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IMPROVEMENT OF SERVICE LIFE OF A WORM GEAR REDUCER BY INTRODUCING AN ELASTIC SUPPORT ELEMENT

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Abstract. The reliability and service life of worm gear reducers largely depend on vibration levels and the wear of gear elements during operation. In this study, a modified design of a worm gear transmission with an elastic support element was developed in order to reduce vibration and mechanical wear. Experimental measurements were carried out for the conventional gearbox and the modified gearbox with the elastic element. Vibration parameters were analyzed in the axial direction. The obtained results show that the introduction of an elastic element into the gearbox structure leads to a noticeable reduction in vibration acceleration, velocity and displacement, which contributes to the decrease of wear processes and the increase of the operational life of the transmission system.

Keywords: worm gear reducer, vibration reduction, elastic support element, vibration diagnostics, gearbox reliability.

Аннотация. Надежность и срок службы червячных редукторов в значительной степени зависят от уровня вибрации и износа элементов передачи в процессе эксплуатации. В данном исследовании была разработана модифицированная конструкция червячной передачи с использованием упругого опорного элемента с целью снижения вибрации и механического износа. Экспериментальные измерения были проведены для традиционной конструкции редуктора и модифицированного редуктора с упругим элементом. Параметры вибрации анализировались в осевом направлении. Полученные результаты показали, что введение упругого элемента в конструкцию редуктора приводит к заметному снижению ускорения, скорости и перемещения вибрации, что способствует уменьшению процессов износа и увеличению срока службы механической передаточной системы.

Ключевые слова: червячный редуктор, снижение вибрации, упругий опорный элемент, вибрационная диагностика, надежность редуктора.

Annotatsiya. Chervyakli reduktorlarning ishonchliligi va xizmat muddati ko'p jihatdan ishlash jarayonida yuzaga keladigan vibratsiya darajasi hamda uzatma elementlarining yeyilishiga bog'liq. Ushbu tadqiqotda vibratsiya va mexanik yeyilishni kamaytirish maqsadida elastik tayanch elementiga ega bo'lgan

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chervyakli uzatmaning modifikatsiyalangan konstruksiyasi ishlab chiqildi. Tajribaviy o‘lchovlar an’anaviy reduktor konstruksiyasi hamda elastik element bilan jihozlangan modifikatsiyalangan reduktor uchun amalga oshirildi. Vibratsiya parametrlari valning o‘q yo‘nalishi bo‘yicha tahlil qilindi. Olingan natijalar reduktor konstruksiyasiga elastik element kiritilishi vibratsiya tezlanishi, tezligi va siljishining sezilarli darajada kamayishiga olib kelishini ko‘rsatdi. Bu esa yeyilish jarayonlarining kamayishiga va mexanik uzatma tizimining xizmat muddatining oshishiga xizmat qiladi.

Kalit so‘zlar: chervyakli reduktor, vibratsiyani kamaytirish, elastik tayanch elementi, vibratsion diagnostika, reduktor ishonchliligi.

INTRODUCTION.

Worm gear reducers are widely used in various branches of mechanical engineering due to their compact structure, high transmission ratio, and ability to provide smooth and stable motion transmission. These gear systems are commonly applied in industrial machinery, transport equipment, lifting mechanisms, and automated production systems where reliable torque transmission and compact design are required.

Despite their advantages, worm gear transmissions are often subjected to considerable mechanical and dynamic loads during long-term operation. The sliding contact between the worm and the worm wheel leads to frictional effects that generate heat, vibration, and progressive wear of gear surfaces. As a result, the operational reliability and service life of worm gear reducers can significantly decrease under intensive working conditions.

One of the most important factors affecting the durability of worm gear transmissions is vibration generated during operation. Mechanical vibrations occur due to dynamic loading, misalignment, gear meshing irregularities, and shaft rotation. Increased vibration levels accelerate wear processes in gear teeth and bearings, reduce transmission efficiency, and may cause premature mechanical failure of gearbox components. [1]In recent years, considerable attention has been devoted to improving the dynamic performance and reliability of mechanical transmission systems. Researchers have proposed different approaches to reduce vibration and mechanical wear in gear mechanisms. These methods include optimization of gear geometry, improvement of lubrication conditions, enhancement of material properties, and application of vibration-damping or elastic elements in structural components.

The introduction of damping elements into mechanical systems is considered one of the effective approaches to reduce vibration transmission. Elastic components are capable of absorbing part of the dynamic energy generated during

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mechanical interaction of rotating elements, thereby decreasing vibration amplitude and reducing the load transferred to bearings and structural parts of the gearbox.

In the case of worm gear reducers, the use of elastic support structures can significantly influence the distribution of dynamic forces within the gearbox system. Properly designed elastic elements can act as vibration isolators, limiting the propagation of dynamic loads and improving the overall stability of the mechanical transmission. [2] Therefore, the development of improved structural design solutions aimed at reducing vibration and increasing the operational life of worm gear reducers remains an important scientific and engineering challenge.

In this study, a modified design of a worm gear reducer is proposed, which incorporates an elastic element into the bearing support structure. The proposed modification forms an updated mechanical transmission system intended to reduce vibration levels and mechanical wear.

Experimental investigations were carried out to evaluate the effectiveness of the proposed design. Vibration parameters of the gearbox were measured in the axial direction before and after the installation of the elastic support element. The obtained results allow assessment of the influence of the elastic element on vibration characteristics and operational reliability of the worm gear reducer.[3]

MATERIALS AND METHODS

Object of study

The object of the present study is a single-stage worm gear reducer used for transmitting rotational motion and torque in mechanical transmission systems. The main components of the reducer include a worm shaft, a worm wheel, a gearbox housing, and bearing supports that ensure stable positioning and rotation of the transmission elements.

The worm shaft acts as the primary driving element of the transmission system and interacts with the worm wheel to transfer motion and mechanical power. The technical drawing and main geometrical parameters of the worm shaft used in the experimental gearbox are presented in Figure 1.

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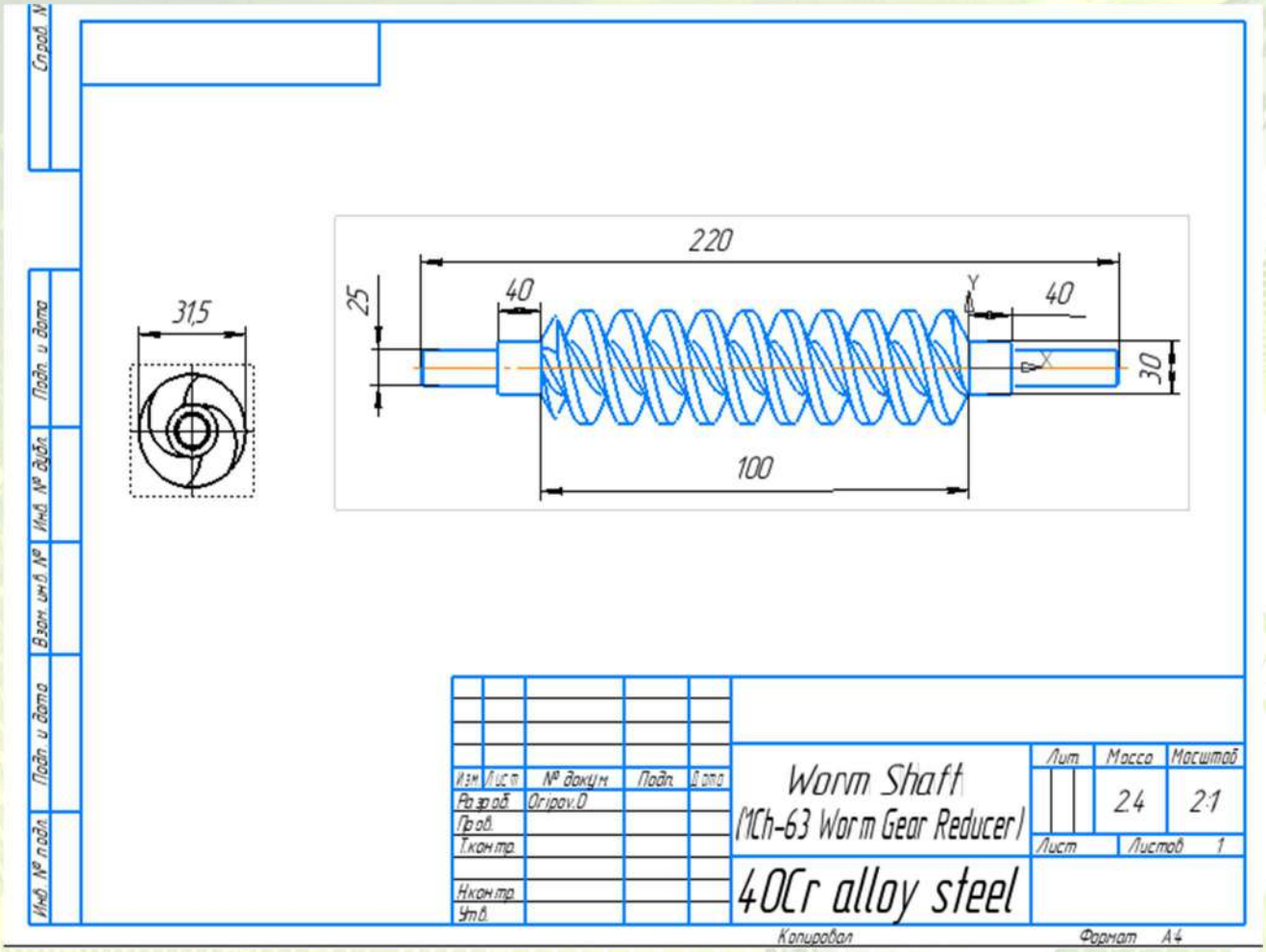


Figure 1. Technical drawing of the worm shaft used in the experimental worm gear reducer.

In the conventional gearbox design, the bearings are rigidly mounted inside the gearbox housing. Under such conditions, dynamic loads and vibrations generated during the meshing process of the worm and worm wheel are directly transmitted to the gearbox structure and supporting elements.[4]To improve the dynamic performance of the transmission system, a modified gearbox design was proposed. In the proposed design, an elastic element was introduced into the bearing support assembly in order to absorb part of the vibration energy generated during operation and reduce dynamic loads acting on the gearbox components. The location of the elastic support element in the modified worm shaft support is illustrated in Figure 2.

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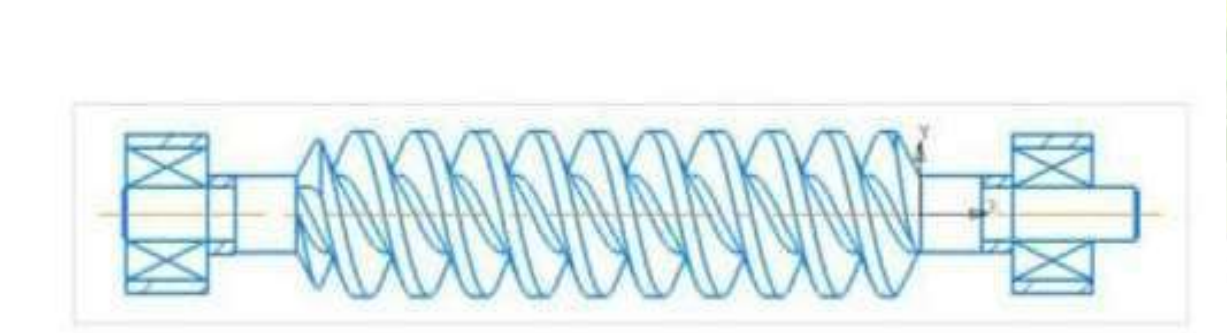


Figure 2. Location of the elastic vibration-damping element in the modified worm gear reducer.

As a result of the proposed structural modification, an updated mechanical transmission system with an elastic support element was obtained. The modified design is expected to improve vibration damping characteristics and increase the operational reliability and service life of the worm gear reducer.

Experimental setup

Experimental studies were conducted to evaluate the vibration characteristics of the worm gear reducer before and after the installation of the elastic support element. The main objective of the experiment was to determine the influence of the proposed structural modification on the vibration behavior of the gearbox and to assess its impact on the operational reliability of the mechanical transmission system. [5]For this purpose, vibration measurements were performed using the portable vibration diagnostic device VibXpert, which is widely used for industrial condition monitoring and vibration analysis of rotating machinery. The VibXpert system allows accurate measurement and analysis of vibration parameters in mechanical systems such as gearboxes, electric motors, pumps and compressors.

During the experiment, the vibration sensor of the VibXpert device was mounted on the gearbox housing near the bearing support area of the worm shaft. This measurement position was selected because vibration generated by the worm–wheel interaction and bearing operation is most clearly transmitted through this structural region.

The measurements were carried out in the axial direction of the gearbox shaft, since axial vibration components are significantly influenced by gear meshing forces and dynamic loads in worm gear transmissions.

The following vibration parameters were measured and analyzed:

• vibration acceleration (m/s^2) – characterizing the intensity of dynamic loads acting on the gearbox structure

vibration velocity (mm/s) – commonly used as a general indicator of mechanical condition and vibration severity

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vibration displacement (μm) – describing the amplitude of mechanical oscillations of the system

The VibXpert diagnostic system recorded vibration signals under stable operating conditions of the worm gear reducer. The obtained data were processed using the internal analysis functions of the device, which allow evaluation of vibration characteristics in different operating modes.

To determine the effectiveness of the proposed design modification, vibration measurements were conducted under two different operating conditions:

1. **Conventional gearbox design (before modification)** – the worm gear reducer operating with a standard rigid bearing support configuration.

2. **Modified gearbox design (after modification)** – the same worm gear reducer equipped with the proposed elastic support element integrated into the bearing assembly.

By comparing vibration parameters obtained in these two configurations, it was possible to evaluate the influence of the elastic element on vibration reduction and mechanical performance of the worm gear transmission.

The experimental results were then used to analyze the effectiveness of the proposed structural solution in reducing vibration levels and improving the operational durability of the gearbox.

RESULTS

The results of the experimental investigation carried out on the worm gear reducer are presented in Table 1. The measurements were performed in the axial direction of the gearbox shaft in order to compare the vibration characteristics of the conventional gearbox design and the modified gearbox equipped with the elastic support element.The comparative vibration parameters obtained during the experiment are summarized in Table 1.

Table 1

Comparative vibration parameters of the worm gearbox before and after modification (axial direction)

Parameter	Before	After	Unit
Acceleration	2.504	2.310	m/s²
Acceleration (max)	11.994	11.381	m/s²
Velocity	2.104	2.002	mm/s
Velocity (max)	7.424	6.789	mm/s
Displacement	8.754	8.423	μm
Displacement (max)	18.704	15.476	μm

The obtained results indicate that after the installation of the elastic support element, a noticeable reduction in vibration parameters was observed.

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The average vibration acceleration decreased from 2.504 m/s² to 2.310 m/s², which corresponds to a reduction of approximately 7.7%. Similarly, the maximum acceleration value decreased from 11.994 m/s² to 11.381 m/s², indicating a reduction in dynamic loading acting on the gearbox structure.

The vibration velocity also demonstrated a decrease after modification. The measured velocity decreased from 2.104 mm/s to 2.002 mm/s, while the maximum velocity value was reduced from 7.424 mm/s to 6.789 mm/s. Since vibration velocity is commonly used as a general indicator of the mechanical condition of rotating machinery, the observed reduction confirms the improvement in the dynamic stability of the gearbox.

A decrease in vibration displacement was also recorded. The displacement amplitude was reduced from 8.754 μm to 8.423 μm, while the maximum displacement value decreased from 18.704 μm to 15.476 μm. This reduction in oscillation amplitude indicates a lower level of mechanical vibration within the gearbox structure.

In addition to the general vibration parameters, additional vibration signals were recorded in fast signal mode for the bearing and machine components. These results are presented in Table 2.

Table 2.

Additional vibration parameters recorded in fast signal mode

Parameter	Before	After	Unit
Acceleration	75.353	52.641	m/s²
Velocity	3.848	3.454	mm/s
Displacement	34.343	31.076	μm

The fast signal mode measurements revealed a significant reduction in vibration acceleration. The acceleration value decreased from 75.353 m/s² to 52.641 m/s², which corresponds to a reduction of approximately 30%. This indicates that the elastic support element effectively absorbs dynamic loads generated during the operation of the worm gear transmission.

Similarly, vibration velocity decreased from 3.848 mm/s to 3.454 mm/s, while vibration displacement was reduced from 34.343 μm to 31.076 μm. These reductions demonstrate that the modified gearbox structure provides improved vibration damping characteristics.

Overall, the experimental results confirm that the introduction of the elastic support element into the worm gear reducer structure leads to a reduction in vibration acceleration, velocity, and displacement. This reduction in vibration

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levels contributes to the improvement of mechanical stability and potentially increases the operational service life of the gearbox components.

DISCUSSION.

The experimental results obtained in this study indicate that the proposed structural modification of the worm gear reducer leads to a noticeable reduction in vibration levels in the system. The comparison of vibration parameters before and after the installation of the elastic support element demonstrates that the modified gearbox configuration provides improved dynamic behavior.

The observed reduction in vibration acceleration, velocity and displacement can be explained by the damping properties of the elastic element introduced into the bearing support structure. In conventional worm gear reducers, the bearing assembly is rigidly mounted to the gearbox housing. Under such conditions, dynamic loads generated during gear meshing and shaft rotation are directly transmitted to the housing and other structural components of the gearbox.[6]

In the proposed design, the elastic element acts as a vibration-damping component. Due to its elastic properties, it is capable of partially absorbing and dissipating the dynamic energy generated during the operation of the worm gear transmission. [7]As a result, the intensity of vibration transmitted to the gearbox housing and bearing supports is significantly reduced.

The reduction in vibration acceleration and displacement indicates that the amplitude of mechanical oscillations in the gearbox system decreases after the modification. This improvement contributes to the stabilization of the rotating elements and reduces the influence of dynamic loads acting on the worm–wheel pair.

Another important observation is related to the reduction of vibration parameters recorded in the fast signal mode. The acceleration value decreased from **75.353 m/s² to 52.641 m/s²**, which corresponds to a considerable decrease in high-frequency vibration components. Such a reduction confirms that the elastic support element effectively mitigates dynamic impacts occurring in the gearbox during operation. Lower vibration levels in mechanical transmission systems lead to several important practical advantages. First, the reduction of dynamic loads decreases the wear rate of worm gear teeth, since excessive vibration often accelerates surface fatigue and friction processes. Second, reduced vibration improves the operating conditions of bearings, which can significantly extend their service life. Third, the overall mechanical stability of the transmission system increases, which contributes to more reliable and smoother operation of the gearbox.[8]

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In addition, the reduction of vibration levels may lead to a decrease in noise generation during operation, which is particularly important for industrial machinery operating in continuous production environments.

Thus, the results of the experimental investigation confirm that the introduction of an elastic support element into the structure of the worm gear reducer is an effective engineering solution for reducing vibration levels. The proposed design modification improves the dynamic performance of the gearbox and can contribute to increasing the reliability and durability of worm gear transmission systems.

CONCLUSION.

In this study, a modified design of a worm gear reducer incorporating an elastic support element was proposed and experimentally investigated. The main objective of the research was to evaluate the influence of the elastic element on the vibration characteristics and operational performance of the worm gear transmission system.

Experimental vibration measurements were carried out using the VibXpert diagnostic device in the axial direction of the gearbox shaft. The measurements were performed for two operating configurations: the conventional worm gearbox with a rigid bearing support structure and the modified gearbox equipped with the proposed elastic support element.

The comparative analysis of vibration parameters demonstrated that the installation of the elastic element leads to a noticeable reduction in vibration acceleration, velocity and displacement. In particular, the results obtained in the fast signal mode showed a significant decrease in vibration acceleration, indicating a reduction in dynamic loads generated during the operation of the gearbox.

The observed reduction in vibration levels confirms the effectiveness of the proposed structural modification. The elastic element functions as a vibration damping component, partially absorbing dynamic energy generated during gear meshing and shaft rotation. As a result, the dynamic loads transmitted to the gearbox housing and bearing supports are reduced.

Lower vibration levels contribute to improved operating conditions of gearbox components. In particular, reduced vibration intensity can decrease wear processes in worm gear teeth, improve bearing operating conditions and enhance the overall mechanical stability of the transmission system.

Therefore, the proposed modified mechanical transmission system with an elastic support element can significantly improve the operational reliability and service life of worm gear reducers. The results obtained in this study demonstrate that the introduction of elastic support structures is a promising engineering

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approach for increasing the durability and vibration resistance of worm gear transmission systems used in mechanical engineering applications.

Future research may focus on further optimization of elastic element parameters, investigation of vibration characteristics in other measurement directions, and analysis of the influence of the proposed design on long-term gearbox performance under different operating conditions.

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