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PROBLEMS IN THE DESIGN OF KEYED BELT DRIVES AND THEIR SOLUTIONS

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Annotation: This article identifies the problems that arise in the design process of V-belt drives during the training of qualified and competitive specialists in the field of mechanical engineering for the production of reliable machines, and highlights the importance of addressing these issues.

It has been shown that the identified issues create challenges in the design of belt drives, and several solutions for overcoming these problems have been proposed.

Keywords: mechanical engineering, keyed belt drive, competitiveness, design engineer, education, reliability.

ПОНАСИМОН ТАСМАЛИ УЗАТМАЛАРНИ ЛОЙИҲАЛАШДАГИ МУАММОЛАР ВА УЛАРНИНГ ЕЧИМЛАРИ

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Аннотация:Ушбу мақолада ишончли машиналарни ишлаб чиқариш учун машинасозлик йўналишларида малакали, рақобатбардош мутахассислар тайёрлашда понасимон тасмали узатмаларни лойиҳалаш жараёнида юзага келадиган муаммолар аниқланган ва уларни бартараф этиш долзарб масала эканлиги баён этилган.

Аниқланган муаммолар тасмали узатмаларни лойиҳалашдаги қийинчиликларга сабаб бўлаётганлиги кўрсатилган ва бу муаммоларни бартараф этиш йўллари таклиф этилган.
Калит сўзлар: машинасозлик, понасимон тасмали узатма, рақобатбардош, конструктор, таълим, ишончлилик.

ПРОБЛЕМЫ ПРОЕКТИРОВАНИЯ КЛИНОРЕМЁННЫХ ПЕРЕДАЧ И ПУТИ ИХ РЕШЕНИЯ

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Аннотация:В данной статье выявлены проблемы, возникающие в процессе проектирования клиноременных передач при подготовке квалифицированных и конкурентоспособных специалистов в области машиностроения для производства надёжных машин, и подчёркнута актуальность их устранения.

Было показано, что выявленные проблемы вызывают трудности при проектировании ремённых передач, и были предложены пути преодоления этих проблем.

Ключевые слова: машиностроение, клиноремённая передача, конкурентоспособность, конструктор, образование, надежность.

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1. Introduction

For the fields of automotive and tractor engineering, undergraduate students pursuing a bachelor's degree at Tashkent State Technical University (TSTU) are expected to perform design and verification calculations of belt drives and ensure their operability, with thorough knowledge of the subject [1; p. 12].

The content of educational programs for the training of future engineers must be maximally approximated to real engineering practice in a way that facilitates the acquisition of necessary professional competencies by graduates [2; pp. 153–167]. Research in this field has shown that students face difficulties during the design process of belt drives, and in the course of finding solutions to these problems, a literature review was also conducted. As a result, it was revealed that there is a methodological deficiency in shaping the necessary skills and competencies for students in belt drive design. The main reason for this is the lack of integration between the theoretical and practical components of educational materials.

Integrating the theoretical and practical parts of educational materials on the design of V-belt drives creates opportunities for forming and developing design-related competencies.

Based on the above considerations, it can be stated that in order to improve the quality of training competitive engineering personnel capable of producing high-performance and reliable machines, the issue of integrating theory and practice in educational materials should be regarded as an urgent problem.

2. Methodology

It is natural that the rapidly developing field of mechanical engineering demands comprehensive excellence from today's specialists. To ensure the required excellence, it is necessary to improve the content of education in higher educational institutions, increasing its scientific character and efficiency.

By the content of education, one should understand the system of scientific knowledge, practical skills, as well as ideological, moral, and aesthetic concepts that students must acquire during the learning process [3; p. 129].

"The scientific nature of the content can be achieved when students are acquainted not only with ready-made conclusions but also with research methods" [4; p. 18]. This, in turn, requires ensuring methodological completeness by giving the content of education an integrative character and implementing new pedagogical technologies with high efficiency in the learning process. "Ensuring the completeness of the elements of the content of education is carried out primarily at the level of the academic subject, as well as at the level of educational materials" [5; p. 79].

Undergraduate students in the field of mechanical engineering are expected to carry out course projects, design works, and diploma projects in specialized subjects. In doing so, they rely on knowledge and experience acquired in courses such as engineering graphics, materials science, theoretical mechanics, strength of materials, theory of mechanisms and machines, metrology and standardization, and machine elements.

According to I.P. Podlasy, "in an educational process consisting of individual steps, the fewer breaks and disruptions in sequence there are, the more successful the process is and the greater results it yields; if regular practice is not maintained, skills are lost" [6; p. 451].

Strengthening the connection between theory and practice with the help of reflective assignments has been one of the main problems in education and remains so today [7; pp. 957–969].

At this point, students face difficulties in performing reflective assignments such as course projects or design tasks in specialized subjects. The main reasons for this can be identified as follows:

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In particular, the inability to apply knowledge gained from general education and general technical subjects in the design of transmissions, insufficient skills in independent problem-solving, the inability to correctly identify solutions based on relevant standards, and inadequate skills in using literature effectively.

It can be observed that the emergence of the first problem waiting to be solved is the basis for the appearance of subsequent problems. Indeed, the requirements of the market economy, such as improving the level of production, enhancing the quality and efficiency of manufactured machines, and reducing production costs, are closely related to the professional training, design competencies, creative thinking, and intellectual potential of future designers in technical higher education institutions. This certainly requires the development and immediate implementation of advanced educational programs that raise the level of education and upbringing to a high-quality standard and prepare young people for independent professional activity.

Due to their numerous advantages, V-belt drives are more widely used in various branches of mechanical engineering compared to other types of belt drives. Therefore, the formation of competencies in belt drive design among students is of significant importance against the background of producing high-quality and reliable machines.

Scientific research and experimental studies have shown that content integration between the theoretical and practical parts of educational materials is not fully ensured. As a result, we will consider the methodological shortcomings that arise during the design process of V-belt drives.

1. In the practical calculation of a transmission, based on the transmitted power P_1 and the rotational speed n_1 , the belt type is selected from a nomogram. This nomogram, as the starting point of the design calculation of V-belt drives, is not presented in the educational literature [11], but is included in theoretical educational sources [8; p. 271; 9; p. 292; 10; p. 38] and practical educational sources [12; p. 134].

2. The diameter of the driving pulley is determined using the formula, and the obtained result must be standardized according to GOST 17383-73. This formula is not presented in the literature [8, 9, 11]. In [10; p. 37] theoretical and [12; p. 130] practical educational literature, it is given as follows:

$$d_1 \approx (3 \div 4)\sqrt[3]{T_1}$$

According to GOST 17383-73, the standard series is given in the educational literature [8; p. 272; 9; p. 292] in an incomplete manner without indicating the GOST number and for another purpose. It is not stated that the calculated value should be chosen as the nearest smaller dimension from this series, and it is not presented in [10, 11] theoretical sources. In [12; p. 120] practical educational literature, it is given as follows according to GOST 17383-73: 40; 45; 50; 56; 63; 71; 80; 90; 100; 112; 125; 140; 160; 180; 200; 224; 250; 280; 315; 355; 400; 450; 500; 560; 630; 710; 800; 900; 1000; 1120; 1250; 1400; 1600; 1800; 2000.

3. The diameter of the driven pulley is calculated using the formula, and the obtained result is standardized according to GOST 17383-73. This formula is not given in [8, 9, 11], while in [10; p. 38] theoretical and [12; p. 137] practical literature, it is presented as follows:

$$d_2 = i_t d_1 (1-\varepsilon)$$

4. Since the calculated pulley diameters are standardized based on the standard series, it becomes necessary to refine the transmission ratio. This is done using the formula, which is not presented in [8, 9, 11]. In [10; p. 38] theoretical and [12; p. 137] practical literature, it is given as follows:

$$i_т^{'} = \frac{d_2}{d_1(1-\varepsilon)}.$$

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5. The deviation of the transmission ratio is calculated, and the resulting difference must not exceed 3%. This conditional formula is not provided in any of the theoretical educational sources [8, 9, 10, 11]. In [12; p. 125] practical literature, it is expressed as follows:

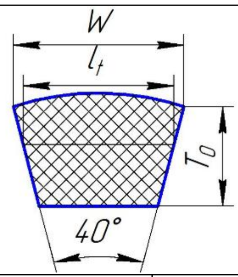
$$\frac{\Delta i}{i_t} \cdot 100 < 3\%.$$

6. The center distance a_t must fall within the following interval,

$$a_{min} = 0{,}55(d_1 + d_2) + T_o$$
$$a_{max} = d_1 + d_2$$

where T_o is the height of the cross-section of the belt type, the numerical value of which is taken from GOST 1284.1-80 (Table 1).

Table 1



Belt section symbol	d_1, not less than	l_t	W	T_o	A	L_t	ΔL	Weight per meter, kg
О	63	8,5	10	6	47	400-2500	25	0,06
А	90	11,0	13	8	81	560-4000	33	0,10
Б	125	14,0	17	10,5	133	800-6300	40	0,18
В	200	19,0	22	13,5	230	1800-10000	59	0,30
Г	315	27	32	19,0	476	3150-14000	76	0,60
Д	500	32	38	23,5	692	4500-18000	95	0,90
Э	800	42	50	30,0	1172	6300-18000	120	1,52

Note: 1. Cross-sectional area of A-belt is in mm²; ΔL is the difference between calculated belt length L_h and L_i.
2. Standard length series L_t: 400; 450; 500; 560; 630; 710; 800; 900; 1000; 1120; 1400; 1600; 1800; 2000; 2240; 2500; 2800; 3150; 3550; 4000; 4500; 5000; 5600; 6300; 7100; 8000; 9000; 10000; 11200; 12500; 14000;16000; 18000.
3. Intermediate length series L_t: 425; 475; 530; 600; 670; 750; 850; 950; 1060; 1180; 1320; 1500; 1700; 1900; 2120; 2360; 2650; 3000; 3350; 3750; 4250; 4750; 5300; 6000; 6700; 7500; 8500; 9500; 10600; 11800; 13200; 15000; 17000.
Conditional designation of belts:
For example, a cord-reinforced belt of section B with a calculated length L_t=2500 mm is denoted as:
B-2500 SH GOST 1284.1-80

These formulas and GOST 1284.1-80 (Table 1) are not provided in any of the theoretical educational sources [8, 9, 10, 11]. They are given in the practical educational literature [12] (Table, p. 131; formula, p. 137).

7. Based on the accepted center distance, the calculated belt length is determined using the following formula, and this length is chosen according to the nearest value from the standard series proposed in GOST 1284.1-80:

$$L=2a_t+0{,}5\pi(d_1+d_2)+\frac{(d_2-d_1)^2}{4a_t}.$$

This formula is presented in all theoretical [8; p. 254; 9; p. 270; 10; p. 7; 11; p. 97] and practical [12; p. 137] educational sources.

8. The center distance value corresponding to the standard length of the belt is refined using the following formulas. In [12; p. 137] practical literature, it is presented as:

$$a_t=0{,}25\left[(L-w)+\sqrt{(L-w)^2-2y}\right],$$

where $w=0{,}5\pi(d_1+d_2)$;

$$y=(d_2-d_1)^2.$$

In theoretical educational sources [8; p. 254; 9; p. 270; 10; p. 7], it is given as:

$$a=\frac{2l-\pi(d_2+d_1)+\sqrt{[2l-\pi(d_2+d_1)]^2-8(d_2-d_1)^2}}{8}.$$

In [11; p. 97] theoretical literature, it is expressed as:

$$a=\frac{\lambda+\sqrt{\lambda^2-8\Delta^2}}{4},$$

Where $\lambda=l-\pi D_{avg}$; $D_{avg}=(D_1+D_2)/2$; $\Delta=(D_2+D_1)/2$;

9. To check the condition $\alpha_1>[\alpha]=120°$, the wrap angle of the driving pulley is determined using the following formula:

$$\alpha_1=180^\circ-57\frac{d_2-d_1}{a_T},$$

This formula is presented in all theoretical [8; p. 253; 9; p. 270; 10; p. 7; 11; p. 97] and practical [12; p. 130] educational sources.

10. The number of belt rows in a transmission is determined using a formula that is not presented in the theoretical educational literature [10, 11]. In the theoretical educational literature [8; p. 273, 9; p. 295], it is given as follows:

$$z=\frac{P}{P_т C_z}.$$

In the practical educational literature [12; p. 135], it is presented as:

$$z=\frac{PC_r}{P_o C_L C_\alpha C_z},$$

Where C_α – coefficient of pulley wrap angle.

α°	180	160	140	120	100	90	70
C_α	1,0	0,95	0,89	0,82	0,83	0,68	0,56

This table is included in all theoretical [8; p. 272, 9; p. 294, 10; p. 19, 11; p. 108] and practical [12; p. 135] educational sources.

In engineering practice, the numerical value of the transmittable power of a single belt P_0 is determined according to the belt type, the diameter of the driving pulley, and the rotation frequency. However, this table is not presented in any of the educational sources [8, 9, 10, 11], but only in the practical source [12; pp. 132–134].

C_r – coefficient accounting for the operating regime. Its numerical value is taken from a specially developed table depending on the operating regime, type of machine, and the number of shifts. This table is not presented in [8, 9, 10, 11], but only in the practical educational source [12; p. 136].

C_L – coefficient accounting for the influence of belt length on the number of belt rows. Its numerical value is taken from a special table depending on the belt length and type. This table is not presented in [8, 9, 10, 11], but only in the practical educational source [12; p. 135].

C_z – coefficient accounting for the number of belt rows:

z	2-3	4-6	> 6
C_z	0,95	0,90	0,85

This table is presented in theoretical [8; p. 273, 9; p. 295] and practical [12; p. 135] educational literature, but not in [10, 11].

11. The initial tension force of the belts in V-belt transmissions F_o is determined using a formula. In theoretical sources [8; p. 274], it is given as:

$$F_o=\frac{850P_1C_rC_L}{zvC_\alpha C_i}+F_t,$$

while in another theoretical source [9; p. 295] it is written as:

$$F_o=\frac{850P_1C_rC_L}{zvC_\alpha C_i}+F_v,$$

It is not presented in [10, 11].

In the practical educational source [12; p. 136], it is given differently:

$$F_o=\frac{85PC_rC_L}{zvC_\alpha}+\theta v^2,$$

where $v=0{,}5\cdot\omega_1\cdot d_1$ – the calculated belt speed; θ–coefficient accounting for centrifugal force, whose values are given as follows:

Type	O	A	B	V	G	D
θ	0,06	0,1	0,18	0,3	0,6	0,9

These empirical values are not presented in the theoretical educational literature [8, 9, 10, 11], but only in the practical source [12; p. 136].

12. The force acting on the shafts from the transmission is calculated by the following formula, given in theoretical literature [9; p. 284, 10; p. 21]:

$$F_r\approx 2F_o\cos\frac{\beta}{2}.$$

It is not presented in [8, 11]. In the practical literature [12; p. 136], it is given as:

$$F_v=2F_oz\sin\frac{\alpha_1}{2}.$$

13. The pulley width B_p, is calculated using the data provided in a table of belt groove dimensions, shape angle, and working diameters corresponding to the belt type, with the following formula noted in the table description [12; p. 138]:

$$B_p=(z-1)e+2f$$

This formula is not presented in the theoretical educational literature [8, 9, 10, 11].

All types of errors and difficulties that lead to the violation of the correct relationship between theoretical and practical actions are connected with the incompleteness of teaching methods [13; p. 179].

Improving the quality of graduate training to be maximally aligned with production requirements is primarily related to the content of education and its implementation in practice [14; p. 38].

Thus, to fully ensure the integration of theory and practice regarding the first issue raised in this article, the following are required:

a) In order to eliminate inconsistencies in machine design, the formulas used in practice must be presented exactly by topic in theoretical literature;

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b) To prevent confusion during the design process, it is unacceptable for the same quantity calculated by formula to be denoted and explained differently in theoretical and practical literature;

c) To facilitate the introduction of corrections into calculations, reduce time and labor expenditures, and improve skill formation, easy methods of determining the required coefficient values must also be taught in theory;

d) Based on the requirements of the concept, in order to develop more practical skills, the completeness of calculation methodologies in theoretical and practical literature must be ensured, that is, integration of theory and practice must be achieved.

Studying in general education schools is the pre-university stage of professional training of future specialists, where naturally a wide range of knowledge and skills are formed, many of which later evolve into professional knowledge and competencies [15; pp. 149–153].

From this it follows that, for students to successfully master the basics of general education and general technical subjects, integration of theory and practice must also be ensured within general education subjects.

The perfection and scientific validity of machine design results are manifested in ensuring harmony between the theoretical and practical components of general education and general technical disciplines.

In the design process, the content of education must be directed towards shaping the graduate's personality and developing professional-specialized competencies [16; pp. 74–76].

According to the current curricula in "Automotive and Tractor Engineering" and "Transport Engineering," after completing their general technical training, students must possess the necessary knowledge and competencies to carry out course projects and graduation qualification works (diploma projects) in specialized subjects. Naturally, an engineer is required to possess specific competencies in processes such as improving the performance of the designed machine or structure in line with economic requirements, reducing labor intensity in manufacturing, or ensuring reliability of operation. Ultimately, one of the most important and urgent issues of design quality is closely related to how students' design competencies are formed and, in this regard, how theory and practice integration is ensured. Clearly, the knowledge level of qualified, competitive engineering personnel must meet international standards.

Knowledge not connected with practice is quickly forgotten. Therefore, one of the key principles of pedagogy—the "connection of theory with practice"—is becoming increasingly important for implementation in the learning process [17; p. 11].

Thus, in our opinion, the second set of problems raised in the article can be addressed through the following measures:

a) To form the skills of applying knowledge from general education and general technical disciplines in practice, integration of theory and practice must also be ensured in these subjects;

b) To develop skills of independent thinking in the design of machine transmissions, it is necessary to eliminate factors leading to inconsistencies and confusion in all educational literature, that is, to ensure theory–practice integration;

c) Skills in finding the correct solution to a problem based on standards will only develop when students make sufficient use of them in solving technical assignments and understand their types, content, and essence, that is, when theory–practice integration is ensured;

d) To adequately form skills in correct use of literature, it is advisable that guidance on performing course works and projects be directed towards greater reliance on literature.

Results and Discussion

The problems addressed in the article can only be solved through the creation of modern educational literature aimed at developing practical skills and competencies on the basis of existing technical literature, in which relevant practical tasks are performed in different forms during lectures, practical-laboratory classes, and the process of independent learning in a harmoniously integrated manner.

It should be emphasized that in order to develop engineering knowledge, skills, and competencies among future bachelor students, the main focus should not be limited only to general technical and specialized subjects. Rather, this process should begin from the study of general education disciplines; otherwise, the requirement of continuity in education will not be ensured in a vertical direction.

The scientific research outcome, which corresponds to the content and essence of the Concept, indicates the need to shift from a theory-oriented educational system, mainly focused on delivering theoretical knowledge, to a practice-oriented educational system that forms the necessary skills and competencies. This requires special attention to the development of the ratio of academic workload that ensures the effectiveness of integration between general technical and specialized disciplines in the educational programs being designed.

Conclusion

In order to design reliable and competitive machines, it is necessary to further develop students' design competencies, creative thinking, and intellectual potential in a systematic way. This includes the creation of a modern generation of educational literature based on innovative pedagogical technologies that ensures the unity and integrity of theory and practice, its integration into the educational process, appropriate use of the experience of leading higher education institutions worldwide, and the transition from a theory-based education system to a practice-oriented education system that develops essential skills and competencies. These serve as a foundation for drawing important conclusions confirming the relevance of such a transition.

Undoubtedly, the didactic principle of ensuring the integration, unity, and ultimately the integrity of theory and practice in education is a scientific-educational approach consistent with the requirements of the Concept, aimed at improving the quality and efficiency of education.

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