchart of decoding STEP-NC data B: Flowchard for process of parameterization

The proposed procedure for parameterization on the base of known types surfaces assignees individual numerical values to specific parameters of a given surface (length, diameter) thus the surface is parametrized, (Ďurík 2013).

The algorithm of the program is designed for the processing of cylinder surface and the cone, but is to remain open, so it can be expanded in the future to the processing of other types of surfaces. The proposed process parameterization describes the flowchart - Fig.10 B.

Graphic verification serves for visually verifying the accuracy of data being loaded and their processing. The values obtained by parameterization must be for graphics function rendering converted due to the coordinate system of the object. Another functionality of the proposed TERMINAL STEP-NC software is *communication*, which allows the decoded data from the STEP-NC format to transform on the real movements of lathe Emco Unimat PC in two axes Z and X. The proposed method of communication, as well as the proposed communication protocol, allows implementing functions of synchronization, working and rapid movements, as well as error detection and limits.

Communication runs by asynchronous transmission serial line through the selected serial channel, which can be in the form of USB virtual COM port.

Verification of functionality, data transmission to the control unit Lathe - Emco Unimat PC is displayed on Fig.11.

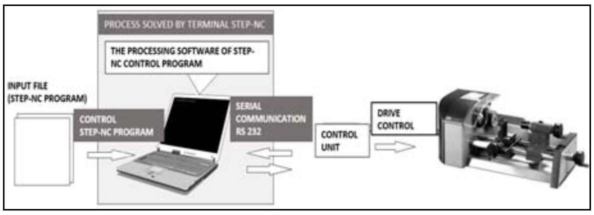


Fig.11. Process of data transmission to the control unit Lathe - Emco Unimat PC

3.2 Operating the software

Software *TERMINAL STEP-NC* is executable on all currently used systems by Windows. It's hardware requirements are minimal; therefore the minimum hardware requirements are requirements of computer operating system.

Software allows visual simulation data transfer. User interface of the program has been established with respect to a simple, intuitive operation and design.

Verification of the correct processing of the control program is possible through displaying of the product model, (Ďurík 2013).

Work environment and the procedure for processing of STEP-NC are displayed at Fig.12.

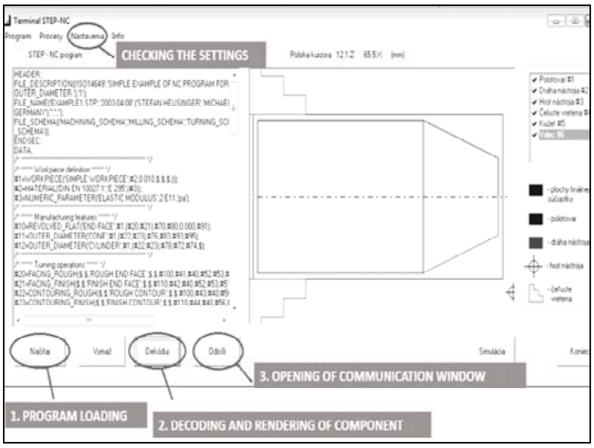


Fig.12. Procedure for processing of STEP-NC

Procedure for realization of communication is shown on Fig.13

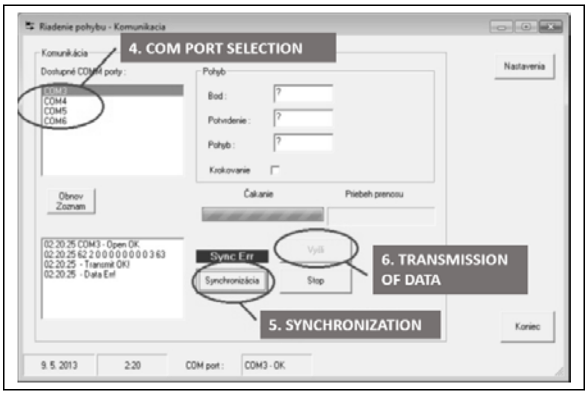


Fig.13. Procedure for realization of communication

4. CONCLUSION

Presented software program "TERMINAL STEP-NC" can process component with the geometry composed of cylindrical and conical surfaces. Algorithm of software is open, so it can be expanded in the future to process other types of surfaces and new features. Communication protocol must be extended by the control unit. Standard STEP-NC allows building a complete database of machining information around it. The database, then, dictates what capabilities must exist in the machine tool controller to cut the part. By using STEP-NC to capture instructions on what steps to follow for machining the part, the "productability" of this part would not be affected by the availability a certain brand of control unit programming system or postprocessor. The project that developed STEP-NC has estimated that it can reduce the time required to program a CNC by about 35%, reduce the number of drawings that have to be sent from design to manufacturing by about 75% and decrease the time required to machine parts on CNC tools by about 50% for small to mid-sized job lots. Based on the above discussion it can be concluded that ISO 14649 data model contains all information about manufacturing information of the part; it has good and clear structure from project, workplan and workpiece, workingsteps and setup to features as well as its operations etc; it is feature-based and task-oriented which tells what to do other than how to do about the part; it is adaptable i.e. independent of machine tools; it also conforms to ISO 10303. Thus, the advent of STEP-NC brings tremendous potential and chances to future development of manufacturing.

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5. REFERENCES

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