New Trends and Issues Proceedings on Humanities and Social Sciences

Volume 7, Issue 1, (2020) 84-91

www.prosoc.eu

Innovation of CNC machining education at the Faculty of Technology

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Suggested Citation:
Koleda, P. (2020). Innovation of CNC machining education at the Faculty of technology. *New Trends and Issues Proceedings on Humanities and Social Sciences*. *7*(1), pp 84–91. DOI: 10.18844/prosoc.v%vi%i.4870

Received from October 2, 2019; revised from March 03, 2020; accepted from June 20,2020.
Selection and peer review under responsibility of Assoc. Prof. Dr. Jesus Garcia Laborda, University of Alcala, Spain.

Abstract

The paper describes the ongoing educational project, which is focused on increasing the quality of teaching and making the study more attractive by introducing new selective courses: CNC technology in bachelor study programs and programming of CNC technology in engineering study programs at the Faculty of Technology of the Technical University in Zvolen, Slovakia. The solution of the project is also to create a background for building a CNC machining workplace. Teaching programming takes place in professional CNC emulators that are commonly used in praxis. These emulators allow program debugging, tests, trajectory drawing and optimising and collision checking of tool and workpiece. Altogether 23 students successfully completed the introduced course. Within the project solution, five theses were defended.

Keywords: CNC programming, CNC simulators, teaching, innovation, workplace building.

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1. Introduction

Nowadays, the development of science and technology is under great pressure and is moving very fast. This is also supported by the ongoing Industry 4.0 revolution (Liao, Deschamps, Loures & Ramos, 2017). The times of innovation and production cycles are shortening (Enkel & Gassmann, 2010), which also affect university education. The boundaries between individual departments are slowly disappearing, and the study programs are intertwined. On students as well as graduates, the universities of technology focus not only on specific knowledge and knowledge in the professional field but also on the ability to apply the acquired knowledge to practice (Dede, 2002; Sujova, Cierna & Zabinska, 2019). A graduate of the technical department with a focus on production technology and engineering of machinery and equipment is expected to be familiar with modern technologies and production machines, as well as with the fundamentals of their programming, from understanding the algorithmic ability of technical problems (Csongrady & Pivarciova, 2006) to applying manufacturing techniques in the form of a program for digital technology using the internet and wireless communications (Monroy, Calderon & Miranda, 2005). Similarly, graduates are expected to know reverse engineering (Hrckova, Koleda & Kassai, 2017).

For industrial practice, graduates with broad theoretical and professional knowledge are important. Knowledge of the production process and technology is essential for the quality and safe realisation of engineering activities (Dado, Kotek, Hnilica & Tuma, 2018; Hnilica, Dado, Messingerova & Jankovsky, 2013; Hnilica et al., 2017). The advancement and continuous improvement of digital technology, therefore, require training in the design and programming of numerically controlled machines. This also brings challenges for the research of online NC teaching and related platforms (Dandashly, Barbar & Antoun, 2019; Tian, 2018). This role is also complemented by higher education institutions (Cierna, Sujova, Habek, Horska & Kapsdorferova, 2017). Often the emphasis is on learning or teaching planning, control and machining of fully automated working machines (Pai, Yap, Dawai, Ramesh & Phoon, 2016). Building on the needs of society and the regional labour market, where there is a growing demand for skilled workforce, it is necessary to introduce the new and innovated vocational courses taught to adapt to their changing market requirements.

Numerically controlled manufacturing machines are characterised by the fact that the control of their working functions is performed by the control system with the direct support of the program. The required actions are written in the program using alphanumeric characters. These groups of characters are gradually arranged in the program into so-called blocks or sentences. As these machines are quickly adaptable to production requirements and they use an automated cycle with numerical control, we are talking about flexible machines (Demec, 2005; Stulpa, 2006). The CNC machining centres perform the machining operations according to the given program instructions, which are commonly programmed by a CNC programmer. The new algorithms for programming machining operations are constantly being developed. In the study of Sharma et al. (2020), a procedure to develop an automatic CNC program for machining different types of holes by using different machine learning algorithms is developed. The programming algorithms for production machines must also include manipulator programming from simple trajectories to complex. These activities can be designed for a progressive learning, starting with simple tasks, such as programming a robot arm movement between different points in space, and concluding with more complex tasks, such as programming palletising cycles or manufacturing a part by machining (Trujillo, Dorado, Lopez-Garcia & Sevilla, 2017).

CNC machines can be divided in terms of the number and types of technological operations, further by chip removal technologies, kinematics and coordinate system (Mihalik, Duplak & Kormos, 2016):

- the number of operations performed: for monoprofessions: are capable of performing only one operation (CNC lathes, milling machines, drills, boring machines, welding and cutting machines; for more professions: performing multiple operations on one workpiece (CNC centres, where according to the product type we can speak of rotary, non-rotary, shaft, flange

and box): drilling, boring, threading, turning, milling, grinding, cutting, welding and forming, for the production of gearing,
- the process of chip removal: high speed, high performance, usual and dry,
- the kinematic of operations: serial, parallel (bipod, tripod and hexapod) and combined.
- The development of a progressive CNC machining centre and the introduction of new courses is a necessary fact which will clearly contribute to increase the attractiveness of engineering studies. This contribution is in the context of the opening of study programs such as management of transportation and energetic technique in the bachelor's degree and the engineering of transportation and energetic technique in engineering degree for the requirements of manufacturing enterprises.

2. Methodology

At present, the Faculty of Technology (FT) does not have a laboratory that would bring students closer to the activities of CNC technology, where they could verify their design and programming skills in the form of simple part manufacturing. Students are familiar with machining technologies, and in the past year of engineering degree, they gain knowledge about control systems used in production technology, especially in the form of programmable controllers. During their studies, they take practical exercises in the form of excursions in production facilities throughout Slovakia. However, this is not sufficient to clarify and understand the operation of modern numerically controlled machines programmed using the ISO code, CAM modules or other programming means. The tangible output of the project will be a modern workplace that will enable to get acquainted with and practically verify the design activity from the drawing of the part to its production on the numerical controlled machine. The material objectives include the creation of textual and visual didactic materials for CNC machinery and the publication of papers in professional journals. The intangible contribution should be better applicability and competitiveness of faculty graduates, not only in the region but also in Slovakia, and increase the attractiveness of the study of technical fields.

The solution of the project KEGA 005TU Z-4/2018 – building a progressive CNC machining centre to innovate forms of education in study programs at the FT is to extend the focus of FT graduates on the knowledge of CNC engineering (NC, CNC and DNC) and its programming using ISO code and control systems. The students will acquire this knowledge in two newly introduced courses of CNC machines and CNC programming in 2 years of the study. The course CNC machines introduce students to the design of the main and auxiliary work mechanisms of the HPM tool clamping, design solution, noise reduction, vibration and dust control measures, with the general requirements for the machinery. It also provides basic information on control and programming (structure), information and correction methods. Course CNC programming is focused on the programming of CNC production technology, programming function structure, trajectory interpolation in machining process, setting tool compensation, description and analysis of preparatory, auxiliary, speed, feed functions and tool change for various production equipment.

The educational team working on the project is made up of experts in the field of mechanical engineering, design and programming of CNC technology, computer science and computer-aided design (Uhlirova, 2018).

To achieve the set goals, a workstation consisting of a numerically controlled machine and a robotic manipulator is required. The manipulator inserts and removes workpieces from the machine tool, making the workplace fully automated and eliminating the physically demanding and monotonous operation of the operating staff, a requirement that is also addressed by manufacturing facilities and future investment opportunities worldwide (Merkova, Drabek & Jelacic, 2015). The educational intention is to demonstrate and teach the students both the possibilities of movement within the working space of the manipulator, the calculation of trajectories and speeds and also the programming of the CNC technology (production machine and manipulator) in the ISO code and by control systems. They will be able to test their theoretical knowledge of design and manufacturing

technologies in a practical implementation on professional CNC technology, which will undoubtedly increase the students' motivation and deepen their knowledge. During the project, practical exercises are planned in manufacturing companies using numerical technology.

Vybervhodnychemulatorov a simulacnychprogramovboldeterminovany ich moznostamipriblizitrealnucinnostprogramatoraprinavrhu program a tiezpri CNC stroji. Edukacnytimzvolilnajpouzivanejsieprostriedky pre programovaniecislicovychstrojov: Sinutrain for Sinumerik Operate, Fanuc, Heidenhein iTNC530.

SinuTain for Sinumerik Operate allows CNC programming on the PC as on the CNC – same operation and programming. Work preparation is possible even whilst the machine is still cutting: test, run in and simulate NC programs on the PC, which means less time stress at the machine. CNC training and education are realised exactly with the same programming and user interface as in the workshop without waiting for 'finally getting to it', without the danger of breaking something and with the possibility of preparing and finishing work at home or on the road (Siemens, 2019). Job shop programming software from FANUC has advantages as follows: operator-friendly programming environment, advanced cycle machining (turning and milling), powerful profile calculation, seamless environment switching, tool management function, measurement cycles, residual cutting and background machining simulation (FANUC Europe Corporation S.A., 2019). The programming station from Heidenhain has various advantages. The programming modes offer the same features as the control on the machine, meaning that students create programs with smarT.NC (only iTNC 530), in Heidenhain conversational format or according to ISO, with graphic support for programming and test run and with all field-proven TNC functions, such as FK-free contour programming. The programming station is working with the original control software. This ensures compatibility: part programs created with the programming station run on any machine tool equipped with the appropriate control (Heidenhain Corporation, 2019).

3. Results

The optional courses of CNC technology and CNC programming were included in the study plans. Their information sheets and syllables were created. They contain fields as control systems of CNC machinery, coordinate systems, tests of programs, the modes of operations, structure of program, program cycle, absolute and incremental programming, G-functions, linear and circular interpolation, programming of turning and milling operations, robot programming playback, teach-in and off-line, measuring probes and calibration. In the subject of CNC technology, students learn about the main parts of the CNC machine (Marek, 2010): frame: main carrier of the machine tool; propulsion electric motors: electric motors for rotation of spindle or tool; ball screws: the main parts of the feed mechanism that transform the rotary movement into translation; linear sliding: they form sliding surfaces on which the slides move; tool magazine: make up the tool magazine for quick tool change; turret heads: heads for holding 6–12 driven or non-driven tools; hydraulic power unit: regulates the system pressure to the value required for the hydraulic functions of the machine; lubrication system: supplies the ball spindles of the feed and sliding axes with the necessary lubricant and cooling system: cools the used coolant in the heat exchanger and returns it to the machine tool tray. The workplace preparation for CNC programming began; the laboratory consists of five computer sets, purchasing of CNC machinery. FeatureCAM® CNC programming software from AutoCAD includes feature recognition and automation tools to reduce programming time (Mendelli, 2019). Safe toolpaths are visualised with simulation. It uses manufacturing knowledge to intelligently make decisions, produce results and remove repetitive processes (Autodesk, Inc., 2019).

The preparation of study materials (procedures for writing ISO code for machining operations): Lectures and materials for the exercises in the subject programming of CNC manufacturing technology are prepared. In the summer semester of the academic year 2017/2018, the teaching of the optional course such as CNC Programming of production technique was started, and 6 students applied for it and successfully completed it. In the academic year 2018/2019, 17 students successfully completed

the course. In the academic year 2019/2020, 6 students successfully completed the course. The success of the students is shown in Figure 1.

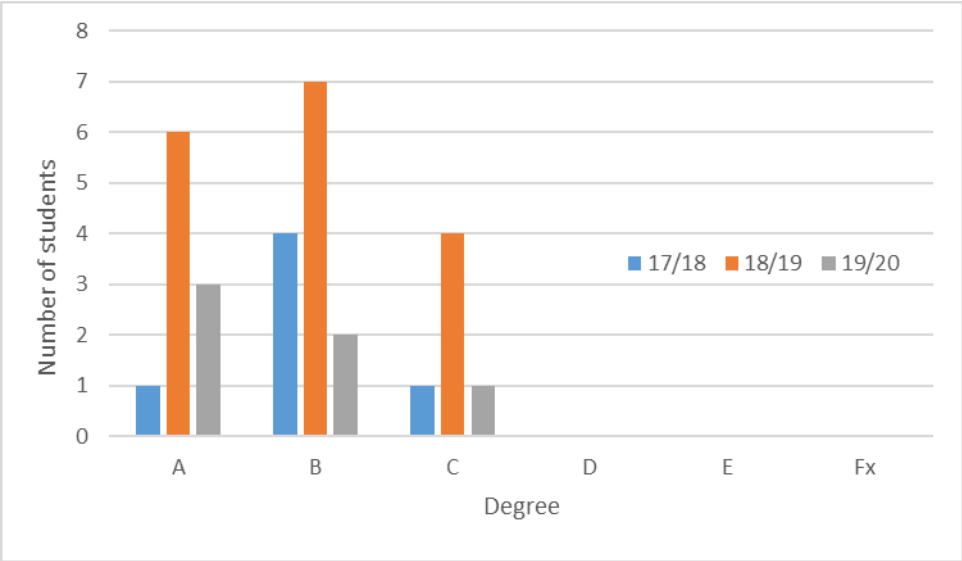

Figure 1. Success of students on their examination

In the exercises, students become familiar with the structure and functions of the ISO code and learn to program the turning operations with direct code writing. The students use SinuTrain for Sinumerik Operate for programming of turning and milling operations. In the second part of the semester, the students will learn the principles and strategies of 2.5 and 3D milling using CAM software FeatureCAM from AutoCAD. Educators who program CNC technology have completed training in a certified training centre. Practical methods are used in the teaching process – practice, exercise and training. Based on learning objectives and curricula, the reproductive methods of learning are used. Problem-solving teaching methods are often used in machining programming – students should correctly apply the already learned knowledge of manufacturing technologies to achieve the desired geometric shape of the machined part. Simultaneously, they will verify the correctness of their procedure (machined/unmachined surfaces, undercut surfaces, tool collision, tool holder collision, etc.).

One of the goals of the project is to identify a suitable affordable CNC machine. After considering the usefulness and feasibility of purchasing the CNC technology from the allocated funds, the research team decided to purchase software licenses to teach the programming of CNC technology from EMCO. It is a WinNC software with an Sinumerik Operate emulator that has an HMI interface the same as a manufacturing machine. In the course evaluation, the subject is evaluated positively, and the students emphasise the possibilities of practical use of the learned knowledge (Franco Caballero & Aguilera, 2019).

Bachelor's thesis was successfully defended: Bartko, J. 2019: Programming of CNC technology – programming environment; Tomcala A., 2019: Modern CNC woodworking machines; Tysowecki, M. 2019: Modern CNC metalworking machines; Zabka, M. 2017: Programming of numerical machines and Kasac, M. 2017: Analysis of linear drive. The work is directly related to programming and programming environments for CNC technology and will be used for the preparation and extension of textual and visual teaching aids – lectures and background papers for the subject of programming CNC machines. They will also be the basis for drafting and publishing scripts from this subject. Purchasing licenses for software versions for CNC programming software.

4. Conclusions

Within its long-term development and cooperation with industry, the technical university in Zvolen itself supports the construction of modern laboratories. FT cooperates on this project with the second largest university faculty – Faculty of Wood Technology.

The successful introduction of new subjects and the improvement of teaching methods improve students' applicability. The project solution brings improvements to the learning process: training – practicing and consolidating the curriculum presented and application – application of the subject matter in the student's practical activities (Lai & Zou, 2018). At the same time, it facilitates the transition from theory to practice in the teaching process. In the following period, the purchase of other emulators of CNC technology is planned, and in the future, the construction of a laboratory with CNC milling machines, resp. machining centres. Its building strategy should take into account low-cost equipment as a didactic resource for training (Peixoto & Monteiro, 2019). The development of programming methods and procedures is still ahead, as evidenced, for example, by the development of CAD/CAM systems. Each programming environment brings advantages and disadvantages. It always depends on the circumstances, i.e., what area of use it is, what is the character of the work and what the main criteria and parameters should meet. It depends on the task of the desired program. In general, the advantages of modernising CNC machine programming include increasing the quality and quantity of production, accuracy, shortening production time, efficiency, variability and software compatibility. On the other hand, the disadvantage can be not only the high price of software demands on professional competence, demanding technological preparation, but also incompatibility with the original already technically obsolete equipment/system, accelerated obsolescence of hardware and software equipment. Ideally, the CNC programmer has knowledge not only in computer science and computer technology but also in the machining technology and economy. Most of the works of the CNC machine tool programmer also include the design of the technological process. Although CAD/CAM systems are a trend, it is not always true that the most modern programming method is the right one.

Acknowledgements

KEGA 005TU Z-4/2018 – Building a progressive CNC machining centre to innovate forms of education in study programs at the Faculty of Environmental and Manufacturing Technology

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