

An innovative approach to teaching engineering graphics focused on CAD/CAM/CAE systems

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Abstract. A new approach to teaching the subject "Engineering Graphics" is developed in the article; it focuses on the use of CAD/CAM/CAE systems as useful tools for solving engineering problems related to mechanical engineering, instead of describing different software options. Thus, the content of the topic is divided into two blocks, one is devoted to the analysis of the results of modeling the motion of dissimilar mechanisms, and the second is devoted to the analysis of various cases of loading structural elements using the FEA module. Both blocks are available in Autodesk Inventor Pro, and students can download it for free. So, students can visualize and understand the complexity of the design process in engineering.

Keywords: CAD/CAM/CAE, FEM engineering graphics, computer lab, collaborative learning.

1.Introduction

As part of the adaptation of Uzbek academic degrees to the European system of academic degrees of higher education [1], a new subject called "Engineering Graphics" was included in the education course of the undergraduate degree in mechanical engineering. Considering the extensive utilization of this topic in many industries [2, 3], there was contemplation of adopting a novel methodology for its instruction, including all phases of the CAD/CAM/CAE process [4]. This method strives to distance itself from the typical simplistic depiction of software alternatives. The objective is to instruct students in the practical application of information and principles acquired in prior engineering subjects, such as machine theory and strength of materials, via the use of contemporary CAD/CAM/CAE software. The subject's content is divided into two sections: (i) a structural section, which analyzes the

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stresses and strains of structural components considering different boundary conditions and loading schemes, and (ii) a mechanical section, which performs kinematic and dynamic analysis of mechanical elements. Autodesk Inventor software was used in both instances. Hence, the majority of students engage in their coursework inside the computer lab, since the topic necessitates a hands-on approach. Consequently, the enhancement of continuous evaluation is achieved by creating a diverse range of practice tasks.

The course "Engineering and Computer Graphics" is part of the second semester curriculum for first-year students majoring in "Mechanical Engineering" at the Tashkent Chemical-Technological Institute. The topic has a workload of 6 ECTS, consisting of 6 hours of weekly instruction and 90 hours of independent student study. Prior knowledge is necessary to fully use the theory of mechanisms and machines and material strength, given the information covered in the course. Upon completion of the course, the anticipated outcomes include the acquisition of "proficiency and expertise in the implementation of engineering graphics techniques."

We selected Autodesk Inventor as our preferred commercial CAE program due to two primary factors. Primarily, it is advantageous to use a single program for the CAD/CAE process since it encompasses all phases, ranging from fundamental CAD design to more sophisticated CAE possibilities like FEA or motion modeling. Consequently, students must acquire proficiency in a singular software. The second factor is related to the economy. Autodesk provides students and educators with an unrestricted three-year license, which may be accessed via <http://student.autodesk.com>. Consequently, students have the ability to get the program and use it on their own computers, so augmenting their self-directed learning with this instrument.

This topic has strong connections to various areas of Mechanical Engineering, including Machine Unit Design, Vibration, and Structural Theory (Design Assistant, FEA, etc.). The objective is to use this information in order to address practical engineering challenges using this tool throughout the whole design process.

The instruction of this topic is often regarded as very pragmatic. The user's text is empty. Thus, from this beginning point, a range of learning activities were devised in order for the learners to gain the requisite abilities. The acts may be categorized into the following aspects:

(i) Theoretical studies encompassing fundamental concepts of the subject, such as the design process and the utilization of Autodesk Inventor as a CAD/CAE tool. (ii) Practical training involving the application of Inventor as a CAE tool to tackle and resolve a diverse range of real-world design challenges. (iii) The presentation and defense of students' projects, providing an opportunity to showcase the outcomes of their independent work.

In order to acquire the necessary abilities, the instructional approach relies only on practical application, whereby a range of technical challenges are resolved via the use of CAD/CAM/CAE systems. Consequently, the majority of the courses take place in one of the computer laboratories belonging to the university. Therefore, this explanation primarily covers the fundamental use of the program, emphasizing the essential tools for operating with such software and pivotal principles such as responsive design or parametric design. After becoming familiar with Autodesk Inventor, participants get a fundamental lecture on the process of creating models of components and integrating them into a mechanical system. This lecture covers the most frequently used 3D procedures. Subsequently, students encounter the suggested methodologies presented on the moodle platform of the Tashkent Chemical Technological Institute, which includes specified due dates for submitting reports that are distributed throughout the course of the semester. At the start of the practice session, a short explanation of each activity is provided. The objective is to systematically enhance the intricacy of the mechanism design and the autonomy to make design choices, as shown below.

Lesson 1: Analyzing the slide-crank mechanism. We use this uncomplicated technique to instruct the fundamental principles of component and assembly modeling, as well as the module of Autodesk Inventor's dynamic modeling. Initially, students are required to meticulously replicate each aspect of the data provided in the practice paperwork, paying close attention to the specified dimensions. Like every design challenge, there are several viable solutions, and students have the option to pick the most straightforward one. Once the mechanism has been developed and built, it is necessary to simulate two scenarios. Initially, they examine kinematic parameters, such as the location and speed of each rod in the apparatus, while the crank undergoes uniform rotational motion. In order to validate the simulation findings, students must juxtapose them with the outcomes derived from the analytical solution using the principles of mechanisms theory. Secondly, it is necessary to deactivate the movement restriction of the mechanism and engage the torque on the crank in order to initiate the motion of the mechanism under two specific circumstances: with and without the presence of gravitational force. Therefore, students have the opportunity to visually examine and scrutinize the impact of varying weight loads on the dynamics of the mechanism. The final component of the first exercise involves examining a slide-crank mechanism that exhibits rapid reverse displacement. Thus, it is advisable for students to first alter the original mechanism by modifying the constraint of the piston axis, positioning it on a parallel guide located above the original one.

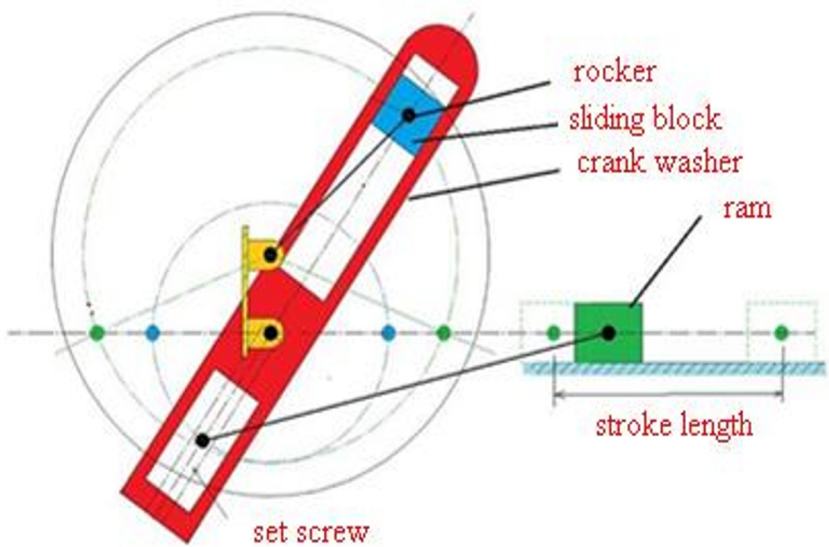


FIGURE 1. Withworth quick return mechanism

After constructing the eccentric mechanism, the student has to simulate a movement that corresponds to the angular velocity. The analysis examines the alterations in the motion of a rapid return mechanism, and, similar to the previous scenario, the students are required to compare the simulation findings with those derived from the analytical solution. To finalize Fig. 1, it is necessary to get the time ratio by comparing the crank angle during the working stroke to the angle needed for the return stroke.

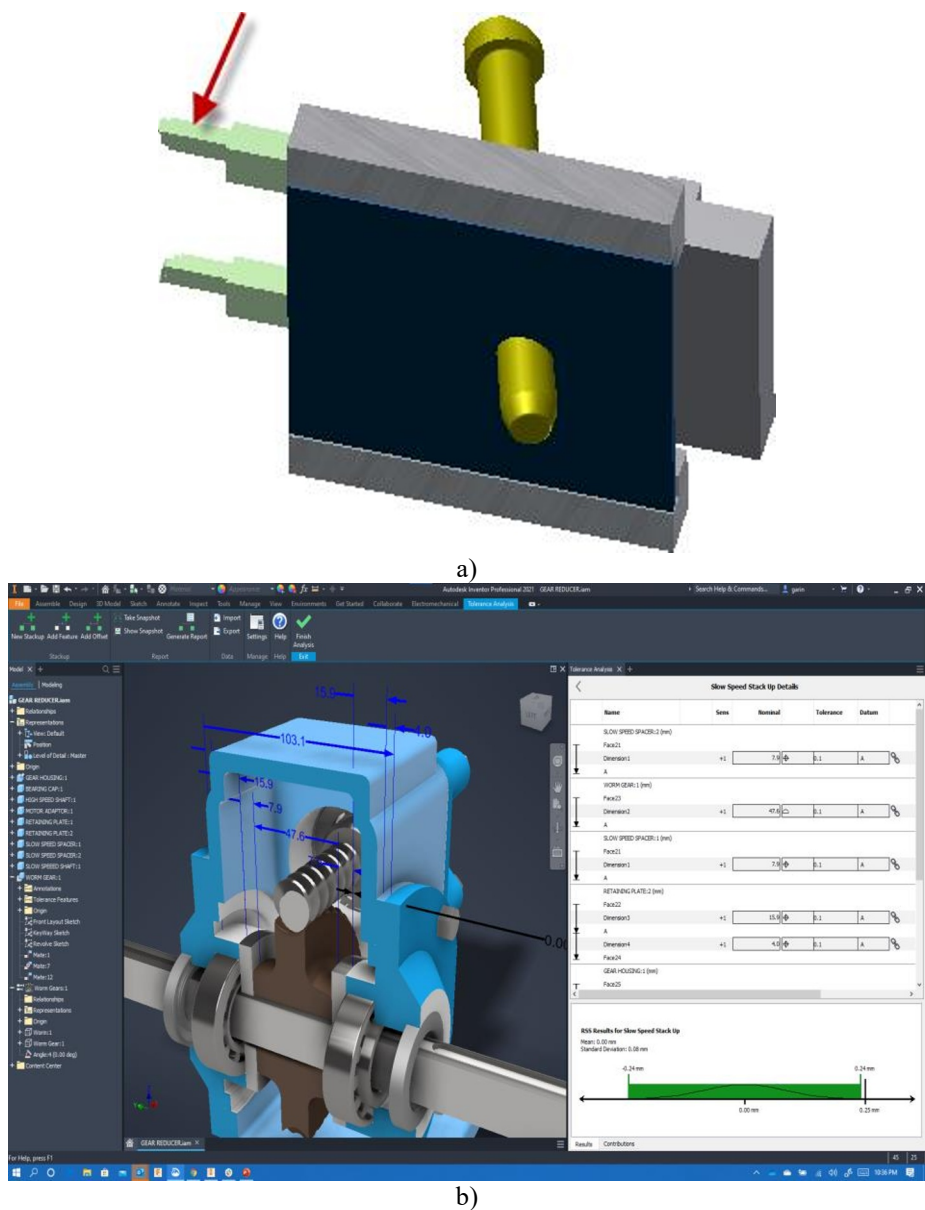


FIGURE 2. Simulation of the slider crank mechanism with Autodesk Inventor:
(a) base model, (b) model displacement

Examination of a four-link hitch. As per past practice, students are required to construct and build a mechanism based on the presented data. Nevertheless, this exercise entails two more tasks. Prior to proceeding, it is necessary to create the connecting bar of the mechanism so that it incorporates the point indicated in the Crones-Nelson atlas (Fig. 2a) [5] into its geometry. The design of this bar is unconstrained, with the only restraint being the placement of the tip. To activate the movement of the mechanism, the second task involves utilizing a toothed gear and CAE tools, as depicted in Figure 2b. To design a transfer train, it is

imperative to minimize the size of the gearbox while adhering to specific time constraints. These constraints include having two stages, a transmission module, no correction, and a desired transmission ratio. Upon model creation, students are required to acquire the transmission angle and various kinematic parameters, including the limits of the rocker arm movement, etc., and subsequently compare these values with those derived from the theoretical equations.

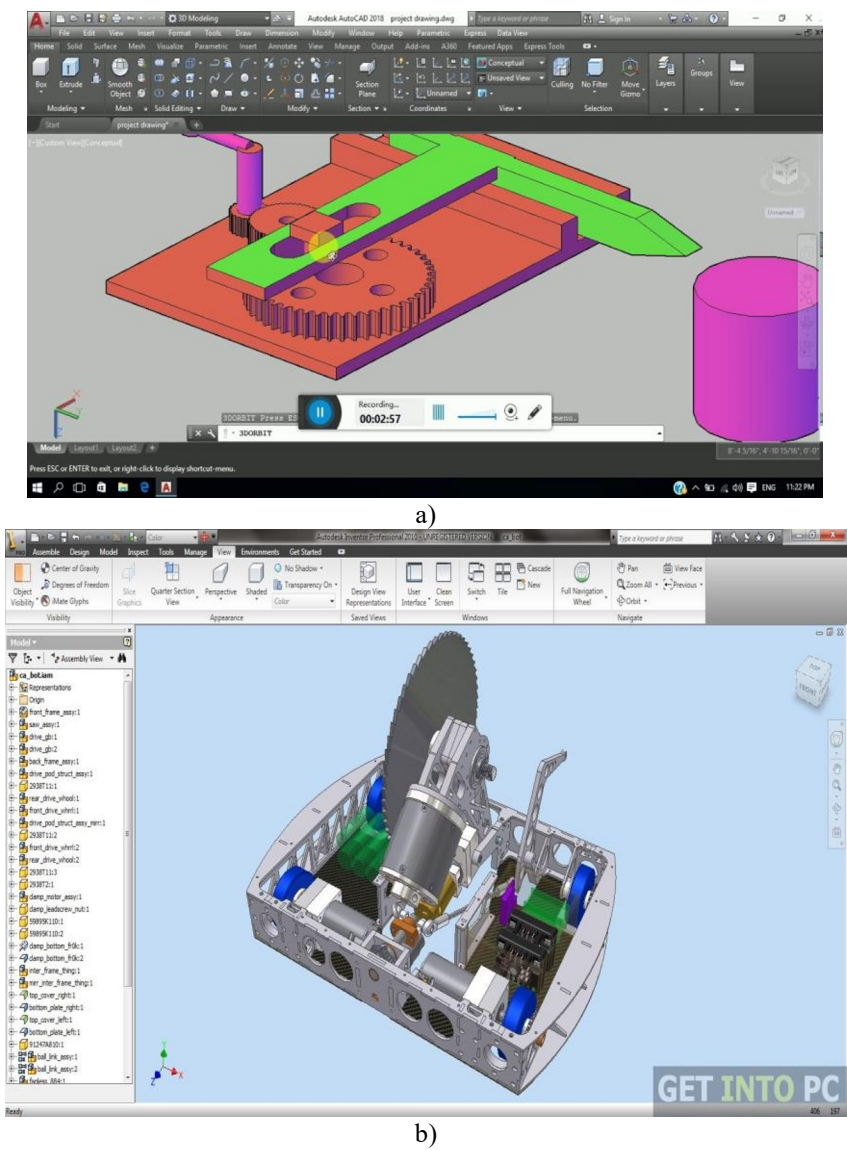


FIGURE 3. Withworth mechanism: (a) draft view and (b) one of the solutions of the mechanism modeled with Autodesk Inventor.

2. Analysis of the crank mechanism.

This method maximizes the autonomy to make design choices. Students get a basic blueprint of the system that includes the distances between the different linkages (Fig. 3a). The objective for students is to do research on actual mechanisms and, using this knowledge, to simulate or create each component of the mechanism, replicating its motion. Here, the learner is required to autonomously do a theoretical examination to contrast the outcomes of numerical simulation. Given that the design is provided to the students at no cost, it is necessary for them to include illustrations of every individual component and the overall assembly in the conclusive report (Fig.3b).

Structural Engineering: The last practice session starts with an introductory lecture where students are familiarized with the fundamentals of Finite Element Method (FEM) and important principles like convergence testing. The primary objective is to enable students to acquire the skill of modeling structures using the CAE tool provided by Autodesk Inventor®. This tool encompasses a comprehensive library of commercial structural profiles and offers a diverse range of tools for the development of structural components. Once the building is built, the student has to do a static analysis of the three learning scenarios using the Finite Element Analysis (FEA) module.

Initially, a simple geometric issue is presented: a cantilever beam is exposed to a combined load, allowing students to evaluate the distribution of stress over the section and make comparisons with theoretical models.

Furthermore, students are required to create a building that has the ability to endure the designated amount of weight. Therefore, pupils must choose a more efficient and productive constructive option. Students should systematically evaluate several grids to verify the convergence of their findings in every scenario.

Skills assessment is performed by the provision of various exercises and the public evaluation of provided design alternatives.

3. Conclusion

This article introduces a novel method for instructing Engineering Graphics by incorporating diverse techniques in which students utilize their prior knowledge in fundamental engineering topics, such as material strength and mechanical theory, through the utilization of free CAD/CAM/CAE software. By engaging in these activities, students analyze the motion of several common mechanisms, enhancing the intricacy and flexibility of design, and using the computer-aided engineering (CAE) modules of the software stated above.

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