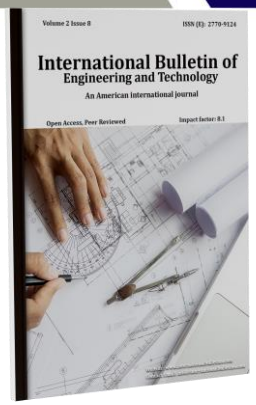

MATHEMATICAL MODELING OF PROCESSES IN WHEEL BEARINGS

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ANNOTATION. The purpose of this article is to build a mathematical model of the processes in the wheel bearing and analyze the unstable movements of the shaft in the sliding bearing, taking into account the elastic properties of the liner for various external loads.

Key words: Wheel bearing, diagnostics, mathematical modeling, information signals, bearing tracks, external factors.

The development of the wheel bearing diagnostic method includes rolling theoretical research and dependency analysis. Characteristics of informative signals from the presence of local defects on circular surfaces and the state of lubrication in the tribocouple are studied. For this, the diagnostic object is characterized by a number of characteristics and external factors affecting it: the loads and pressures in contact are stiffness (radial and axial), the condition of the lubricant contact, the kinematics of the structural elements, etc. It is a p-dimensional structure, which does not allow conducting the necessary experimental studies, which in turn creates the need to implement the mathematical modeling process.

It should be noted that most of the work on vibration characterization and electrofluctuation characteristics only affects single-row bearings that are not used in automotive hub assemblies (probably the most common bearing type in a hub assembly is double-row radial thrust).

Taking into account the influencing factors of element geometry and operation of wheel bearing surfaces, operating conditions and modes, as well as the necessary conditions for creating a comprehensive diagnostic method, along with mathematical modeling should take into account:

- kinematics of bearing elements;
- contamination with wear products and elements from the outside, taking into account the characteristics of the parameters of the lubricant, as well as its own characteristics;
- dynamics and displacement of centers of rolling elements, contact angles, static preload, etc.;
- microgeometric properties (local presence and size of defects, their position and possible combinations) of center bearing elements;
- macrogeometry of bearing tracks and rotating elements.

Processes and phenomena are difficult to describe and model in three cases.

Wheel bearing configurations are subject to a number of constraints and assumptions placed on the analyst:

- the contact interaction of bearing elements is elastic, its form is explained by Hertz's contact theory;
- the description of the surface is carried out taking into account that the only model will be the description of the segment of the sphere.

It is carried out taking into account the fact that the connection of rough surfaces is given. The characteristics of the data curve are as follows:

- electrical resistance of the tribocouple is considered as a combination of compression resistance and friction resistance;
- modeling is performed without considering the gyroscopic effect.

The mathematical model of double-row angular contact bearings is similar to the model of two single-row bearing sets in terms of design and operation. In most cases, double-row angular contact bearings have structural inner and outer rings, and automotive wheel bearings have an inner ring, which facilitates preloading. The need to determine the causes of vibration associated with monitoring and diagnosing the condition of hub axle tightening nut bearing assemblies can be classified as distributed processes and local defects. Disseminated defects include: waviness of round surfaces, inconsistency of nominal, minimum values of macrogeometric parameters of rolling bearing, local defects and vice versa, cracks, pits, various types of deformations and rolling elements.

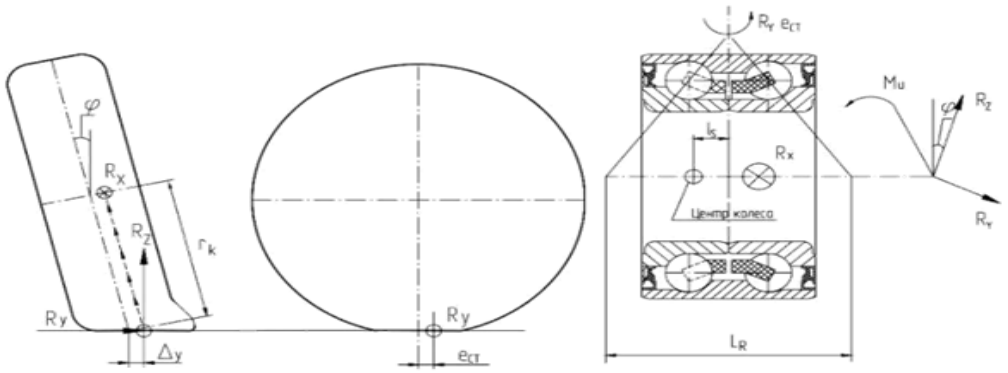

Figure 1. Diagram of the forces acting on the wheel and wheel bearing.

Figure 1 shows the distribution of forces applied to a car wheel. Due to the fact that the suspension kinematics has a complete structure, forces are applied to the wheel bearing.

The pattern of forces acting on the wheel and wheel bearing is subject to the wheel bearing due to the presence of camber. Radial and axial reactions of the bearing rows are calculated due to and according to the interaction of the force with the components.

Mathematical models of vibration of roller bearings and rational parameters for calculation of vibrations are widely studied. A large number of studies focused on the study and modeling of vibration processes, and rolling bearings were the first to be introduced.

The mathematical model of bearing vibration, taking into account the presence of local defects, does not take into account defects in the tracks and circular elements. Calculation of the load according to the contact theory of the system with two degrees of freedom, including the properties modeled as a bearing, but the properties of the rolling elements did not take into account the inertia.

The effects for different modes of motion are taken into account in the calculation of circular objects (rolling, sliding, twisting), radial change and vibration processes.

Based on previous studies, it is assumed that the vibration of the defective bearing can be active signs and parameters for comprehensive diagnosis.

After reviewing the literature on the modeling of vibration processes, we can distinguish the main elements of the models:

a) three-dimensional model;
b) deviations of the macrogeometry of the bearing;
c) hydrodynamic properties of tribocoupling;
d) taking into account the effect of the separator;
e) effect of temperature;
e) taking into account the influence of the deformation of the outer ring of the bearing;
g) the adequacy of the model is confirmed experimentally.

Results of theoretical simulations of vibration and electricity. On the basis of the mathematical model, a practical program was developed for the digital calculation of the deterministic component of resistance and vibration at different values of the influencing factors of the wireless. It is written in software. Ensuring the universality of the received results, the output parameter R of the program is the angular dependence of the separating coordinate (for uniform rotation, the resistance function equal to u with respect to time R(t)) and the oscillation time function. This condition makes it possible to carry out joint calculations of resistance bearing and vibration.

Figure 2. Vibration velocity spectra of wheel bearing with local defect mode in inner (a) and outer (b) rings

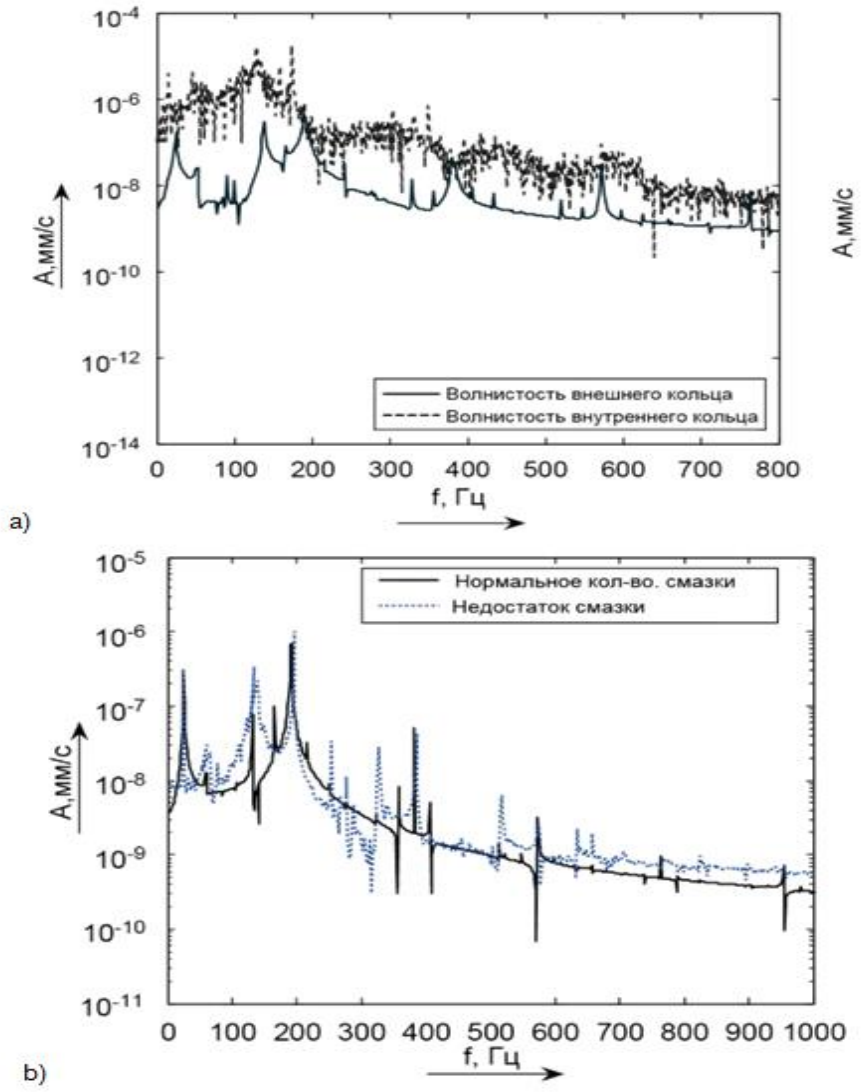

Figure 3. Wheel bearing vibration speed spectra with varying regime of waviness and lubrication

Simulation conditions - Double row angular contact ball bearings at ring speed n = 100 min-1 ke Fr = 1000 N.

The parameters of the wheel bearing 537907 are given in table 1.

Table 1.

Bearing parameters	Meaning
Diameter (d) Outside diameter	34 mm
(D) Width (H) Mass	64 mm
Ball diameter Loading	37 mm
The level is static Nominal	0,445 kg
Speed Number of balls	9,525 mm
The loading rate is dynamic	27,9 km

Spectra of the theoretical vibration speed of the wheel bearing local defect elimination (120 micron square hole), raceway waviness (wavelength less than 1 μm). The bearing ring, as well as the change in the amount of lubrication tribocoupling are presented in Figures 2, 3.

Fig. 2 Vibration velocity spectra of wheel bearing with mode local defect repair in inner (a) and outer (b) rings.

The earliest signs of bearing problems appear at ultrasonic frequencies, which are around 20 kHz.

Ultrasound or high-frequency vibration methods are used to detect this first symptom. Importantly, all of these methods can be very effective in detecting many faults. At the initial stage of failure, microscopic cracks appear that create elastic waves. The energy content of these elastic waves is still weaker than the low frequency with very low magnitudes in several of these stages, but measurable.

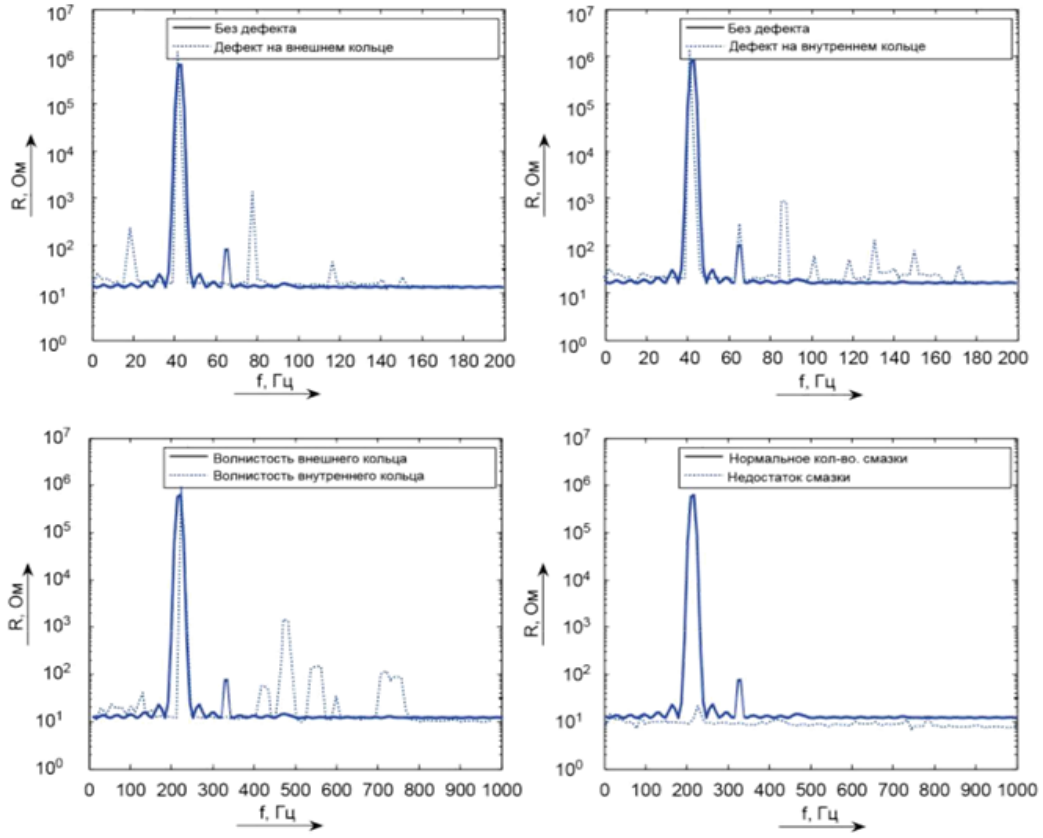

Figure 4. Resistivity function spectra with simulation of the presence of local defects, waviness, and lack of oil

When modeling local defects in the outer ring, but at a frequency close to the transmission frequency, the increase of the first harmonic passes through the loading zone, the sensitivity of the model is confirmed by the frequency domain changes in the ripple, which is confirmed by the increase in the low-level signal.

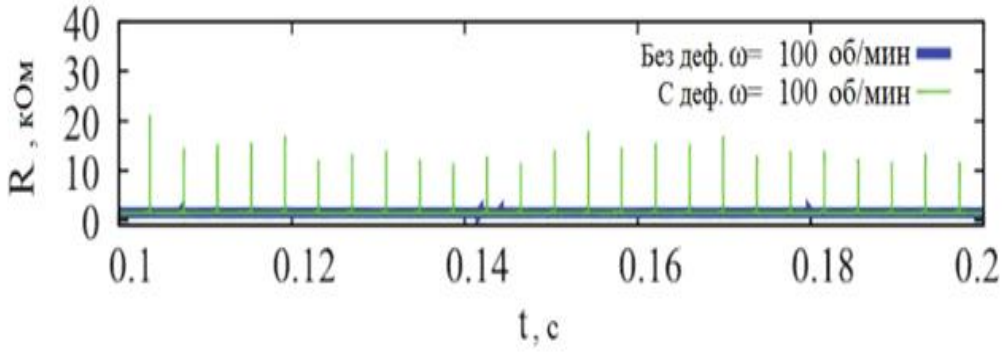

Figure 5. Transient signal of wheel bearing resistance modeling of local defects

Data analysis shows that when changing the lubrication parameters, the signal oscillation speed changed significantly, which confirms the calculations that the oscillation processes are not sensitive to the lubrication regimes.

When studying the nature of the details of the change in the bearing resistance, it was found that it is not the resistance of the working bearing without the work of the working

surfaces during its operation. Even with the "ideal" without deviations, the shape of the work surface changes periodically. Figure 2.5 shows examples of frequency spectra for this case.

As can be seen from the figure, when the bearing works with "ideal" surfaces, under constant load and operating conditions, the surface periodicity of its resistance function is expressed. The smooth redistribution of the load between its presence, first of all, is explained by rolling elements: at different times in the loading zone, there are different numbers of rotating bodies in the bearing, and the load perceived by them has different meanings.

As can be seen from the graphs, depending on the contact type, the cutting details affect the contact resistance differently due to the local defects of the working surfaces. In enveloped acceleration, the spectrum is visible, and the frequency response is large enough for the sensor type, sensitivity (10 mv/g, 100 mv/g, 500 mv/g, etc.), mounting technique (magnetic, adhesive, or stud mounting), or most the important thing is the right settings. In addition, the sensor, if present, is installed as close as possible to the load zone of the bearing (inlet). A very effective shock pulse transducer or a combination of a standard accelerometer and a shock pulse transducer can be used, especially for bearings in low-speed applications. The remaining service life at this stage is 10% to 20% of the life of the L10 bearing.

To briefly summarize the above chapter:

- the developed mathematical models allow us to study the effect of local defects, waviness, the condition of the lubricant, vibration and resistance signals of the wheel bearing;

- in the mathematical modeling of electrical resistance, a two-row bearing, expressed in parallel with it as a sum of combined contact resistances for each of the circular elements;

- when the bearing is working, its electrical resistance and these vibration gauges are constantly changing, the resistance in time with the change function has two characteristic components: deterministic, taking information about the type and importance of healthy work and transition path The condition of circular elements and raceways with defects and random information, as well as the condition of the lubricant;

- average bearing resistance and vibration parameters of the object comprehensively describe the quality of the wheel bearing.

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