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THESIS ABSTRACT

„Impact of selected modifications applied between meshing zone and gearbox housing on gearbox vibrations"

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Gearboxes are commonly used in drive systems of many means of transport, for e.g. in motor vehicles, rail vehicles, aircraft and means of water transport, as well as civil engineering facilities. This is presented in detail in the first chapter.

Issues related to their vibroactivity significantly affect, among others on the comfort of using transport devices, and the operation of gearboxes is related to vibrations. The main source of these vibrations is the meshing zone. The vibrations generated in this zone are transmitted to: gears, shafts, their bearings and the transmission housing. The gearbox housing stimulated in this way affects the immediate surroundings and users of means of transport not only through vibrations, but also noise related to them. In connection with the above, in order to reduce vibrations and noise, it is very important to look for possibilities to reduce the transmission of vibrations already in the section between the meshing zone and the gearbox housing.

The review of the literature on the vibroactivity of gearboxes and the analysis of current state of knowledge presented in the thesis have shown that the possibilities of reducing the vibrations of operating gearbox are sought mainly through modifications to the housing structure and attempts to develop meshing shapes alternative to the involute outline. While the author of this thesis looked for the possibility of limiting the transmission of vibrations already in the section between the meshing zone and the gearbox housing, e.g. by modifying

the internal structure of the gear. Based on the review of European and global patent applications, it was found that the subject is up-to-date, but the presented structures very often have significant limitations regarding their use and drawbacks that prevent, among others, transmission of significant torque values.

In search of a solution to the presented problem, the author of this thesis performed preliminary experimental tests of a kinematic gearbox with the use of one of the gears mounted on the axis by tiled joint. 24 positions of the axis were analyzed relative to the shaft of the driving gear. On the basis of these tests results, no significant reduction in the RMS values of vibration accelerations of gear axis and the gearbox housing was noted, and in some cases an increase in the RMS values of vibration accelerations was up to 249%. Also, the analysis of changes in the amplitudes sums of the first six meshing frequency harmonics did not result in a significant reduction in the value of the adopted measure Σ amp. 1÷6·fz in relation to the classic mounting of gear on the axis. For the above reasons, it was found that another design solution should be sought to reduce vibrations on the way between the meshing zone and the gear housing.

As part of this doctoral thesis, an innovative gear structure was developed, which is also the subject of a patent application submitted to the Patent Office of Poland in September 2020. The proposed design of the gear is characterized by the separation of the toothed rim from the hub and their reconnection using an element characterized by a lower Young's modulus and a higher damping coefficient than the material of rim and hub. This construction of divided gear was presented in detail in chapter five of this dissertation. In addition, in order to obtain an additional possibility of limiting the transmission of vibrations between the gearbox bearings and housing, it was proposed to use sleeves also equipped with flexible elements, used to mount the shaft bearings in the gear housing.

As part of this dissertation, experimental research was also conducted to assess the impact of the use of the above-mentioned modification on transmission of vibrations from the meshing zone to the gear housing. These researches were divided into three stages:

1. Testing of gears (classic and divided - proposed by the author) which were excited to vibrate together with the shaft by the shaker.

2. Testing of gears (classic and divided - proposed by the author) and classical and modified bearings sleeves mounted in the gear housing and using impulse excitation with a modal hammer into the top of the gear tooth.
3. Testing of gears (classic and divided - proposed by the author) and classical and modified bearings sleeves in the case of an operating and load-transmitting gearbox.

Based on the conducted research, it was found that:

1. In the case of using the shaker to excite the vibration of a divided gear, a reduction of at least a dozen percent of the maximum amplitude of the modulus of the frequency response function was achieved in the places where the shaft interacted with the bearings, than in the case of using a classic gear. The obtained reductions, depending on the analyzed point of future cooperation of the shaft with the bearing and for the significant direction related to the circumferential meshing force, were 18% and 14%.
2. In the case of points located on the housing and housing cover of the gearbox equipped with the proposed modifications: the gear and the bearing mounting, a reduction of the frequency transfer function maximal value of nearly 50% was noted, on the tooth head - gear body path, compared to the classic gear not equipped with the aforementioned modifications.
3. In the case of a gearbox operating with a rotational speed changing over time and a constant load, as well as the application of the proposed modifications of the gear and bearings mounting, the ranges of rotational speed were determined, in which the vibrations reduction of operating gearbox was achieved by a maximum of 55% compared to the classic gearbox not equipped with the mentioned modifications.
4. In the case of the gearbox operating at a constant rotational speed and the simultaneous use of both proposed modifications of the gear and bearings mounting, and the torque value of 144 Nm, the RMS values of vibrations acceleration was reduced by 54% compared to the classic gearbox not equipped with the aforementioned modifications.