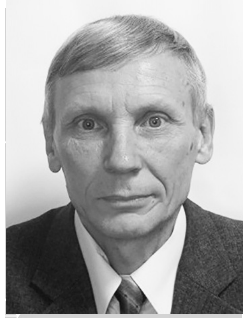

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Mathematics in Engineering Education within the Framework of CDIO Standards: Methodological Aspect

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"In studying science, examples are more important than rules"
Issac Newton

The article describes the CDIO standard effect on the teaching methods of mathematics in technical institutions and focuses on the integration tools in mathematical and engineering training. Teaching tools in designing learning activities to implement the integration objectives and recommendation for their application during the teaching process have been examined based on a specific example.

Key words: : engineering education, CDIO standards, integration of engineering and mathematical training, teaching methods in mathematics, technical universities.

Since engineering (technical) education has embraced definite learning tools and has become an independent domain, mathematics, as a science, could be considered practical in training future engineers. Moreover, mathematics is a fundamental discipline in engineering and, for more than 200 years, student selection during entrance exams has been based on their mathematical skills. The basic contradictions arise from the content of mathematical education of future engineers and, even more, from the teaching to be applied.

Within the framework of the engineering education there exist two competitive theoretic-methodological approaches in the didactics of teaching mathematics. The first approach is based on the fact that mathematics itself has its own internal structure and logic to understand, assimilate and facilitate its regular application. Applied mathematics does not exist independently. It is an integrated science and, as such, teaching mathematics for engineers should not be considerably diverged from other university courses [1, pp. 88]. The second approach includes that the objectives of mathematics teaching and academic interests of engineers are quite different from those of the mathematicians. Thus, mathematics within the framework of engineering education is something special, i.e. "engineering mathematics." And, in this case, it is necessary to teach it in a different way, incorporating the professional requirements, as well as characteristics of engineering mentality [2, pp. 285-289].

Based on the international CDIO Initiatives, teaching mathematics is considered obviously related to the second theoretic-methodological approach, asserting the fact of professional-oriented teaching. According to Standard 1 (version 2.0), CDIO facilitates the required CDIO engineering environment, within which, theoretical knowledge and practical skills are taught, assimilated and applied [3, pp. 5]; Standard 3-focuses on the integrated curricula promoting teaching systematization, involves interdisciplinary development and determines the maintenance of discipline integration into the teaching process via university academic staff [3, pp. 7, 8]; and Standard 5 in achieving stated tasks methodological learning activities are provided to develop student skills in applying theoretical knowledge throughout their engineering practice [3, pp. 9].

Regarding the content of CDIO standards and education programs, it can be stated that, in this case, methodologically, this is project-oriented education technology (EdTech), focused on the integration of both theoretical and practical training of technical university students.The application of the project method in domestic engineering education is not novel. In the 20's and 30's of the last century this method was promising and was widely integrated, including as a part of the mathematical prerequisite of future engineers. However, this method became irrrelevant, as its application often resulted in the degradation of the mathematical knowledge and roused unfavorable criticism from profile departments. From the point of view of modern pedagogics, the project method was unsuccessful due to the following: "The concept seemed to have been logical, i.e. to establish learning (cognitive) process, involving face-to-face learning. However, one factor was excluded- the more the immediacy elements (experiments, research, uncertainity) are included in the learning process, the more indirect supporting elements should be provided" [4, pp. 40].

Historically, a successful education project is already identified in the conceptual phase itself. In the case of specific academic courses, the implementation of the CDIO base, defined by the standards and programs, should be supported by relevant methodological support tools, i.e those tools designed in terms of philosophy and the conceptual CDIO orientation -their application in the learning process. As the teaching methodology of mathematics in engineering universities has been developing and upgrading during the last few centuries, the proposed methodological support of CDIO standards can not be developed "overnight". According to the opinion of university mathematical instructors, the reform of engineering education within the framework of one specific discipline is based on the requirement of explaining the mathematical examples in order to convey the meaning fully. In this case, the instructor is not considered with the question; "what to do?", but how to achieve this (what tools should be used)?"

New philosophy elements of education, modern standards, upgraded curricula and the international CDIO Initiatives are being more frequently implemented into the Russian engineering education. Based on regulatory documents, the above-mentioned items have already been integrated into the content of new education standard versions within different engineering profiles, therefore, the content of mathematics, as a discipline, itself, has been directly and significantly influenced also. In the context of CDIO standards, mathematics in a technical university should be integrated into the engineering education system. In this case, an excellent integrative methodological tool could be individual learning activities (i.e. projects), involving content-based interdisciplinary subjects. As the departmental teaching content remains unchanged and the mathematical aspect is actually the priority of most mathematical teachers, then the methodological problem-how to compile such assignments-emerges. This is rather a new aspect, and, moreover, quite difficult as its implementation involves not only mathematical but also engineering content. As Alfrйd Rйnyi wrote: " Those, who want to apply mathematics are like warriors in a two-horse chariot.......One should know something about both the chariot, and, of course, about the horses."[5, pp. 62].

According to CDIO Initiatives, the integrating learning activities, concerning mathematics, should be engineering projects and should combine both engineering problem-solving and mathematical research methods. The author states that the problem-solving of typical tasks invokes considerable difficulties for students. Based on didactic principles it is recommended to divide such tasks into two sections: the first-propaedeutic (preparatory instruction), where the teacher only instructs the student involved in the mathematical problem statement, selects the problem-solving method, comments and step-by-step controls the problem-solving process itself; the second-creativity, where the student independently solves equivalent tasks either through the application of the methodological tools from section one or could reasonably improve the methods in section one, which, in its turn, functionally assigns required mathematical tools and further becomes the pilot project. This is described in the following task-example (1-year students of Penza State Technical University).

Engineering task statement:

Engineering design of a device with face cam which ensures the pusher reciprocal motion (in-out movement) from the starting position to the end position and visa versa. Specified kinematics of pusher motion results in the cam profile shape, including two Archimedean spiral branches (fig. 1). The disadvantage of proposed engineering design is angular points in spiral branch joints (points A and B in fig. 1). This results in the failure of smooth device performance and further vibration of the machine itself, which, in its turn, causes undesirable technical problems. The engineering problem-design the cam profile shape which would rivet kinematic criteria and dynamics of device performance.

Section 1 Propaedeutic (preparatory instruction). The student receives a ready-made solution-cam profile shape as a disk cam (fig. 2) and should only perform the required of-design operation. In this case, the following mathematical problems are formulated:

1) determine radius R and position of circle center, corresponding to cam profile and compile the equation of this circle in polar coordinate system with displacement of pole in respect to the center by ε: (answer: $r = r_э(\varphi) = \sqrt{r_0(R+\varepsilon)+\varepsilon^2\cos^2\varphi} - \varepsilon\cos\varphi$);

2) investigate the radius direction of the disk cam deviation $\delta_э(\varphi)$ from the compound curve of Archimedean spiral branches so as to determine its asymptotic (maximum) value $R \to \infty$, and further determine the extremal value of obtained equation: (answer:

$$\delta_э(\varphi) = \sqrt{\left(r_0 + \frac{2\varepsilon\varphi}{\pi} + \varepsilon\cos\varphi\right)^2 + \varepsilon^2\sin^2\varphi} - R,$$

$$\delta_э(\varphi) \approx \varepsilon\left(\frac{2\varphi}{\pi} + \cos\varphi - 1\right), \ |\delta_э|_{\max} = 0{,}210514\varepsilon \text{);}$$

3) deduce the quality of engineering problem-solving, demonstrating its mathematical research results.

Attaining smooth device performance definite alterations in the engineering design were made. However, such questions emerge -how did these alterations affect the kinematic characteristics of the device itself? Is the disk cam deviation value acceptable to the theoretical profile? Could this be decreased if alterations are included? These questions further the possible research and the definition of the second section.

Section 2 Creativity. The task includes a cam profile as a smooth closed line reproducing the cam shape better than the disk cam, i.e. it involves less deviation than in the case of the theoretical profile. The obtained result should be explained and critically evaluated.

The creative task element is determined by the design solution freedom. However, this could be limited by the application of mathematical tools, and, this principally induces the possible standard set of curves: ellipse, hyperbolic, parabolic and other curves. It should be noted that the solution of this task could be an elliptic spline: closed curve of two semi-ellipses: $r_1(\varphi)$ and $r_2(\varphi)$, depicted in fig. 3. Mathematical research is conducted according to the methodology stated in section 1.

The described elliptic spline is a smooth convex curve. In the polar coordinate system if the polar is centralized, then the elliptic spline branches have the form of the following equation:

$$r_{эс}(\varphi) = \begin{cases} r_1 = \dfrac{r_0(r_0+\varepsilon)}{\sqrt{r_0^2 + \varepsilon(2r_0+\varepsilon)\cos^2\varphi}}, -\dfrac{\pi}{2} < \varphi \le \dfrac{\pi}{2}, \\ r_2 = \dfrac{(r_0+\varepsilon)(r_0+2\varepsilon)}{\sqrt{(r_0+\varepsilon)^2 + \varepsilon(2r_0+3\varepsilon)\sin^2\varphi}}, \dfrac{\pi}{2} < \varphi \le \dfrac{3\pi}{2} \end{cases}$$

The above-mentioned curve is depicted in Cartesian (coordinate) system $(r;\varphi)$ (fig. 4). The limited spline deviation from Archimedean spiral branches is investigated as in the first section and, if parameter r_0 is increased, then it is estimated in the following asymptotic equation:

$$\delta_{эс}(\varphi) \approx \begin{cases} \varepsilon\left(\dfrac{2\varphi}{\pi} - \sin^2\varphi\right), -\dfrac{\pi}{2} \le \varphi < \dfrac{\pi}{2}, \\ \varepsilon\left(\dfrac{2\varphi}{\pi} - 2 + \sin^2\varphi\right), \dfrac{\pi}{2} \le \varphi < \dfrac{3\pi}{2} \end{cases}.$$

Fig. 1.

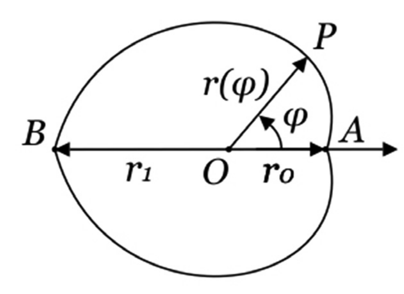
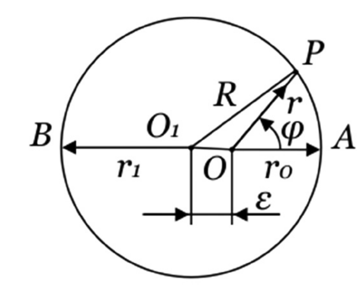


Fig. 2.



Determining the extremal values of the function $\delta_{эс}(\varphi)$ for the maximum deviation of the proposed engineering design of cam profile to the theoretical one the following asymptotic assessed value is obtained $|\delta_{эс}|_{\max} = 0{,}105257\varepsilon$. In comparing this to analogous assessed value for disk cam the fact indicates in the case of an elliptic spline the error magnitude is two-fold less, i.e. the kinematic characteristics of the device are improved. This is the practical project result.

The above-described example gave a detailed explanation of the application principles of CDIO standards with regard to the mathematical education of engineers: 1) mathematical training of university students should be integrated

Fig. 3.

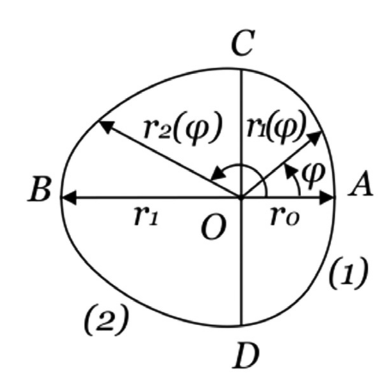
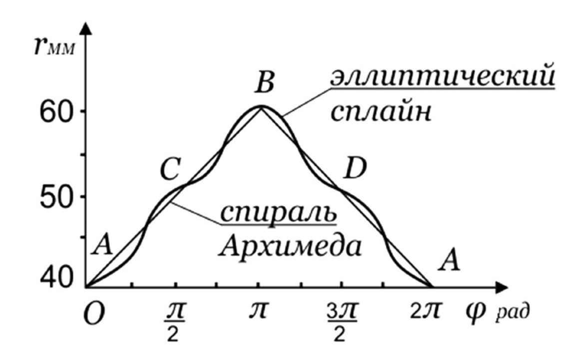


Fig. 4.



into the engineering education system; 2) achieving the discussed objective is through integrated curricula (IC); 3) engineering task involves the objective, content and further mathematical research within the framework of IC; 4) selecting an engineering task initially depends on the teaching requirements of mathematics and then professional interests, i.e. the engineering task is based on the mathematical tools, which, in its turn, should be rather "saturated" and informative in accordance with the learning outcomes; 5) engineering task should be simple and understandable for a 1-2 year student, while the results of the mathematical research-illustrative, assuming conceptual interpretation and possible empirical verification; 6) questions in didatics should also be included, for example, application of problem-based learning technology or other of active learning methods; 7) the author recommends the described task division into propaedeutic (preparatory instruction) and creativity, indicating different elements of student self-assessement.

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Competences of Management and Engineering Staff in the Sphere of En-ergy Conservation as a Base for Retraining Program Design

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Demand for personnel capable of making innovative decisions and designing innovative facilities conditions the necessity for training managerial and engineering staff. The offered programs of three types based on the energy conservation competence models of managerial and engineering staff con-tribute to the solution of professional problems and development of compe-tences in planning, design, production, and implementation in the conditions simulating professional activity.

Key words: competencies of energy conservation, management and engineering personnel, requirements, retraining programs, design.

Energy use and conservation problems are urgent all over the world. Experts have noticed the common regularities: less energy use in comparison with the predicted one, dependence of energy use on the rate of production development, continuous growth of energy resource utilization, in the developed countries – low usage of renewable energy sources. Energy consumption tends to decrease, which indicates high rate in energy conservation. In Russia energy conservation problems were not so urgent due to availability of great amount of resources, low population density in some regions, an increase in the energy intensity of the gross product in the first half of the 20-th century, which has had consequences so far [1].

Nevertheless, economic, ecologic, moral and other factors condition the specific character of energy conservation problem and urgency to solve it in Russia. To solve this problem one needs to take a number of engineering and management decisions that would require corresponding qualification of both managerial and engineering staff. It updates the issue of managerial and engineering staff retraining in terms of their energy conservation competence development. The given problem is one of the crucial ones which has to be solved in the course of the CDIO international project.

The foundation of the managerial and engineering staff retraining program rests on a competence-based approach. The competences present both a foundation and a goal (expected outcomes) of retraining syllabus implemen-tation.

Traditional competence models of managerial and engineering staff are based on classical foundations: requirements of the Federal State Educational Standards (FSES), job description, research in competences and their empirical study [2 – 10].

To examine the competences the standards of the majors 140400 – Electric Power and Electrical Engineering and 140100 Thermal Power and Thermal Engineering were studied [7-10]. According to the standards and a survey among engineers the developed traditional competence model of managerial and engineering staff in energy conservation includes the following competence units grouped in terms of similar activity types: