REDUCING VIBRATIONS IN WORM GEAR DRIVES MORE EFFECTIVELY

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Abstract. Worm gear drives are widely used in many mechanical systems due to their compact structure and high torque transmission capability. However, traditional designs often suffer from drawbacks such as excessive friction, backlash, and vibration. This study investigates the potential for improving the dynamic characteristics of worm gear mechanisms through the integration of elastic elements. A comprehensive analysis was performed, including structural parameters, material selection, load evaluation, stiffness assessment, and efficiency analysis. It was found that installing a 3 mm thick elastic element in the bearing transmission zone significantly enhances the system's damping performance. Experimental results show that the use of the elastic element reduces vibration velocity by 10–20%, decreases maximum acceleration by up to 15%, and lowers displacement amplitude by up to 20%. The most pronounced improvement was observed in the horizontal direction. The findings confirm that the proposed design solution has high potential for increasing the efficiency and reliability of worm gear transmissions.

Key words: Worm gear transmission, Vibration reduction, Elastic element, Damping, Shaft load, Dynamic characteristics.

Annotatsiya: Chervyakli uzatmalar ixcham tuzilishi va yuqori moment uzatish qobiliyati sababli ko‘plab mexanik tizimlarda keng qo‘llaniladi. Biroq an’anaviy konstruksiyalar ortiqcha ishqalanish, lyuft va vibratsiya kabi kamchiliklarga ega. Ushbu tadqiqotda chervyakli uzatma mexanizmlarining dinamik xususiyatlarini elastik elementlarni integratsiya qilish orqali yaxshilash imkoniyatlari o‘rganildi.

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Konstruktiv parametrlar, material tanlovi, yuklama tahlili, qattiqlik va samaradorlikni baholash kabi omillar kompleks ravishda tahlil qilindi. Podshipnik uzatish zonasiga qalinligi 3 mm bo‘lgan elastik elementni o‘rnatish tizimning damping xususiyatlarini sezilarli darajada oshirishi aniqlandi. Eksperimental natijalar elastik element qo‘llanilganda vibratsiya tezligi 10–20% ga, maksimal tezlanish 15% gacha, siljish amplitudasi esa 20% gacha kamayganini ko‘rsatdi. Eng katta ijobiy ta’sir gorizontal yo‘nalishda kuzatildi. Tadqiqot natijalari taklif etilgan konstruktiv yechim chervyakli uzatmalar samaradorligi va ishonchliligini oshirishda yuqori potensialga egaligini tasdiqlaydi.

Kalit so‘zlar: Chervyakli uzatma, Vibratsiyani kamaytirish, Elastik element, Damping, Valga tushadigan yuklama, Dinamik xususiyatlar.

Аннотация. Червячные передачи широко применяются во многих механических системах благодаря их компактной конструкции и высокой способности передавать крутящий момент. Однако традиционные конструкции часто имеют недостатки, такие как повышенное трение, люфт и вибрации. В данном исследовании рассматривается возможность улучшения динамических характеристик червячных механизмов путем интеграции эластичных элементов. Проведен комплексный анализ, включающий оценку конструктивных параметров, выбор материалов, анализ нагрузок, оценку жесткости и эффективности. Установлено, что установка эластичного элемента толщиной 3 мм в зоне подшипниковой передачи значительно повышает демпфирующие свойства системы. Экспериментальные результаты показали, что применение эластичного элемента снижает скорость вибраций на 10–20%, уменьшает максимальные значения ускорения до 15% и снижает амплитуду перемещения до 20%. Наиболее выраженный положительный эффект наблюдался в горизонтальном направлении. Полученные результаты подтверждают высокий потенциал предложенного конструктивного решения для повышения эффективности и надежности червячных передач..

Ключевые слова: червячная передача, снижение вибраций, эластичный элемент, демпфирование, нагрузка на вал, динамические характеристики.

Introduction

In contrast to conventional spur gears, which rely on several straight-toothed wheels, worm gears have a much simpler layout, consisting of only one helical and spiral-shaped element. These mechanisms are widely used in industrial equipment that may operate in fluid environments, such as hydraulic machines, where heavy loads must be lifted with few components. Although gears are common in power transmission, they are not always ideal because frictional heating and backlash can result in notable energy losses.[4] Traditional worm gears, in particular, suffer from

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major drawbacks—including high friction losses, backlash, and undesirable vibrations. Excessive friction causes overheating and wasted power, while backlash is unacceptable in high-precision applications. Issues like noise and vibration also accelerate wear and may lead to system failure. To address these challenges, this article explores the use of elastic components within worm gear mechanisms. Elements such as springs and rubber dampers can absorb shocks, reduce backlash, and improve the overall functioning of the drive. Integrating such elastic parts helps minimize the negative effects of misalignment and dynamic loading, enabling smoother and longer-lasting operation. [1]The development of effective design and analytical methods for worm drives with elastic elements requires several sequential steps. This section outlines the direction of these studies while considering the inherent structural limitations of worm gear systems.

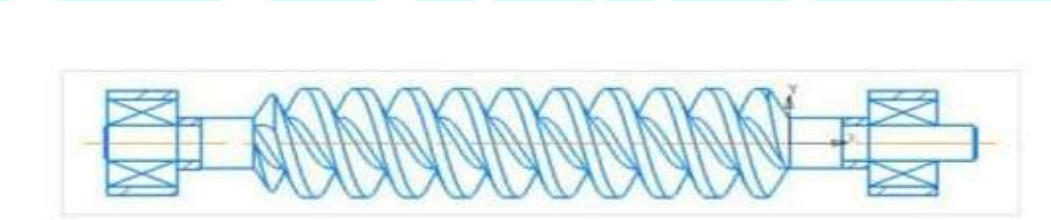


FIGURE 1. Curvilinear shaft with elastic elements[1]

Materials and methods

The outcomes of the study and the methodologies applied must be presented in a clearly organized report that includes project parameters, experimental findings, and proposed enhancements. Throughout the investigation, various disciplines were utilized, including advanced mathematics, machine and mechanism theory, vibration theory, machine dynamics, and testing techniques commonly used in mechanical and technological engineering.[3]

Results and discussion

During the study, the vibration parameters of the **1Ч-63А** worm gear were measured, and its kinematic and dynamic characteristics were calculated. Based on the results, the introduction of a flexible (elastic) element made of **polyurethane (Shore A 90, 3 mm thick, TU 2513-006-01296014-2015)** was recommended. The elastic element was incorporated into the design at the **bearing mounting location** (on the outer layer of the bearing housing). Measurements of the system's vibrations were taken using the **VIBXPERT II** portable professional vibroanalyzer both before and after installation to enable comparison.

The experimental prototype of the newly designed worm gear with a variable-parameter polyurethane damper demonstrated the following positive characteristics during testing:

1. **Absorption of mechanical shocks and noise reduction.**
2. **Smooth operation of the mechanism and enhanced operational efficiency.**
3. **Improved meshing and alignment between worm gear pairs.**

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Technological Test Results

The tests conducted on the **1Ч-63А** worm gear in its new design, equipped with a variable-parameter polyurethane damper, demonstrated the following results:

- Stationary vibrations of varying amplitudes were observed in the vertical and horizontal directions.
- The addition of the polyurethane element significantly improved shock absorption and reduced noise during operation

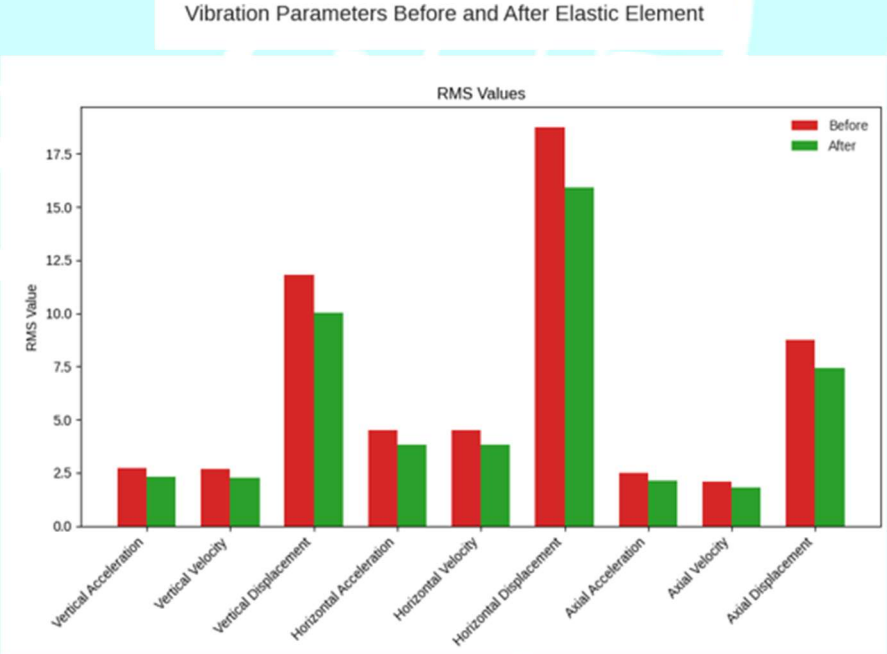


FIGURE 2.

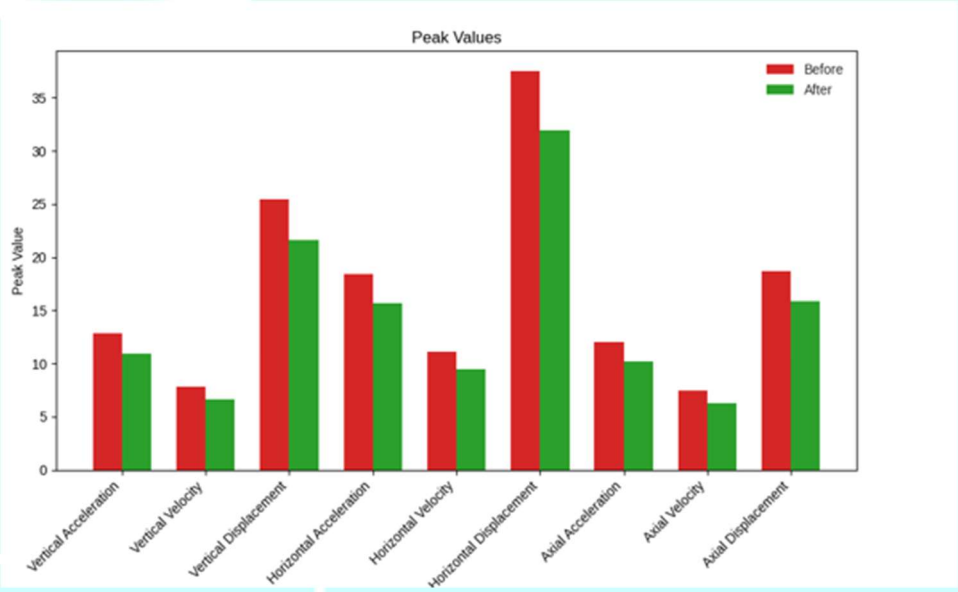


FIGURE 3.

The proposed new design of the worm gear transmission effectively absorbs vibrations in all three directions: horizontal, vertical, and along the shaft axis. The

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introduction of the elastic element significantly reduces vibration amplitudes, resulting in:

- **Horizontal vibrations:** The most pronounced reduction is observed in the horizontal direction, where lateral oscillations are efficiently damped by the elastic element, leading to improved alignment and stability of the shaft during operation.
- **Vertical vibrations:** Vertical vibrations are also noticeably diminished, which reduces the dynamic load on the gearbox housing and minimizes the risk of resonance in the vertical plane.
- **Axial (shaft) vibrations:** Axial vibrations along the shaft are effectively mitigated, contributing to smoother torque transmission and reducing wear on bearing surfaces.

As a result of these improvements, the service life of the transmission components is extended, operational reliability is increased, and maintenance requirements are reduced.[2] This demonstrates that the proposed construction not only enhances the dynamic performance of the system but also contributes to its long-term durability and efficiency.

Conclusion

The introduction of an elastic element with a thickness of 3 mm in the bearing transmission zone increases the damping characteristics of the system and reduces the vibration load on the gearbox housing and shaft. The results confirm the effectiveness of the proposed design. According to the measured vibration values, before and after the introduction of the elastic element:

- The vibration velocity decreased by 10–20%;
- The maximum acceleration values were reduced by up to 15%;
- The displacement amplitude decreased by up to 20%;
- The most noticeable effect was observed in the horizontal direction.

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