DYNAMIC TESTS OF GEARING

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Abstract: The paper deals with an experimental assessment of the dynamics of gears. The experimental station for dynamic tests of gears is described and methodic for assessing their dynamic characteristics is chosen. The results of the tests made to verify the correct function of the test station and the appropriateness of the chosen methodic for measurement of assessed parameters are listed.

Keywords: dynamics, gearing, technical diagnostics.

1 Introduction

The role of technical diagnostics of transmission mechanisms is to provide informations about technical condition of gearboxes, under which it is possible to:

- In the case of gear manufacturers to optimize the production technology, their design, to verify the data on performance parameters and the selection of recommended oils, respectively method of gear greasing.
- In the process of operation can be identified a damage of machine parts, respectively to ensure strategic planning and managing the maintenance of machinery and equipment and thus prevent the occurrence of disrepair of machinery.

2 Experimental stations for dynamic tests of gearings

Fig. 1 Experimental station for dynamic tests of gearings with members of the management (The real view)

As part of project solution focused on impact research of dynamic load to the lifetime of the gear drives in the Department of technical systems design Faculty of Manufacturing Technologies, TUKE with a seat in Prešov was built experimental station (Fig. 1) for the implementation of comparative tests of the gear drives, [1], [3].

With this experimental station can be realized short-term and long-term stress tests of transmissions with purpose to improve their parameters and to increase their lifetime. Further has been developed metodology for assessment of technical condition of gear mechanisms using several methods of non-destructive diagnostics.

The appropriateness of the proposed methodology for the assessment of gearings technical condition was verified by a series of experimental measurements of two commonly produced worm reducers of the same type and parameters. The role of these tests were also to verify if the experimental station meets the specified requirements from a functional point of view. The measurements were realized under the accelerated process of load to the experimental station [1], [3], which allows the simulation of real operating conditions of gearbox, respectively entire fuel station and working machine.

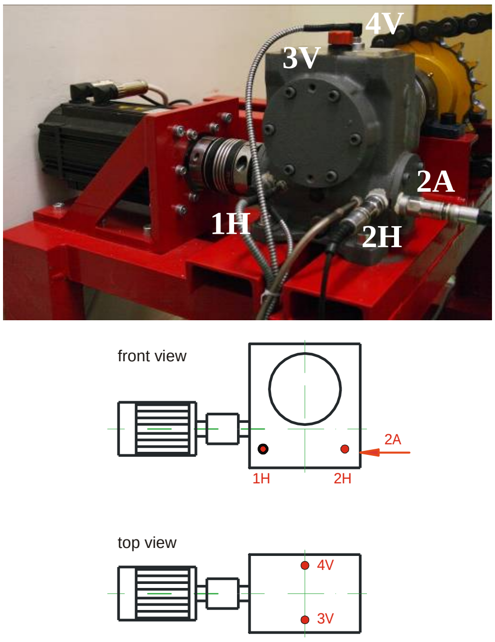


Fig. 2 Location of sensors at the surface of the worm gearbox

3 Description of measurement

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 the 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 (Fig. 2).

Table 1 Parameters measured online

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

In measuring points 1H, 2H and 4V individual values (Table 1) were measured in online mode. Dynamical data (vibrations and ultrasound) from measuring points 2H and 2A were collected in offline mode.

3.1 The measuring instruments

Sensors:

- accelerometers PCB IMI of type 607A11 with integrated cable (sensitivity 100 mV / g, frequency range up to 10 kHz),
- accelerometers SKF SEE.

NI PXI:

- data acquisition was performed by NI PXI measurement system (measurement card type PXI 4472B, 8-channel simultaneous acquisition, 24-bit A/D converter, sampling frequency up to 102kHz, dynamic range 110 dB),
- Data were analysed using Lab View Professional Development System, including the Sound and Vibration Toolset and Order Analysis Toolset.

Octagon 2K:

- double-channel online system Octagon 2K from company Technical diagnostic, spol. s.r.o. Prešov, based on the LWMONI2 module, through which the power supply of sensors and the evaluation of vibrations were realized.
- application programmed in the system Promotic for the realization of data acquisition.

Microlog GX a CMVA 55:

- dataloger and frequency analyser from SKF Company.

3.2 Used methods of technical diagnostic

Gear functional surfaces attrition was evaluated on the basis of these measurements:

- gearbox temperature measurement and determination of the temperature gradient,
- low-frequency vibrations versus time (DTMF - measuring the speed of vibration),
- High frequency vibrations (MFA (Acceleration) - measuring the acceleration of vibration),
- low-frequency and high-frequency vibrations, depending on temperature of the gearbox,
- determine the natural frequencies of mechanical system,
- ultrasonic emission See - measured offline by Microlog CMVA 55,
- high-frequency vibrations - measured offline by Microlog CMVA 55 (ENV 1,2,3,4 (Enveloping) - measuring the envelope of the acceleration of vibration),
- continuous measurement of the oil temperature,
- tribotechnical diagnostics of oil,
- continuous measurement of the tooth thickness,
- visual assessment of the gear functional surfaces.

4 Results of the measurements and discussion

In relation with wear in contact points of teeth sides were described by all used diagnostic methods in section 3.2 determined the same rundowns of attrition. Based on this fact, the proposed methodology of dynamic tests was evaluated as suitable for testing of gearings. In relation to the objective assessment of the technical condition of the tested worm reducer gear set, it can be stated that within six hours of service there was a significant attrition in the worm wheel in contact surfaces with the spiral worm.

The results of the measurements are processed and evaluated in detail in, [2] and [3]. To significant deterioration of meshing ratios on gearing was due to significant resonant actions, high mechanical vibrations above the recommended limiting values according to ISO 10816-3. Unfavourable were running conditions for motor acceleration and deceleration (of gearbox), especially at higher loads - vibration of the supporting structure of the experimental station and inadequate conducting of chain, what resulted in the transmission of vibrations up to the gearbox. Under these circumstances it was not possible to make an objective assessment of the technical condition of the tested reducer.

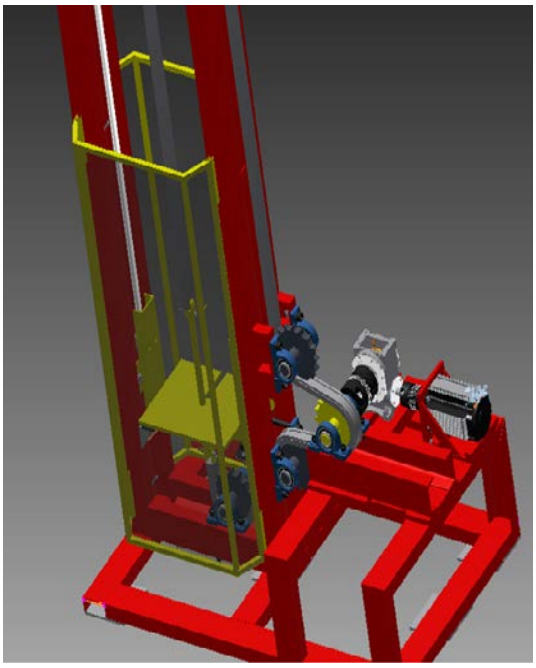


Fig. 3 Experimental station for dynamic tests of gearings (3D model created in Autodesk Inventor)

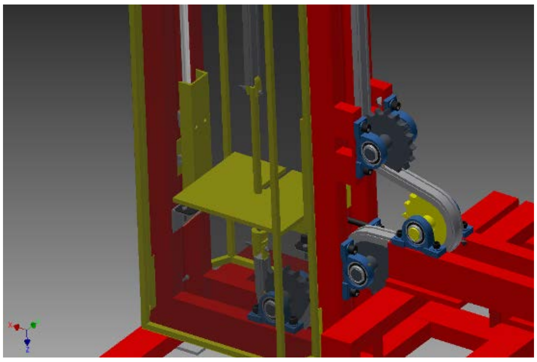


Fig. 4 3D model experimental station gearings (detail)

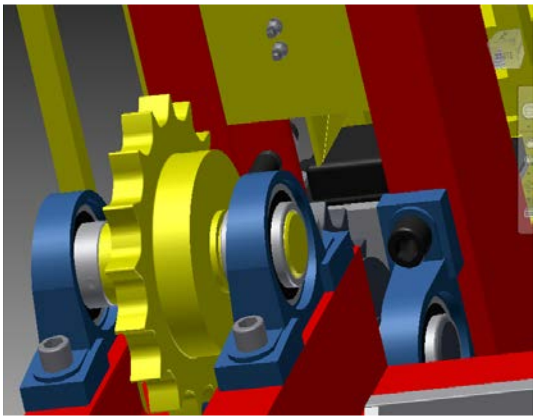


Fig. 5 Detail of 3D model experimental station gearings

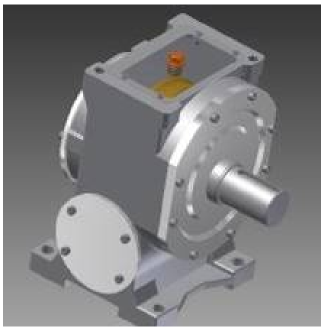


Fig. 6 3D model of the test worm gear

The results of monitoring of the technical condition of worm, respectively other tested gearings will be acceptable only after optimization of the supporting frame design (stabilization). Several alternative solutions for modification of the supporting structure of the experimental station was developed. Optimal modification will be selected on the basis of the results of computer simulations realized on a 3D model of the test station. Fig. 3, 4 and 5 show the 3D model of the test station in the original version created in Autodesk Inventor Professional 2011. Fig. 6 shows a 3D model of the test worm gear. 3D model of the test station is modified according to the proposed design changes. Dynamic analysis of the worm gear and the supporting frame of the test station will be performed by Dynamic simulation module in Autodesk Inventor

Significant attrition illustrates the state of the surface of the tooth flanks of the worm wheel of tested worm gears. The appearance of the surface of the tooth flanks of the gearbox worm wheel No.1 before the experimental running is shown in Fig. 7. The appearance of the teeth side at the end of the first phase of laboratory tests is shown in Fig. 8. Attrition of the tooth flanks is unequal and it has not the same character. Fig. 8a shows the tooth side status in the course of upward stroke of the weight with visible signs of attrition surface elements and pitting. Fig. 8b shows the changed status of the tooth side surface from the other side, when sinking the weight.

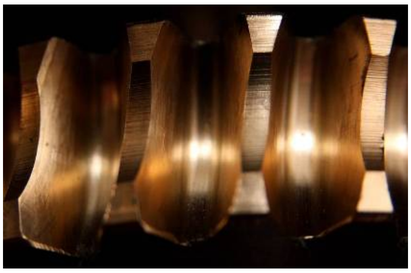
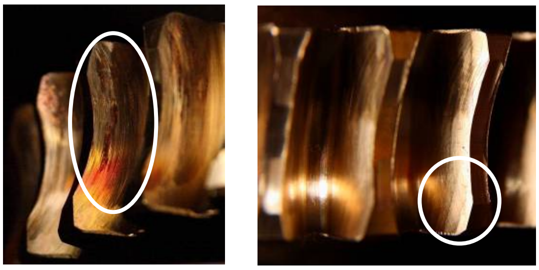


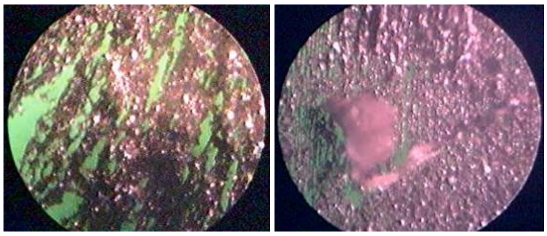
Fig. 7 The tooth flanks surface of unused gearbox worm wheel.



a) b)

Fig. 8 The tooth flanks surface of the worm wheel at the end of the first phase of experiment

By magnetic separation of attrition elements by using Ferro graph from the taken oil sample were obtained samples for investigation under a microscope. For both adjudicated oil samples in Fig. 9 are clearly visible particles of Cu and Sn alloys (bronze coloured particles). In the worm gear is worm wheel made from bronze. The presence of Cu and Sn alloys elements confirms significant attrition of contact surfaces of the tooth flanks of the gearbox worm wheel. Other measured values are specified and evaluated in [3].



Operation mode 1 Operation mode 2

Fig. 9 Particle identification – traces of bronze

5 Conclusion

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 characteristics 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 can 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 on durability;
- assessment of individual components, mainly gearing, bearings, grease, chain wheel and chain.

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