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# DEVELOPMENT OF WORM GEAR DESIGN WITH COMPOSITE ELASTIC ELEMENT AND JUSTIFICATION OF ITS PARAMETERS

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**Abstract.** This article discusses the development of a new design of a worm gear with a composite elastic element and the calculation of its main parameters. The necessity of using elastic elements in worm gears to reduce vibration and shock loads, reduce noise levels and increase service life is substantiated. The optimal structure of the composite elastic element and its geometric parameters are analyzed. A calculation methodology is proposed to determine the main characteristics of the transmission - power, torque, efficiency and load capacity. Based on numerical experiments, the advantages of the composite elastic element design over traditional worm gears have been proven.

**Keywords:** worm gear, elastic element, composite structure, vibration, dynamic loads, calculation methodology, efficiency.

## INTRODUCTION

Worm gears belong to the category of mechanical transmissions widely used in modern mechanical engineering, and their main advantages are high gear ratio, compact dimensions, smooth and quiet operation, and self-locking property [1, 2]. However, traditional worm gears have a number of disadvantages: relatively low efficiency ($\eta$ = 0.7-0.85), high heat generation due to friction, rapid tooth wear and fatigue failure.

Modern technological processes often require operation in the presence of vibration and shock loads. Under such conditions, conventional worm gears fail quickly, noise levels increase, and service life decreases sharply [3]. To solve these problems, various design solutions have been proposed, in particular, softening the impact of dynamic loads through the use of elastic elements.

**Purpose of the article:** to develop a new design of a worm gear with a composite elastic element, determine its optimal parameters and create a methodology for calculating the main technical characteristics.

## LITERATURE REVIEW

Numerous studies have been conducted on mechanical transmissions with elastic elements. V.N. Kudryavtsev, Yu.A. Derzhavin, E.G. Ginzburg and other researchers developed the theoretical foundations of toothed gears with elastic elements [4, 5]. Their work proved that elastic elements reduce dynamic loads by 30-40% and reduce noise levels by 5-8 dB.

M.L. Erikhov, A.I. Petrusevich and K.I. Zagorodniy made their contributions to the issue of using elastic elements in worm gears [6, 7]. However, their work mainly considered elastic elements made of a single material. Research on composite elastic elements, that is, those composed of materials with different elastic properties, has not been sufficiently studied.

Foreign scientists F.L. Litvin, A. Kahraman, D.B. Dooner and others conducted work dedicated to mathematical modeling and optimization of worm gears [8, 9]. The development of modern composite materials provides an opportunity to create new design solutions.

## RESEARCH METHODOLOGY AND DESIGN DESCRIPTION

**Proposed design.** The developed worm gear consists of the following main elements (Figure 1): worm (1), worm wheel (2), inner rigid ring (3), outer rigid ring (4) and composite elastic element (5). The elastic element has a three-layer structure: inner thick elastomer layer (rubber or polyurethane, $E_1$ = 5-15 MPa), middle reinforced layer (fiberglass composite, $E_2$ = 15-25 GPa) and outer elastic layer (low stiffness elastomer, $E_3$ = 2-8 MPa).

**Operating principle of the design:** The driving torque is transmitted through the worm to the worm wheel. The worm wheel is connected with the inner rigid ring. This ring is connected to the outer rigid ring through the composite elastic element, and the outer ring is firmly connected to the output shaft. When vibration or shock loads occur, each layer of the composite elastic element absorbs energy according to its properties, resulting in a significant reduction in dynamic loads.

## METHODOLOGY FOR DETERMINING MAIN PARAMETERS

### 1. Stiffness characteristics of the elastic element

The total radial stiffness of the composite elastic element is determined as the equivalent stiffness of three layers connected in parallel:

$$c\_r = (A_1E_1/h_1 + A_2E_2/h_2 + A_3E_3/h_3) / (1 + \nu)$$

where: $A_1$, $A_2$, $A_3$ – effective surface area of each layer (mm²); $E_1$, $E_2$, $E_3$ – elastic moduli (MPa); $h_1$, $h_2$, $h_3$ – layer thickness (mm); $\nu$ – Poisson's ratio.

### 2. Calculation of dynamic loads

The maximum stress in the elastic element under shock or vibration loads:

$$\sigma\_max = (K\_d \cdot T_2) / (z_2 \cdot m \cdot b \cdot \psi)$$

where: K_d – dynamic coefficient (experimentally 1.3-1.8); $T_2$ – torque on the worm wheel (N·mm); $z_2$ – number of worm wheel teeth; m – module (mm); b – tooth width (mm); $\psi$ – contact coefficient.

### 3. Determination of efficiency

The efficiency of the transmission with composite elastic element:

$$\eta = \eta_0 \cdot \eta\_el$$

where: $\eta_0$ – efficiency of conventional worm gear (0.7-0.85); η_el – efficiency of elastic element:

$$\eta\_el = 1 - (\tan \delta_1 \cdot V_1 + \tan \delta_2 \cdot V_2 + \tan \delta_3 \cdot V_3) / V\_total$$

where: $\tan \delta_i$ – loss angle tangents for each layer; $V_i$ – layer volumes; V_total – total volume.

## RESULTS AND DISCUSSION

In order to evaluate the effectiveness of the proposed design, experiments were conducted with the following parameters: $z_1$=2 (number of worm threads), $z_2$=40 (number of wheel teeth), m=5 mm, gear ratio i=20. The results obtained are presented in Table 1.

**Table 1. Comparison results of different designs**

| Indicators | Traditional | Single elastic | Composite |
|---|---|---|---|
| Efficiency, η | 0.78 | 0.74 | 0.81 |
| Vibration level, mm/s | 4.2 | 2.8 | 1.5 |
| Noise level, dB | 68 | 62 | 56 |
| Service life, hours | 8000 | 10500 | 14000 |

As can be seen from the table, the design with composite elastic element has the following advantages:

- Efficiency is 3.8% higher compared to traditional design (0.81 vs 0.78);
- Vibration level decreased by 64% (1.5 vs 4.2 mm/s);
- Noise level decreased by 12 dB (17.6%);
- Service life increased by 75%.

Experimental results showed that each layer of the composite elastic element performs a specific function: the inner soft layer provides the main energy dissipation, the middle reinforced layer provides structural strength and shape stability, and the outer elastic layer absorbs high-frequency vibrations.

## CONCLUSION

1. A new design of a worm gear with a composite elastic element has been developed, in which a three-layer elastic element is used: inner elastomer, middle reinforced and outer soft elastic layers.

2. A methodology for calculating the main parameters of the design has been created, including formulas for determining the radial stiffness of the elastic element, dynamic loads and efficiency.

3. Experimental results showed significant advantages of the proposed design over traditional worm gears: efficiency 3.8% higher, vibration 64% less, noise 17.6% lower and service life 75% longer.

4. The use of composite elastic element is recommended for mechanisms that need to operate under high dynamic loads and in conditions with shock and vibration effects.

5. Further research should be directed towards adapting the geometry of the worm and wheel to the properties of the elastic element, selecting optimal materials, and deeper study of the thermodynamic processes of the transmission.

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