UDC 621.82

SCOPUS CODE 2213

https://doi.org/10.36073/1512-0996-2025-2-259-266

On Issue of Helicopter Gearboxes Strength Reliability Analysis and Quality Control of Rolling Bearings

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Abstract. In the article are considered the issues of improving the parameters of technological processes during the restoration of the kinematic chain included in the helicopter gearbox in a small-scale enterprise, for example, in the Tbilisi Aviation Plant, in order to increase their reliability and control of radial-support rolling bearings, which together are of relevance.

Attention is drawn to the characteristics of the accuracy of manufacturing the teeth of an aviation gearbox, which is of particular importance where harmful deformation effects occur during working loads - twisting and bending vibrations.

The modification of the involute tooth profile by the “Reischauer” company is discussed, as a result of which vibrations are reduced during working loads.

It is shown that in aviation gear transmissions, tooth breakage is widespread due to the concentration of stress along its profile, as well as their poor processing and the use of undesirable lubricants.

In order to increase reliability, the established strength reserve coefficient is used and the image is considered as a way to determine the safety coefficient.

An original design device is proposed (patent N AP 20058182A, developed at the Georgian Technical University and implemented in the Tbilisi Metropolitan Union.

The article uses mathematical analyzer geometry methods for measuring the radial clearance of rolling bearings with a non-contact device, followed by theoretically mathematical representation of the axis

Keywords: Original divice for quality control of bearings; Strength reliability; Torsional and bending vibrations.

Introduction

To improve the reliability of rolling bearings, various parameters have been studied, such as the kinematic accuracy of the chain, the quality of the gear transmission of reducers, the resulting torsional and bending vibrations, and ways to improve strength reliability.

Considering the issues of monitoring rolling bearings and their selection, on which the quality of the accuracy of the entire process chain largely depends, it is proposed to monitor the value of the radial and support-axial tolerance by an original design of the measuring device [15].

Using the original design of the device with a built-in rocker mechanism and a measuring metering lever of force, strict control of the tolerance of the gap deviation is ensured [15, 12].

Using the conclusions of analytical geometry when considering an equilateral triangle, the obtained values \u200b\u200bare determined by two-plane - radial and support values \u200b\u200bof the gap tolerance.

Main Part

In aircraft gearboxes, control of their precision characteristics is of particular importance, including load-bearing rolling bearings. When operating cogwheels, high kinematic precision of rotation must be ensured with an involute profile [7, 11].

According to the materials of the Swiss company "Reishauer", [7] it is indicated that an involute is subjected to complete modifications compensates well for the harmful effect of deformations occurring under the working load, and the obtained parameters when assessed according to GOST 1643-72 and ST SEV 186-75, and in the opinion of the indicated company, the transmission will be assessed as inaccurate. This principle of control is acceptable for assessing and standardizing the precision of low-load gear transmissions for general mechanical engineering with working surfaces of teeth with low hardness [7]. Therefore, it is considered incorrect to evaluate the accuracy of aircraft gears exclusively according to GOST 1643-72 elemental indicators [7, 11].

Contact tooth failure is the main cause of failure of high-speed gears in well-lubricated gear transmissions. During repair of aircraft engines, up to 85% of the total number of rejected gears are rejected due to contact tooth failure caused by chipping and peeling [7, 13].

The most common causes of contact tooth failure are the concentration of load along the length and profile of the teeth and their poor running-in ability, and the greater the concentration of stresses, and unfavorable lubricants contribute to the failure of the tooth. For aircraft gearboxes, it is necessary to establish a fatigue strength reserve (safety factor) for the cogwheel, determined [7]:

$$n_{-1} = \frac{\sigma_{-1}}{\left(\frac{\kappa_\sigma}{\xi_\sigma}\right)\sigma_{0.a} + \psi_\sigma \, \sigma_{om}} \le [n_{-1}] \,, \qquad (1)$$

where σ_{-1} - is the fatigue limit of the cogwheel;

κ_σ- is the effective stress concentration factor;

ξ_σ- is the absolute size factor of the wheel;

ψ_σ - is the cycle asymmetry influence factor;

$[n_{-1}]$- is the permissible value of the safety margin.

The amplitude value of extreme local normal stresses $\sigma_{0.a}$ and the average value of these stresses σ_{om} are equal to [7]:

$$\sigma_{0.a} = (\sigma_{0\max} - \sigma_{0\min})/2 \; ; \qquad (2)$$

$$\sigma_{om} = (\sigma_{omax} + \sigma_{0min}) /2 \; , \qquad (3)$$

where σ_{omax} and $\sigma_{0\min)}$ – are extreme values of local normal stresses in the rim of the cogwheels under consideration, determined by the corresponding formulae [7,13].

As not only the rim, but also the teeth of the satellite in the gearbox operate under conditions of an asymmetric alternating stress cycle, and the asymmetry coefficient of the cycle $r = \sigma_{min} / \sigma_{max}$ changes with an increase in the gap and a decrease in the thickness of the rim [8], it is necessary to calculate the loaded tooth of the satellite and the rim using the formula for cogwheels during their vibrations [6, 7].

Increased dynamic loads in the engagement of gearboxes caused by resonant torsional vibrations of gear drives are dangerous.

There are existing two types of torsional vibrations. Low-frequency vibrations caused due vibrations of the system, which include: gear transmissions; engine rotor, helicopter p

The most dangerous are high-frequency torsional vibrations with a tooth frequency and with a multiple of its harmonic. The main source of such vibrations is the different rigidity of the teeth in engagement [1, 7]. Considering that the majority of highly loaded gear transmissions have an overlap in engagement of 1<<2, and the total rigidity of the teeth of a two-pair engagement is approximately 1.75 times higher than the rigidity of a single-pair engagement, which under operating conditions is a source of excitation of torsional parametric oscillations of cogwheels, under some circumstances - the most dangerous parametric oscillations. The amplitude of parametric oscillations depends on the accuracy of manufacture and loading of the wheels with the working moment and is limited by the magnitude of static deformation of the teeth [1,7]. High-frequency torsional oscillations of wheels are amplified due to cyclic errors in the manufacture of teeth and assembly of wheels, which especially affects the operation of bevel gears. Dynamic loads in gear engagement caused by torsional oscillations of wheels are amplified by their transverse oscillations in the presence of compliant shafts and supports [7]. One of the main methods of monitoring helicopter gearbox gears is endurance testing of active tooth surfaces, where such factors as material properties, tooth surface condition, geometric and precision parameters of the gear, operating and loading conditions must be taken into account. The criterion for destruction during contact fatigue of tooth surfaces is

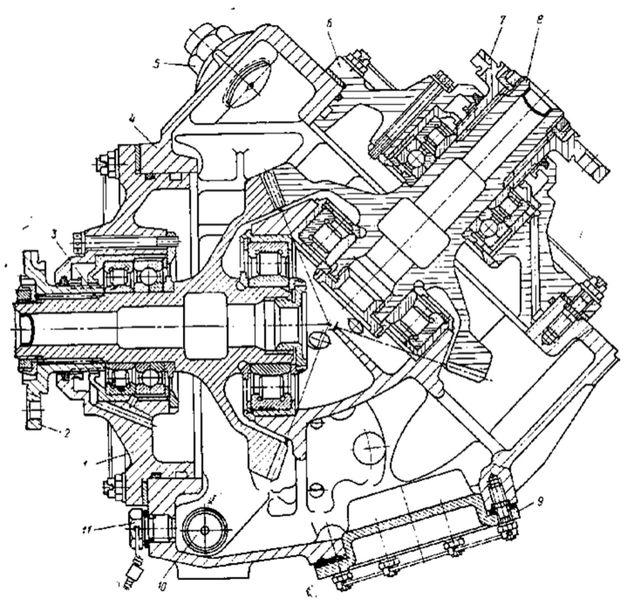

Fig. 1 Main gearbox VR-8 of the helicopter [7].

Bearing supports installed on the main gearbox VR-8 of the helicopter (Fig. 1) include: 1. main rotor shaft, 2-upper gearbox housing; 3- satellite and pinion housing; 4- satellites; 5- gearbox housing, etc.

Parametric resonant vibrations are a source of increased noise in gear transmissions due to intensive wear of tooth profiles. Reducing the excitability of parametric vibrations is an important task for reducing the level of bending vibrations of wheels and increasing the reliability and durability of the gear transmission [6, 7].

The listed loads affect the rolling bearings, causing an increased friction moment to appear in them. Therefore, when performing restoration work, it is necessary to select bearings with high precision indicators [6, 15].

To control the radial and support-axial clearance tolerance in rolling bearings of helicopter gearboxes during restoration work, it is proposed to use a horizontally located rocker-lever device with the required load for measuring the radial measured bearing device (Fig. 2), where the specified parameters are measured separately. However, when rearranging the bearing with a change in the fastening base for measuring the axial tolerance, this entails the accumulation of error, as well as due to the inaccuracy of the action of the pressing force. Since for support-radial roller bearings with a removable outer ring, the axial tolerance is adjusted using a bearing cover, and when checking a non-separable support-radial bearing with an outer ring, use a tested device (Fig. 2) and the analytical geometry method [15, 8].

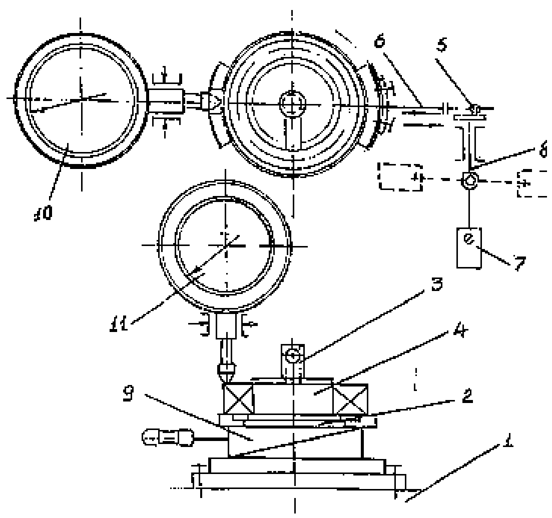

Fig. 2. Device for monitoring radial and support-radial clearance of rolling bearings [15].

It is known from analytical geometry that the solution to the problem of the parameters of an equilateral triangle is considered in the coordinate system on the XOY plane, a fixed point (Fig. 3), which will correspond to one value on one of the coordinates of the specified plane. The middle of the segment AB (Fig. 3), where the points $A(-a, 0)$ and $B(a, 0)$ are given, and the point $C(x, y)$ for which $CA = CB$, where the value a is half of the segment $AB = 2a$.

From Fig. 3 it is clear that the point C is taken incorrectly with respect to the coordinate axes (and in fact cannot occupy such a position) [8].

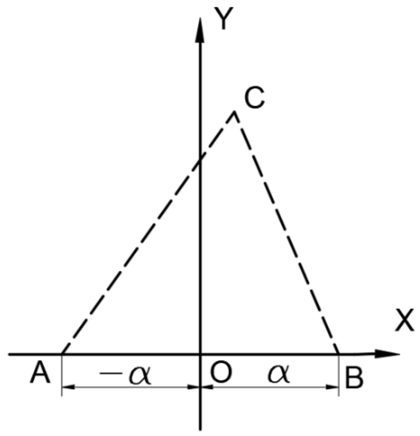

Fig. 3. To determine the parameters of an equilateral triangle in the *XOY* plane [8]

It is necessary to find the geometric location of points perpendicular to the segment AB and passing through its midpoint. accepting the segment AB as one of the coordinate axes for the abscissa axis and choosing the origin in the middle of the segment AB (Fig. 3), where the points $A(-a, 0)$ and $B(a, 0)$ are given. It is necessary to find the location of points $C(x, y)$ for which $CA = CB$. The value a is half of the segment $AB = 2a$.

Due the Fig. 3, point C is taken incorrectly (and really cannot occupy such a position). We find the geometric place and compose an equation that the current coordinates x and y would satisfy to:

$CA = CB$ (4)

Let's express CA and CB through the coordinates. The distance CA between $A(-a, 0)$ and $C(x, y)$, where we have $CA = \sqrt{(x+a)^2 + y^2}$, and the distance CB between $B(a, 0))$ and $C(x, y)$ - is the expression $CB = \sqrt{(x-a)^2 + y^2}$. According to condition (4), it is equal to

$$\sqrt{(x+a)^2 + y^2} = \sqrt{(x-a)^2 + y^2} \qquad (5)$$

ISSN 1512-0996
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And to determine that for this line we simplify the expression (5) by squaring both parts, we have

$(x + a)^2 + y^2 = (x - y)^2 + y^2$

and after opening the brackets and reducing similar terms it is equal to:

$4ax = 0$ (6)

From that it follows that $a \neq 0$and represents the ordinate axis at x=0, which is perpendicular to the segment AB and passes through its midpoint and is the perpendicular drawn through the midpoint. The value of the height of an equilateral triangle is considered when finding the center of gravity of triangle ABC in the coordinate system we find the geometric location of the point M, the sum of the squares of the distances of which to the vertices A and B is twice the square of the distance to the vertex C.

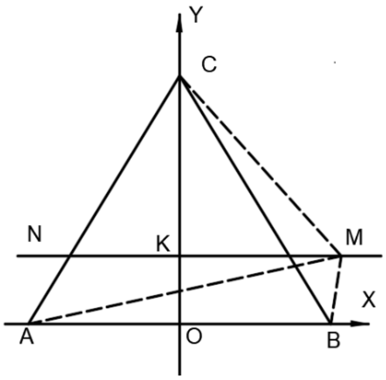

Fig. 4. To determine the main parameters of an equilateral triangle [8]

Accepting the segment AB as the abscissa axis, where the origin of coordinates O is in the middle of AB and the vertex of point C lies on the ordinate axis. The distance 0C is the height of an equilateral triangle and is equal to $a\sqrt{3}$ and thus we have $C(0, a\sqrt{3})$. Since in the value $a\sqrt{3}$, where a is half the tolerance of the radial deviation, then √3 - this value would be corrected, similar to the tables of the values of the reduced coefficients of various designs of rolling bearings when determining their service life [8,13]

Conclusion

1. To improve the reliability of rolling bearings, such parameters as the kinematic accuracy of the chain, the quality of the gear chain of the gearboxes, the resulting torsional and bending vibrations and their ways of increasing the strength reliability using the original design of quality control of bearings are taken into account [15].
2. In order to reduce torsional and bending vibrations in the kinematic chain of helicopter gearboxes, it is recommended to use a modification of the involute profile and the technology of the Reishauer company, which reduces the harmful effects of deformations occurring under the working load and increases the reliability of the helicopter gearboxes [7].
3. The methods of analytical geometry for two-plane control of rolling bearings - radial and axial clearances were used with the help of the original design of the device (Patent No. AR20058182A, GO135/14), Georgia
4. The advantage of the device with a rocker-lever mechanism is the gap-free movement with a changing force, which ensures high accuracy of measuring the radial deviation, and based on the output of the analytical geometry result, the axial deviation is determined and is equal to a√3, where a is half the tolerance of the radial deviation.

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UDC 621.82
SCOPUS CODE 2213
https://doi.org/10.36073/1512-0996-2025-2-259-266

ვერტმფრენის რედუქტორების სიმტკიცის საიმედოობის გაანგარიშებისა და გორვის საკისრების ხარისხის კონტროლის საკითხი

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ანოტაცია. მცირე სერიულ საწარმოში, მაგალითად თბილისის საავიაციო ქარხანაში, ვერტფრენის რედუქტორში შემავალი კინემატიკური ჯაჭვის აღდგენითი სამუშაოს შესრულებისას განხილულ იქნა ტექნოლოგიური პროცესების პარამეტრების სრულყოფის საკითხები, მათი საიმედოობის გაზრდის მიზნით და რადიალურ-საყრდენი გორვის საკისრების კონტროლი, რაც ერთობლიობაში ძალიან აქტუალურია.

ყურადღება გამახვილებულია საავიაციო რედუქტორის კბილანების დამზადების სიზუსტის მახასიათებლებზე, რომელსაც განსაკუთრებული მნიშვნელობა აქვს, სადაც მუშა დატვირთვისას წარმოიშობა დეფორმაციის მავნე მოქმედებები – მგრეხი და ღუნვადი რხევები.

მოცემულია “რეისხაუერის“ ფირმის მიერ ევოლვენტური კბილის პროფილის მოდიფიკაცია, რის შედეგად რხევები მუშა დატვირთის დროს მცირდება.

ნაჩვენებია, რომ საავიაციო კბილანურ გადაცემებში გავრცელებულია კბილების მსხვრევა, გამოწვეული ძაბვის კონცენტრაციის გრძივად მის პროფილზე, აგრეთვე მათი ცუდი მუშაობისას და არასასურველი საპოხი მასალის გამოყენებისას.

საიმედოობის გაზრდის მიზნით გამოყენებულია დადგენილი სიმტკიცის მარაგის კოეფიციენტი და გამოსახულება უსაფრთხოების კოეფიციენტის განსაზღვრის სახით.

შემოთავაზებულია ორიგინალური კონსტრუქციის მოწყობილება (პატენტი N AP 20058182A) რომელიც დამუშავებულია საქართველოს ტექნიკურ უნივერსიტეტში და დანერგილია თბილისის მეტროპოლიტენის გაერთიანებაში.

საკვანძო სიტყვები: გრეხითი და ღუნვითი რხევები; ორიგინალური ხელსაწყო საკისრების კონტროლისათვის; სიმტკიცის საიმედოობა.

The date of review 22.01.2025
The date of submission 04.02.2025
Signed for publishing 16.06.2025