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ANALYSIS OF PROBLEMS, SOLUTIONS, AND PROPOSALS IN THE DESIGN OF WORM GEARS

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Abstract: This article highlights the importance of analyzing the problems encountered in the design of worm gears and proposing appropriate solutions to improve the reliability of manufactured machines.It also emphasizes the significance of developing highly effective proposals based on innovative approaches to ensure the production of high-quality and reliable machines.

Key words: worm gear, design, competitiveness, reliability, competence, machine.

Аннотация:Ушбу мақолада ишлаб чиқарилаётган машиналарнинг ишончлилигини оширишда червякли узатмаларни лойиҳалашдаги муаммоларни таҳлил этиш ва зарурий ечимлар таклиф этиш долзарб масала эканлиги баён этилган.

Шунингдек унда инновацион ёндошган ҳолда ишлаб чиқаришда юқори самара берувчи таклифларни ишлаб чиқишнинг, юқори сифатли ишончли машиналарни тайёрлашдаги аҳамияти такидланган.
Калит сўзлар: червякли узатма, лойиҳалаш рақобатбардош, ишончли компетенция, машина.

Аннотация:В данной статье рассматривается актуальность анализа проблем, возникающих при проектировании червячных передач, и предложений по их решению с целью повышения надёжности разрабатываемых машин.

Также в статье подчёркивается важность разработки высокоэффективных предложений на основе инновационного подхода для производства надёжных и высококачественных машин.

Ключевые слова: червячная передача, проектирование, конкурентоспособность, надёжность, компетенция, машина.

1. Introduction

Ensuring the reliable operation of power transmission components in machine manufacturing contributes to the overall reliability of the machine. Therefore, students pursuing a bachelor's degree in the field of automotive and tractor engineering are expected to have a thorough understanding of how to design high-quality and reliable worm gear transmissions, just like any other type of transmission, and how to ensure their operational efficiency [1].

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Hence, improving the training of engineering personnel with high competence in the design of mechanical transmissions at the bachelor's academic level is a pressing issue for the design and production of high-quality and reliable machines.

The production of quality, competitive, and reliable machines is directly related to the quality and content of education. It is of great importance to carry out scientific and analytical monitoring of existing educational literature, identify and eliminate shortcomings, and train qualified, competitive specialists based on the real demands of the economy – all of which contribute to enhancing the reliability and efficiency of manufactured machines**.**

2. Methodology

According to the curriculum of the subject "**Machine parts**", which constitutes the final stage of general technical training in the educational process, students are expected to complete a course project as part of lectures, practical sessions, laboratory work, and independent study. Based on the tasks of the course project, students are required to design cylindrical, conical, worm, chain, and belt drives, and to evaluate their quality indicators through analytical calculations. The completion of the course work or project marks the end of the student's general technical training phase.

Higher education pedagogy deals with the issues of education and upbringing of students in higher educational institutions [2]. From this perspective, during the process of designing machines, students face specific challenges when performing reflective tasks such as calculation and drawing exercises, or completing course projects – particularly in the design of worm gear drives.

An analysis of the root causes of this situation revealed the following main difficulties:

In particular, at the initial stages of the design process, students often lack adequate skills in selecting appropriate materials for the transmission. They also experience challenges in independently designing worm gear drives, finding proper solutions to engineering problems based on industry standards, and effectively utilizing reference literature.

The conclusion to be drawn from this situation is that the primary issue requiring a solution in education and training is underpinned by a second, deeper problem.

“Today, the methodology for teaching exact and natural sciences is criticized for its complexity, the disconnect between theoretical knowledge and practical application, the lack of continuity in curricula, and the unsatisfactory content and quality of textbooks” [3].

Scientific research conducted to eliminate the above-mentioned shortcomings has shown that, in the process of machine creation, there is still a lack of full integration between theoretical and practical knowledge in the instructional materials related to the design of worm gear drives.

The inconsistency between theory and practice has always been a persistent issue in education [4]. The following examples can be given as evidence of this.

1. The table of mechanical properties—specifically contact and bending stresses – of materials used for selecting appropriate materials in the design of worm gear drives is either completely absent in theoretical literature [6, 8], or, although it is presented in some sources [5, 7], it is only suitable for introductory familiarization with the materials, not for practical design.

In particular, the values of yield strength (σ_T) and ultimate strength (σ_B) are provided, but the mechanical properties necessary for evaluating contact and bending stresses—critical for

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actual design—are not included. Therefore, despite their presence in some literature, these tables are insufficient for practical engineering purposes in worm gear design.

2. In practical calculations of the transmission, the formula for determining the allowable bending stress for the selected material is given in practical literature [9] in the form: $[\sigma_{oF}]=K_{FL}[\sigma_{oF}]'$ while in theoretical literature [7], it is presented as: $[\sigma_F]=[\sigma_F]_0 K_{FL}\leq[\sigma_F]_{max}$ However, this formula is not provided in theoretical literature sources [5, 6, 7].

The formula for determining the center distance is given in theoretical literature [6, 7, 8] in the following form:

$$a_w=0{,}625(q/z_2+1)\sqrt[3]{\frac{E_{kel}T_2}{[\sigma_H]^2(q/z_2)}},$$

In theoretical literature [5], it is presented in the following form:

$$a_w=0{,}625(q/z_2+1)\sqrt[3]{\left[\frac{170}{(q/z_2)\sigma_{ир}}\right]^2 T_2K_H},$$

In practical literature [9], it is presented in the following form:

$$a_w=\left(\frac{z_2}{q}+1\right)\sqrt[3]{\left(\frac{170}{\frac{z_2}{q}[\sigma_H]}\right)^2 T_2K}.$$

4. The formula for calculating the module is $m=2a_w/(z_2+q)$ [5, 6, 7, 8] which is generally not presented in theoretical literature.

5. The theoretical literature does not provide tables for the module m, the lead angle γ of the worm thread, the permissible contact stresses according to the bending condition of the worm wheel tooth, tables of variations for the module mmm and the relative diameter q of the worm (GOST 2144-76), nor tables of the dynamic load factor K_v values used to determine the accuracy class of the transmission.

6. For worm gears, the load coefficient for both contact and bending stresses is taken as equal and is calculated using the following formula:

$$K_H=K_F=K_\beta K_v$$

additionally, here:, K_β - coefficient accounting for uneven load distribution; K_v - coefficient accounting for dynamic load in the transmission. This formula is presented in theoretical literature [5, 6, 7, 8], along with the values of the corresponding coefficients. In practical literature [9] and theoretical literature [7, 10], the coefficient - K_β , which depends on the deformation of the worm and changes in the load characteristics, is calculated using the following formula:

$$K_\beta=1+\left(\frac{z_2}{\theta}\right)^3(1-x),$$

here, θ - the deformation coefficient of the worm, and its value is given in the corresponding table. This table, as well as the value of xxx in the formula, are respectively provided in practical literature [9] and theoretical literature [7, 10].

$K_\beta-$ in theoretical literature [6, 7, 8], it is recognized as the coefficient accounting for load concentration, but in practical literature [9], it is called the coefficient of uneven load distribution. In theoretical literature [10], the theoretical load concentration coefficient under

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seizure-free conditions is given as follows:

$$K_\beta=1+\left(\frac{z_2}{\theta}\right)^3$$

It is noted that under constant load in the transmission, there is a risk of complete seizure and no-load concentration, meaning $K_\beta=0$. However, under variable load, load concentration persists, and the efficiency coefficient of load concentration is determined by the following formula:

$$K_\beta=1+\left(\frac{z_2}{\theta}\right)^3(1-x).$$

Thus, it can be seen that $K_\beta-$ in theoretical literature [3, 4, 5] is referred to as the coefficient accounting for load concentration or uneven load distribution along the tooth length; in theoretical literature [10], it is called both the theoretical load concentration coefficient and the efficiency coefficient of load concentration. In practical literature [9] and theoretical literature [5], as mentioned above, it is called the coefficient of uneven load distribution.

In fact, due to the large distance between the worm shaft bearings, bending of the worm shaft causes uneven load distribution along the tooth length. This, in turn, leads to a higher load effect at certain points along the tooth length, i.e., load concentration.

This aspect causes the K_β coefficient to have two different names in theoretical literature [6, 7, 8]. This reflects that the same coefficient is sometimes named differently within the same literature or varies in terminology across different sources.

7. The calculation formula for worm gear contact stress according to theoretical literature [5] is as follows:

$$\sigma_H=\frac{170}{z_2/q}\sqrt{\left(\frac{z_2/q+1}{a_w}\right)^3 T_2K_H}\leq\sigma_{ир},$$

and in theoretical literature [6]:

$$\sigma_H=1{,}8\sqrt{\frac{E_{kel}T_2K_H\cos^2\gamma}{d_2^2d_1\delta\varepsilon_\alpha\xi\sin2\alpha}}\leq[\sigma_H],$$

and in theoretical literature [7, 8]:

$$\sigma_H=1{,}18\sqrt{\frac{E_{kel}T_2K_H\cos^2\gamma}{d_2^2d_1\delta\varepsilon_\alpha\xi\sin2\alpha}}\leq[\sigma_H],$$

is given in the following form.

In practical literature [9], it is given in the following form:

$$\sigma_H=\frac{170}{\frac{z_2}{q}}\sqrt{\frac{T_2K\left(\frac{z_2}{q}+1\right)^3}{a_w^3}}\leq[\sigma_H].$$

8. The calculation formula for contact stress of the worm gear according to theoretical literature [5] is as follows:

$$\sigma_F=0{,}7Y_F\frac{\omega_{Ft}}{m_n}\leq\sigma_{FP},$$

According to theoretical literature [6, 8], it is as follows:

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$$\sigma_F = 0{,}7Y_F \frac{F_{t2}K_F}{b_2 m_n} \leq [\sigma_F],$$

In theoretical literature [7], it is as follows:

$$\sigma_F = 0{,}74Y_F \frac{F_{t2}K_F}{B_2 m_n} \leq [\sigma_F],$$

is given in the following form.

In practical literature [9], it is given in the following form:

$$\sigma_F = \frac{1{,}2T_2KY_F}{z_2 b_2 m^2}.$$

Based on the evidence presented above, the formulas related to the design of worm gears are given in different forms in various literature sources, and the same physical quantities are expressed using different names. Furthermore, the tables, standards, and calculation methodologies necessary for designing worm gears are often insufficiently covered. These inconsistencies in formulas and terminology cause confusion and uncertainty among students. Therefore, there is a need to address the aforementioned shortcomings in order to train qualified specialists with competencies for high-quality and reliable worm gear design.

The purpose of education determines the content and methods of teaching [11]. Higher education didactics is an initiative aimed at improving the quality of teaching in higher education institutions [12]. Therefore, to eliminate the inconsistencies mentioned above, which are identified as the main cause of difficulties faced by students, and to ensure the design of high-quality and reliable machines, it is necessary to develop a set of didactic materials focused on developing worm gear design skills. These materials should form the necessary professional competencies based on integration and be promptly introduced into the educational process.

By ensuring the consistency between theoretical and practical formulas in calculations, it is possible to eliminate confusion and ambiguity, thereby achieving a unified approach [13].

Therefore, in order to address the first issue raised in this article – namely, improving the quality and efficiency of training specialists capable of designing high-quality, competitive machines, as well as ensuring full integration of theory and practice in education – the following measures must be implemented:

a) to eliminate all ambiguities arising in the design of worm gear transmissions, it is necessary to ensure the consistency and clarity of formulas used in design by integrating theory and practice;

b) to eliminate all ambiguities arising in the design of worm gear transmissions, it is necessary to ensure the consistency and clarity of formulas used in design by integrating theory and practice;

c) In line with conceptual requirements, to effectively develop practical skills, the calculation methods used in theoretical and practical literature must be compatible – or at least closely aligned – thereby ensuring integration of theory and practice;

d) all necessary tables required for the design of worm gear transmissions should be included in theoretical sources, and the rules for their correct usage must be clearly and understandably explained, as this is of great importance.

Knowledge that is not connected to practice is quickly forgotten. Therefore, one of the important principles of pedagogy – the necessity of applying "the unity of theory and practice in education" in the learning process – holds great significance [14].

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Therefore, in our opinion, the second set of issues raised in the article can be addressed by implementing the following measures:

a) in order to effectively develop students' skills in selecting appropriate materials for worm gear transmissions, it is essential that the necessary information is provided in theoretical literature and explained during lectures;

b) to foster independent thinking in the design of worm gear transmissions, contradictory information and factors leading to confusion in the literature should be eliminated;

c) standards related to worm gear transmissions should be reflected in theoretical literature, and the procedures for using these standards should be covered in lectures to help students improve their ability to find correct solutions to problems based on industry standards;

d) to sufficiently develop the skill of proper use of literature, the guidance provided for course works and projects should be aimed at encouraging reliance on primary theoretical sources.

Conclusion and Remarks

Improving the quality of worm gear design problems finds its solution not only in practical technical literature but also through the development of practical skills, abilities, and competencies. These should be implemented in the form of appropriate practical tasks, delivered through lectures, practical and laboratory classes, as well as independent learning, all logically interconnected and following each other coherently. New educational materials aimed at this integrated approach need to be developed.

To effectively form and develop knowledge, skills, qualifications, and professional competencies in worm gear design, a complete and consistent connection between the information presented in theoretical and practical literature must be ensured. This is because essential professional skills and competencies are formed precisely on the basis of an organic link between theoretical knowledge and practical experience.

Conclusion

The analysis of this scientific research leads to the following important conclusion: To ensure the reliable operation of worm gears in mechanical engineering, it is necessary to further systematically develop students' design competencies related to worm gear design, as well as personal qualities such as creative thinking ability and intellectual potential.

Furthermore, it is of great importance to create didactic materials based on innovative pedagogical technologies that ensure the integration and unity of theory and practice, and to introduce them into the educational process.

In addition, effective utilization of the experiences of leading global higher education institutions and manufacturers, as well as the transition from a theoretical education system to a practical education system – focused on developing necessary skills and competencies – once again confirms the urgency of this issue.

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