Acta of Turin Polytechnic University in Tashkent, 2021, 11, 32-37
Published Online June 2021 in Acta TTPU (http://www.acta.polito.uz/)

CAD/CAM/CNC course framework based on "process-oriented" for Uzbek Higher Education Institutes (HEI's)

Ikrom Kambarov[1] **and Jamshid Inoyatkhodjaev**[2]
Turin Polytechnic University in Tashkent.
[1]Email: ikrom.kambarov@polito.uz
[2]Email: j.inoyatkhodjaev@polito.uz

Abstract– Despite the increase of importance, the emerging technologies in manufacturing industry in the last decades, the role of the human factor is still necessary for the future manufacturing. The skills and qualifications of the workforce will become the key to success of a highly innovative digital factory. Therefore, the engineering universities are highly pressured to develop a new "process-oriented" curriculum to keep up with the rapid changes in other fields, especially, information technology (IT). For this reason, in a continuous effort to develop and incorporate innovative teaching styles in the Mechanical Engineering curriculum at Turin Polytechnic University in Tashkent (TPUT) a new lab course titled CAD/CAM/CNC has been introduced under MechaUz Erasmus project, wherein the bachelor students are exposed to Computer Aided Design (CAD) and computer aided manufacturing (CAM) skills. The main goal of this course is to introduce the knowledge in the area of CAD/CAM technology and its application in computer numerical controlled (CNC) machines. The "process-oriented" project is being developed in order to integrates theory, practice and laboratory modes. Systematic Literature Review (SLR) on CAD/CAM/CNC course designs are surveyed to identify the limitations in traditional teaching on the courses. The current state of the art teaching curriculum of Uzbek technical universities has been studied to define gap between current teaching techniques and future education requirements. The mechanical CAD/CAM/CNC technology course is oriented to the entire process of the design and manufacturing based on "process-oriented" and after completing this course students cultivate numerical control skills with high quality, innovative ability and practical ability that meet the needs of enterprises..

Key words– Engineering Education, CAD, CAM, CNC

I Introduction

Higher Education Institutes (HEI's) in Uzbekistan have limited freedom in developing their own curriculum, because 95% of the HEIs are under the control of the Ministry of Higher and Secondary Special Education, which sets state education standards and thus limits the level of flexibility. The lack of this freedom results in lower creativity and innovation in teaching, research, and academic processes, and limits students' abilities to gain additional qualifications and have double major programs [1]. However, in recent year's higher education in Uzbekistan leap forward towards new era. For example, according to presential degree №5847 "About approval the Concept of development of the higher education system in the Uzbekistan till 2030", the following key areas of developments have been defined:

- phased transition from theoretical knowledge, to the practical skills proceeding from the international experience;
- adjustment of system of training of the highly qualified personnel capable to find the place in the labor market;
- ensuring the academic independence of the highest educational institutions;
- step-by-step implementation of the concept "University 3.0" and etc.

In order to meet this degree, the Mechanical Engineering curriculum at Turin Polytechnic University in Tashkent (TPUT) a new lab course titled CAD/CAM/CNC has been introduced.

At the same time, Uzbekistan's industry is evolving with transformation of the advanced technologies in the recent years, the need more diverse skills like information technologies like CAD/CAM set in important for new employees. However, the teaching content on mechanical course was heavily oriented toward theory. Thus, due to excessive

theory, students feel bored and lose concentration, which ignores subjective motivations. In addition, they cannot possess important theoretical knowledge from the explanation of basic software and thus fails to satisfy the sustainable development of students. Therefore, HEIs should be given greater autonomy in designing programs they offer, more flexibility in curriculum management, more "process-oriented" contents, and greater control of their management. Such freedom is necessary to encourage and support the development of a competitive environment in the higher education sector, with players competing for the best students, which generate extra- income (e.g., research and development projects, training programs, etc.) [1].

Based on the above-mentioned description of the educational aspects of CAD/CAM, the remainder of this article is organized as follows: Section 2 describes state of art of existing courses and the content, teaching methods and practical links in the course are summarized. Section 3 describes the current teaching status on CAD/CAM in Uzbek higher education institutes. Then, in Section 4, a new CAD/CAM/CNC "processes-oriented" framework is proposed.

In general, reformed course reflects teaching methods to make the teaching process serve the enterprise's requirements for students and to cultivate numerical control skilled talents with high quality, innovative ability and practical ability that meet the needs of social and economic development.

II THE METHODOLOGY

A Systematic Literature Review (SLR) was used as an as a means of identifying, evaluating and interpreting state of art all available CAD/CAM/CNC courses developed by international researchers. To cover relevant publications in the fields of education, engineering and production from both academia and business, the authors took advantage of three publication databases (Science Direct, Research Gate and Google Scholar). The literature review aimed at identifying central aspects of CAD/CAM/CNC courses developed by international researchers in order to be able to derive existing problems in current curriculums.

In addition, to identify the current state of art CAD/CAM/CNC courses in local universities, to gain insight, interviews and google form questionnaires were conducted with 20 technical universities from Uzbekistan. The average length of these interviews were be about an hour and focus on how they implemented CAD/CAM/CNC courses to their educational systems.

Through the inputs and relationships identified in the survey study and SLR, the framework of CAD/CAM/CNC was developed, which will be further discussed in Section 4.

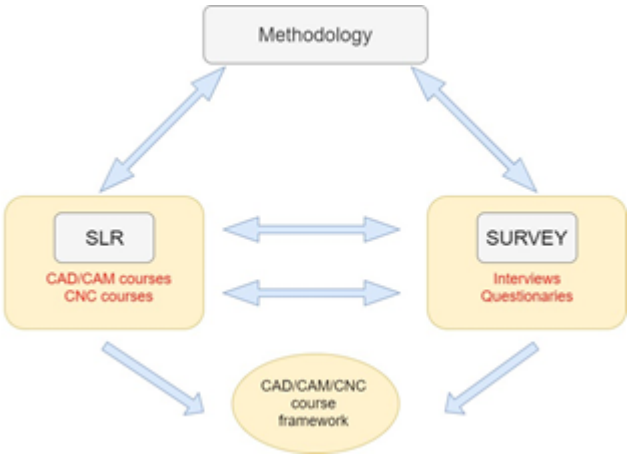

Fig. 1: Methodology

III STATE OF ART

Computer Aided Design reference to CAD, is the means of designing and creating geometry and models that can be used in the process of product manufacturing [2-4]. Computer Aided Manufacturing reference to CAM, it is the means of processing a designed part model, creating and simulation machine toolpath for its various components and creating a G-code that is then uploaded to a CNC machine [2-4]. The goal of CAD/CAM technology is to automate CNC machines and allow engineers and CNC businesses to manufacture products, bringing them to market faster and more profitably than ever before [4]. With the help of today's CAD/CAM technology, design team can work to create a complete product. In addition, they are used for simulation which seek to create virtual manufacturing environment. Many uncertainties which may result in time delay, rework or production of defective parts can be eliminated through simulation or manufacturing, whether it is CNC machining, plastic injection molding, casting, forging or welding [4].

Literature analysis shows that the most technical universities are mainly focused on the CAD model design in the practical course of software operation. Nevertheless, some universities enrich CAD/CAM practice teaching links using a series of means. For example, [5] organized students to participate in professional competitions by assigning a "Big homework". Juan (2013) developed graphics engineering teaching methods based on the simulation of a mechanical motion [6]. The method developed by Juan increased the application capacities of students to a certain extent, but systematization and comprehensiveness are still lacking. The five-axis machining programming tool brought by [7] into the CAD/CAM course. In 2014, [8] introduced CAD/CAM and CNC machining course by using a feature-based methodology in the Mechanical Engineering curriculum at King

Fahd University of Petroleum and Minerals. The CAD model designed in this study is consists of the combination of 2.5 D and 3 D features. These features are boss, cavity or multi surfaces. Moreover, this course consists of introduction of CNC machines, G-code writing, use of CAM software, selection of machining parameters according to work piece material and cutting tool. Later on, Du (2014) proposed the reorganization of teaching resources to enhance the practical teaching [9]. Pan (2017) developed the design competition into CAD/CAM course to design the course standard for competition and teaching [10]. Zheng (2019) [11] and others developed practice of mechanical CAD/CAM course for applied undergraduates' students. This teaching method adopts the teaching mode of theory and practice, from two-dimensional to three dimensional sketches, determines the teaching mode of the course in the form of case and simulation.

The course is conducted with a teaching reform to refine the teaching goal after the teaching survey of mechanical CAD/CAM/CNC technology curriculum at local and international universities. The students can learn the necessary knowledge modules to rebuild the teaching content. First, the complex theoretical knowledge on CNC has been closely organized according to the actual production needs. Second, the computer laboratories of students are emphasized. Students can solve practical problems with innovative spirit to break the unitary teaching idea by formulating typical tasks. The teaching forms are enriched to develop the initiatives of students.

IV CURRENT CAD/CAM/CNC TEACHINNG STATUS IN UZBEKISTAN

According to statistics, there are 16% of technical HEI in Uzbekistan and stands 20 institutions. The mechanical engineering students are not rigorously trained in software like AutoCAD, SolidWorks and UG. Great difficulties exist in learning, which directly affects enthusiasm for learning. Teachers only briefly introduce and not deeply discuss the concept. Teachers should focus on curriculum teaching and practical operation, which play an effective role in future employment. However, currently, many universities in Uzbekistan are involved into the programs of international quality assurances programs with European universities within European Union programs, such TEMPUS, ERASMUS MUNDUS and other North-South projects. For example, Tashkent Automotive Road Institute and Jizzakh Polytechnic Institute – "Computer-Aided Engineering /Design/Manufacturing Computer Modeling Tools: Joint Bachelors, Masters and PhD Degrees"

Figure 2 presents available CAD courses in Uzbek Higher Education Institutes.

The results show that there is CAD courses in Higher Education Institutes in Uzbekistan, however it is only 30% of technical HEI's are integrated CAD technologies into their educational curriculum.

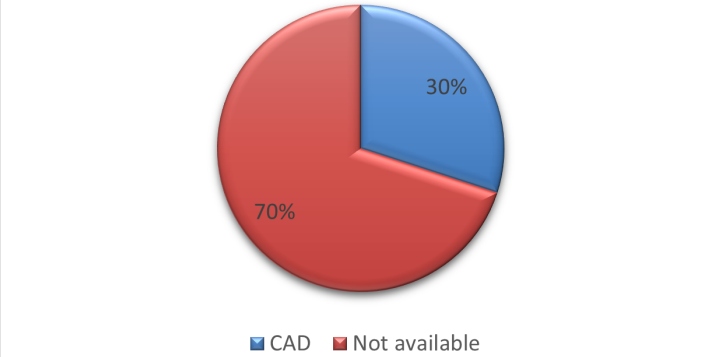

Fig. 2: Available CAD courses in Uzbek HEI's

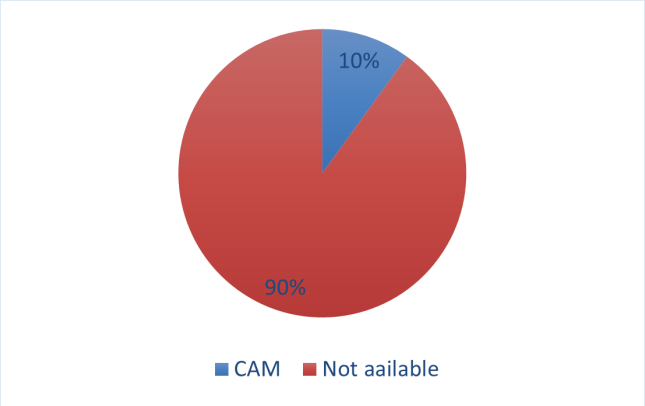

Fig. 3: Available CAM courses in Uzbek HEI's

Figure 3 shows integrated CAM courses in Uzbek Higher Education Institutes.

According to percentage of Figure 3, we can say that only 10% of technical universities are adopted CAM technologies into their education systems. Unfortunately, the survey and interview results showed that, any technical university in Uzbekistan designed CAD/CAM/CNC integrated courses (see Table 1).

Therefore, professors of Turin Polytechnic University in Tashkent developed a new CAD/CAM/CNC course based on "process-oriented" for teaching engineering discipline students in Uzbekistan which will lead towards digital manufacturing.

V FRAMEWORK DEVELOPMENT

Based on relevant knowledge and skills, the teaching content is optimized by taking product design, modeling, tech-

University	CAD	CAM	CAD/CAM/CNC
Islam Karimov State Technical University	Compass AutoCAD MathCAD	Not available	Not available
Almalyk branch of the Islam Karimov State Technical University	Compass AutoCAD MathCAM	SprutCAM	Not available
Andijan Machine-Building Institute	NX Unigraphics	NX Unigraphics	Not available
Tashkent Automotive Road Institute	Ideas Solid works Solid edge	Not available	Not available
Jizzakh Polytechnic Institute	Solid works	Not available	Not available
Tashkent Institute of Irrigation and Agricultural Mechanization Engineers	Solid works	Not available	Not available
Tashkent Chemical Technology Institute	AutoCAD	Not available	Not available
Fergana Polytechnic Institute	AutoCAD Solid works	Not available	Not available

TABLE 1: CURRENT CAD/CAM/CNC TEACHING STATUS IN UZBEK TECHNICAL HEI'S

nology analysis, and CNC programming as the teaching mainline. Students fully understand the entire process of product design and production after the theoretical learning and practical skill training of the whole process (part pattern analysis, 2D drawing, solid modeling, process design, simulation processing, and automatic programming).

In this course, according to the teaching content, the framework is divided into four teaching modules:

Module 1. Theory: This part is aimed at developing the basic knowledge on Computer Numerical Control programming of milling and turning machines, control systems, feedback systems, tool types, holder types, tool nomenclature, introduction to G and M Codes. In class-based lectures they will write programming codes for given parts. After this theoretical part, students will able to choose process and tool technology for machining operation.

Fig. 4: CAD/CAM/CNC integrated teaching process

Module 2. CAD: Geometric modeling technology is the precondition of achieving CAD/CAM and the integration. Students will learn to master the concepts and methods of 2D drawing and 3D modeling, and the method of feature modeling for the manufacturing process. The students use mod-

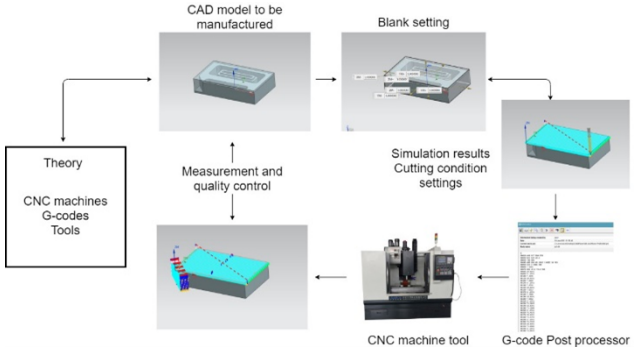

Fig. 5: The flow diagram of CAD/CAM/CNC framework

eling software, which includes NX UG, and SolidWorks, to quickly sketch and edit 2D graphics. The appropriate modeling method is selected to conduct 3D solid and surface modeling.

Module 3. CAM: Students will learn to use software, such as CNC programming software NX UG. The appropriate parameters are set to generate process simulation. Thus, students learn post-processor to generate G-code for given sample and will use this code for prototyping in next module.

Module 4. CNC: This module is intended for prototyping. Students using CNC machines like milling and turning will produce the elements done on CAD/CAM modules.

Based on module organization teaching, we obtained the CAD/CAM/CNC framework with more systematic teaching content with highly consistent knowledge and efficient teaching.

VI RESULTS AND DISCUSSION

The content of the mechanical CAD/CAM/CNC course is complex and the operation of software is difficult. Due to the high technology and large amount of information, the traditional teaching method is difficult to adapt during the teaching work. It is undoubtedly one of the key points of teaching reform that how to enable students to grasp relevant skills quickly in a relatively short period of time and to enter the brand-new field of design and manufacturing as early as possible. For this reason, in order to optimize the teaching process, we adopted the "process-oriented" teaching mode to reassemble the teaching resources rather. Teaching combines the theory and practice training. Based on NX Unigraphics software of the CAD/CAM the following flow diagram has been generated (see. Fig 3).

A Multimedia courses

Firstly, in the process of teaching theory, the multimedia courseware is applied to make the teaching content vivid. Making full use of the advanced teaching conditions using video, animation and on-site operation and other forms of teaching, the teaching effect has been significantly improved.

B Teaching and training

To realize the connection between theoretical teaching, practical and laboratory training. In the course of teaching, experiment and theory are carried out simultaneously.

VII CONCLUSION

Survey analysis showed that there is low integration of CAD and CAM technologies in local technical HEI's, 30% and 10% respectively. In addition, all these available courses are not "process-oriented".

Therefore, in this paper, the authors offered CAD/CAM/CNC "process-oriented" course for undergraduate students of engineering degree programs. The developed course is consists of detail introduction of CNC machines, manual code writing, use of CAD and CAM technology, and selection of machining parameters according to work piece material and cutting tool.

Integrated CAM application with CAD using NX Unigraphics software is helpful for the smooth transition of CAD to CAM and is expected to shorten the learning time of the students but with a greater depth than the existing course.

Combining the practical teaching of CAD/CAM software application with the teaching of advanced NC programming technology organically, every student can use CAD/CAM software to complete the whole process of parts from design, modeling to generating NC processing program and machine tool processing, and solve students' problems in the operation process.

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