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DYNAMIC ANALYSIS OF GEARS

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Abstract. The article deals with an experimental assessment of the dynamics of gears. There is given a description of the test station for measuring the dynamic characteristics of the gears and the methodology for assessing the dynamic behaviour of the gear.

Keywords: gears, dynamic analysis, vibration, ultrasound

1. Introduction

Efforts to continuously improving performance of machinery and ensure their operational reliability places ever increasing demands on the machine parameters, which is reflected in the growth of dynamic loads in the nodes of kinematic chains.

Knowledge of dynamic processes in the machine aggregates in various working modes is a prerequisite for solving those problems.

To obtain objective information it is necessary to research the dynamics of machinery in their real operating conditions.

In doing so, these conditions may be true, respectively very close to the fact, made in the experimental methods of research or created artificially by setting up a dynamic (mathematical) model, which sufficiently precisely captures the properties of machine aggregate in terms of dynamics.

One of the areas of scientific research at the Department of Technological Devices Design of the Faculty of Manufacturing Technologies with a seat in Prešov, TU in Košice, is the development and use of methods of analysis of dynamic phenomena occurring in machines and mechanisms.

2. Experimental analysis of the dynamics of gearing

Gears are frequently used as drives of machines and devices. In connection with other parts of machine devices they present dynamical system and gears are just an element that affects the dynamic properties of the whole system.

In solution of the above scientific projects were developed methodology for determining and assessing the dynamic characteristics of the transmission mechanisms using several methods of non-destructive diagnostics without disassembly. The proposed methodology for assessing the dynamics of gears was in terms of possibility to obtain objective results of measurements, verified by a series of laboratory measurements commonly produced of two worm gears of the same type and parameters. Measurements were made in the process of simulated operation of a test station [1, 2], which was built on KNTZ FVT TU in Košice. The test station that is designed for the realization of comparative tests of various types of gears was exposed to verification tests. It is also possible to carry out short-term and long-term tests of transmissions in order to improve their performance and increase their life.

Stand allows the simulation of real operating conditions of gear, respectively whole driving station and the working machine. Principal scheme of the stand for dynamic testing of gears is in figure 1. Working machine (winch, hoist) is driven by an electric motor M connected by clutch SP1 with gearbox ZP. Gearbox output shaft ZP is connected through clutch SP2 with sprocket RK1, which is part of the chain transfer RP, which plays the role of the working machine in this case. To the chain R, whose direction of shift is determined by the position of sprockets RK1 - RK6, is attached a weight ZAV7. The weight moves vertically in line protected by a cover in both directions and so burdens gearbox output shaft. For reduction of shocks serves absorber with springs. The running of the test station is controlled by frequency converter, according to a predetermined program of loading which includes a reverse running and a change of the number of revolutions.

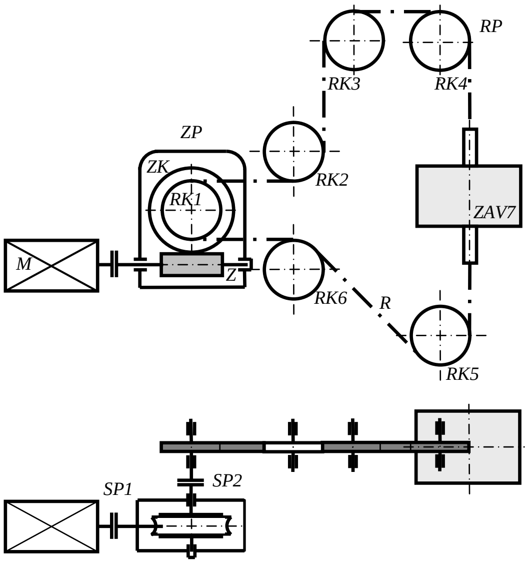


Figure 1. Scheme of the test station

Test transmissions were prepared before measurement (hole in the top of the gear box) and individual functional elements (the worm shaft, worm wheel, shaft and gear box) undergo a thorough control of accuracy. Dynamic model of the warm gear was created [4]. By the appropriate choice of the entrance parameters of load on the basis of the results of the PC simulation of the gear load it is possible to prevent the damage during the laboratory tests. During the experimental operation the technical condition of worm gears was monitored in two different working modes. Running conditions of Operational mode 1 were designed so that work performance achieves 70 ÷ 80 % of nominal gearbox performance guaranteed by its producer and stables oil temperature under limitations. In case of Operational mode 2 the load on gearbox was lower.

Dynamical values (temperature, vibrations, ultrasound) were monitored during the operation in selected measure points of gearbox (figures 2, 3).

Table 1. Parameters measured online

Measuring point	Measured parameter	Device
1H	Vibrations	NI PXI
1H	Temperature	Oktalon 2K
2H	Temperature	Oktalon 2K
4V	Vibrations	NI PXI

In measure points 1H, 2H and 4V individual values (Table 1) were measured in online mode using double-channel online system Oktalon 2K on the basis of module LWMONI2, through which the power supply of sensors and the evaluating of vibrations were realized.

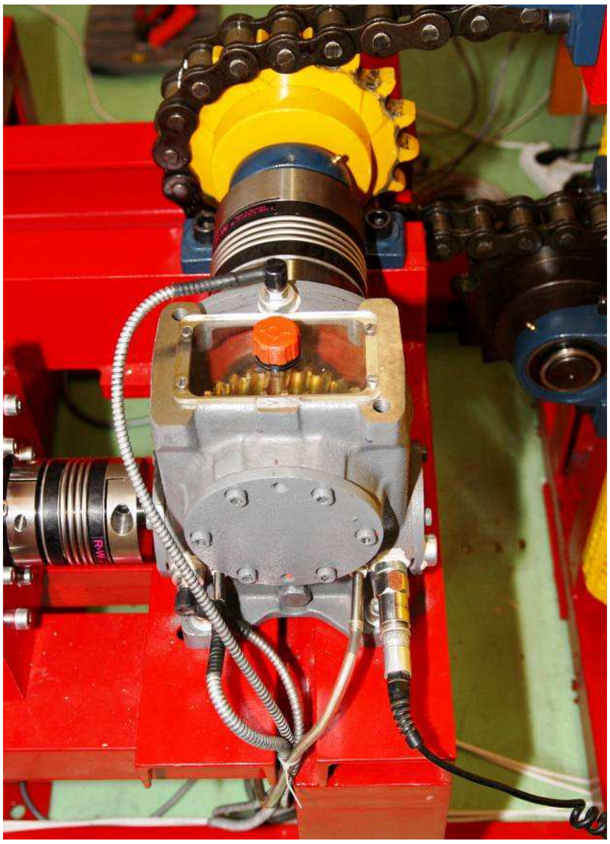


Figure 2. The placing of the sensors on the surface of worm gearboxes

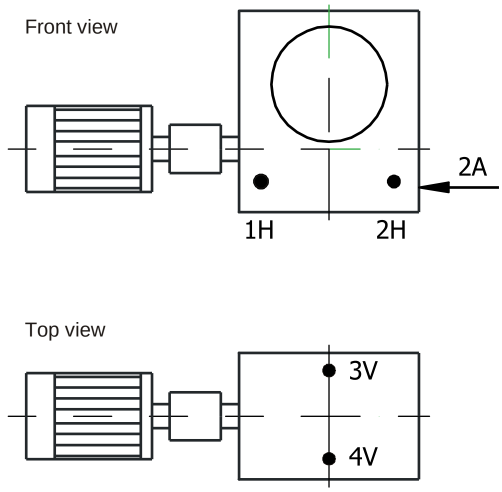


Figure 3. The scheme of the placing of the sensors on the surface of worm gearboxes

Dynamical data (vibrations and ultrasound) from measure points 2H and 2A were collected in offline mode. Data collection was realized by measuring system NI PXI (measuring card type PXI 4472B, 8-channel simultaneous acquisition, 24 bit A/D converter, sampling frequency up to 102 kHz, dynamical rage 110 dB). Data analysis was realized with Lab View Professional Development System, including Sound and

Vibration Toolset and Order Analysis Tools. Form measuring of ultrasonic emission Microlog GX a CMVA 55 – datologer and frequency analyser from SKF company were used.

Wear intensity on contact surfaces of teeth sides of worm gearing was monitored using more diagnostically methods.

3. The methods used for dynamic analysis

3.1. Measuring of gearbox temperature

At worm transmissions it comes to the fast gearings overheat, that is why continual monitoring of the oil temperature increase, respectively in this case, gearbox was important part of the tests. The state of the temperature conditions on the surface of the gear box was also assessed by temperature gradient. Temperature gradient indicates by how many degrees the temperature was changed in the last minute.

3.2. The measurement of the low-frequency vibrations depending up the time (MFV)

MFV - measurement of the vibration velocity is a method designed for detecting dynamic unbalance, shaft misalignment, released bases, bent shafts, resonant processes and vibrations in the low-frequency area (0.2 Hz to 1 kHz).

Recommended limits (figure 4) for the total level of mechanical vibrations (VELOCITY), (mm /s rms), in the range 10-1000 Hz is in according to a norm STN ISO 10816-3. On figure 4 is an example of a graphical representation of measured values of the mechanical vibrations for the measuring points 1H and 4V in the Operational mode 2. Vibration values measured in the point 1H and in the point 4V at the output of the gearbox are located below the warning limit.

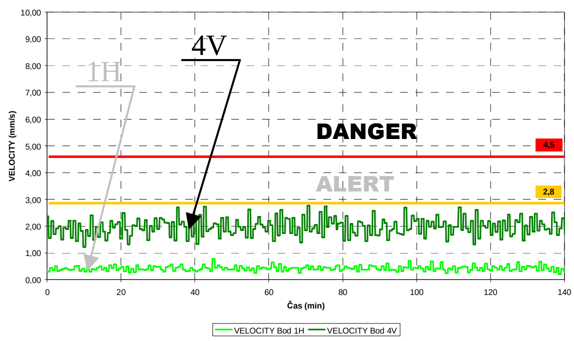


Figure 4. The low vibration mechanical system

3.3. High-frequency vibrations (MFA)

MFA (Acceleration) - vibration acceleration measurement is method designed for the monitoring of the nodes in area of the High Frequency (up to 20 kHz), for example, for the detecting of the status of bearings and gears, metal contact or seizing. On figure 5 is an example of the process of the high-frequency vibrations which were measured in the Operational mode 2.

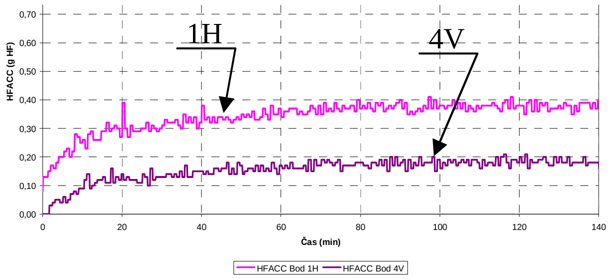
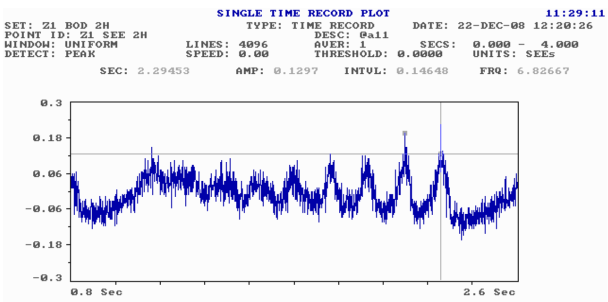


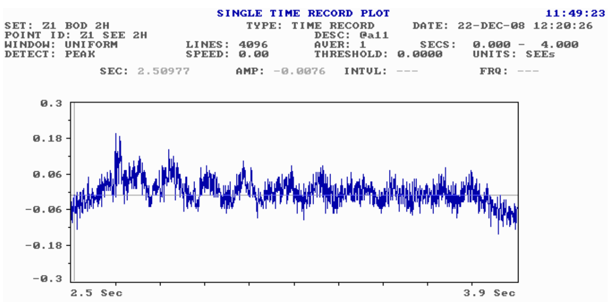
Figure 5. High-frequency vibration in the measured points 1H and 4V

3.4 Ultrasonic Emission Measurement

Technical condition of mechanical system is given by amplitude of ultrasonic emission and by its location on the time line.



a) Mode of lifting weight



b) Mode of weight running down

Figure 6. Ultrasonic emission, Time See point 2H Operating mode 1

On figure 6 there is a record of amplitude of ultrasonic emission from the measurement in Offline mode in the interval of lifting (figure 6a) and in the interval of running down (figure 6b) in the point 2H in Operational mode 1.

After processing particular signals in their entire time line using frequency analysis (FFT) dominant frequencies were determined.

Example of calculation from the entire time course (running down and lifting) in point 2H, for Operational mode 1, where was observed dominant frequency 6.8 Hz is in figure 7.

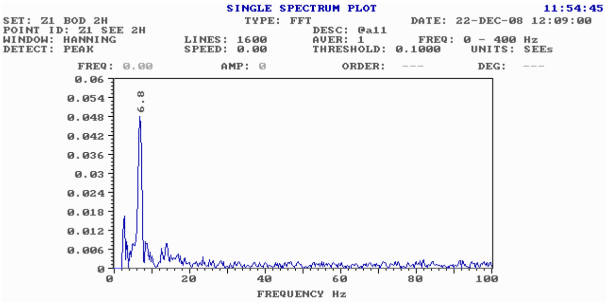


Figure 7. Ultrasonic emission
See FFT spektrum, 2H

3.5 High-frequency vibrations

Measured by Off Line device Microlog CMVA 55 (ENV 1,2,3,4 (Enveloping) - measure-ment of the envelope of vibration acceleration vibration).

Enveloping filter out low-frequency vibration noise and amplifies high-frequency vibration signals of bearings and gears. It is a special method SKF primarily for the assessment of the state of rolling bearings and gears with a possibility of the choice of four frequency bands as necessary. The unit of measurement is g ENV PtP.

3.6. Continuous measurement of the oil temperature

The oil temperature check was measured in time of the stop of the operation test gears at pauses to change the chosen parameters for the various operating modes.

3.7. Tribotechnical diagnostics of oil

Tribodiagnostics task is to identify and assess the presence of foreign substances in the greasing oils. The oil analysis can discover signs of an emerging disorder, respectively locate the place of mechanical damage and also monitoring the symptoms and consequences of degradation of oil in the operational process. On the oil samples taken before and after each working regime were assessed: the life of greases; determining the regime of friction and the level of wear of functional parts of the gear; magnetic separation of abrasion particles from the sample of oil using ferrograph, visual identification of abrasion particles using bichromatic microscope and determining the size, shape and origin of the particles.

4. Conclusions

The results of the assessment of the technical state of the test gears by different methods led to the same conclusion within the assessment [3].

The proposed methodology for assessing the technical state of gears has been assessed as suitable for obtaining objective measurement results of the dynamic characterstics of the gear. There was also prepared a proposal for elimination of identified failures of the test station.

Test device after modification and removal of identified failures will be used primarily for testing these parameters of gears, respectively parts of the gearing station:

- durability, reliability, wear (change of geometry - abrasion of contacts);
- efficiency, temperature, temperature gradient, thermal expansion, friction performance, friction moment, axial load;
- running actions, intensity and duration of running, change of load carrying capacity after running, the impact of abrasion on the contact surfaces, effect on grease, effect to durability;
- assessment of individual components, mainly gearing, bearings, grease, chain wheel and chain.

Assessment

Note: This paper is part of solution to the issue of scientific projects VEGA 1/0884/10 and VEGA 1/0558/08.

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