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TEMPERATURE OF BEARINGS OF ROTATING MACHINES AS A RESULT OF VIBRATION

TEPLOTA LOŽISEK TOČIVÝCH STROJŮ JAKO DŮSLEDEK VIBRACÍ

Abstract

The article deals with the analysis of influence of vibration on temperature of sliding bearings. In this work, attention is paid to the basic principles of diagnostic measurements, such as methods of vibrodiagnostics and thermography used in the case of sliding bearings. The final part is elaborated on the basis of information from practice. Description of the measurement, data analysis and final interpretation of dependence of vibration on temperature are presented.

Abstrakt

Článek se zabývá analýzou vlivu vibrací na teplotě kluzných ložisek. V této práci se věnuji základním principům diagnostických měření, jako jsou metody vibrodiagnostiky a termografie praktikované na kluzná ložiska. Závěrečná část je zpracována na základě informací z praxe. Popis měření, analýza dat a závěrečné vyhodnocení závislosti vibrací na teplotě.

1 INTRODUCTION

One of parameters observed during the operation of sliding bearings is the temperature of the bearings or the temperature of oil in the bearings. If the temperature in the bearings exceeds a certain limit, not only lubricant degradation and lubricating capability deterioration may occur, but also properties of bearing lining may be affected unfavourably. This contribution observes the dependence of vibration on temperature of sliding bearings of turbogenerators by means of in-situ direct measurement.

2 VIBRATION MEASUREMENT

Using a vibration analyzer and data collector ADASH 4300 – VA3, data are collected and analysed either immediately in the course of in-situ measurement on a display of the analyzer or later in a PC.

The analyzer makes it possible to record statistical data (vibration total values, in the range of rms, peak, swing), further dynamic data in the form of time record, vibration spectra, transient phenomena. It records the measured data in units of velocity (mm.s^{-1}), acceleration (m.s^{-2}, g).

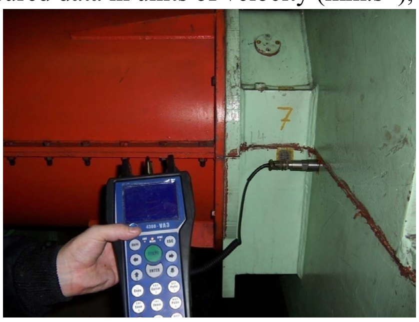

Fig.1 Location of measurement points

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Measurements were done on exposed parts of the machine (Fig. 1), which are readily accessible, to achieve maximum vibrational energy transfer to a sensor, and thus to minimize signal attenuation. The sensor is always located in the directions of maximum propagation of signal energy. For this reason, the coat of paint is removed in the areas of measurements points. If the surface is rough, steel plates having smooth surfaces are mounted on the object concerned.

If possible we measure vibration in the following there planes:

a) horizontal,

b) axial,

c) vertical.

3 MEASUREMENT OF TEMPERATURES AND TEMPERATURE FIELDS USING THERMOGRAPHY

Temperature, as one of parameters observed in diagnostics and maintenance, is a phenomenon characterizing a certain physical state of the object being measured. Thanks to the observation of temperature, manufacturing processes can be regulated, operating conditions of machines and equipment can be checked, overheating of electric connectors, cables and mechanical components (e.g. gearboxes) and construction and thermal properties of buildings can be diagnosed.

Thermographic measurement is the contact-less measurement of temperature. It utilizes infrared radiation for the safe measurement of surface temperatures of subjects. The behaviours of temperature and temperature distribution are observed and recorded by a thermovision camera and stored in the form of temperature pixels, a so-called thermogram. It is possible to measure even distant and inaccessible surfaces without putting equipment being diagnosed out of operation.

Thermographic measurement is carried out by means of an infrared camera system, which measures and displays infrared radiation emitted by the object. On the basis of reality, this temperature can be displayed and evaluated. To document the object being measured, an image – thermograph is recorded on a plug-in memory card. Thermographs are evaluated in a PC using software.

3.1 Principle of Thermography

Thermography utilizes the measurement of parts of the electromagnetic spectrum that is divided into several wave bands (Figs. 2 and 3).

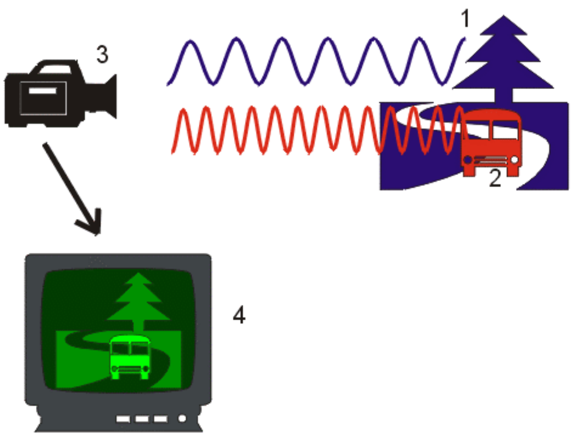

Fig.2 Principle of recording of thermal radiation of bodies in IR region

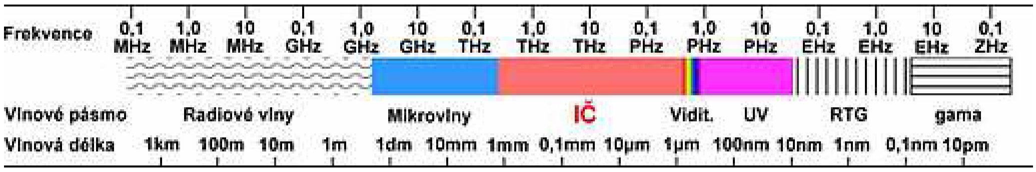

Fig.3 Electromagnetic spectrum

A thermocamera does not measure directly surface temperatures, but the surface temperature is calculated on the basis of measured infrared radiation and set boundary conditions. To the most important boundary conditions, surface emissivity belongs. The surface emissivity is a dimensionless number moving in the interval from 0 to 1 and expresses a ratio of energy emitted by the object at its given temperature to energy emitted by an ideal black body at the same temperature. The emissivity of ideal black body is 1.

4 MEASUREMENT AND PROCESSING

All measurements of dependence of vibration on temperature of sliding bearings were made on fully loaded turbogenerators in the power plant of the company ARCELORMITTAL Ostrava, JSC.

4.1 Vibration Analysis

All measurements were stored in the measurement instrument Adash for detailed analysis. Each measurement and each measurement point can be later analysed easily. These are data that are necessary for diagnostics to make correct decisions concerning the condition of the machine. This database also includes the whole history of the machine, and thus it is possible to find out in which parts of the machine problems have occurred, and to find out characteristics of them.

Subsequently, data were downloaded into a PC. After data import to the PC, frequency spectra of velocity and acceleration in measurement points were evaluated according to Figures 4 and 5. For one bearing, 6 frequency spectra were thus defined (Figs. 4 and 5).

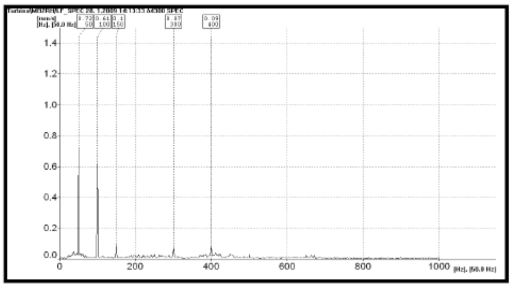

Fig. 4 Frequency spectrum of rms values of vibration velocity

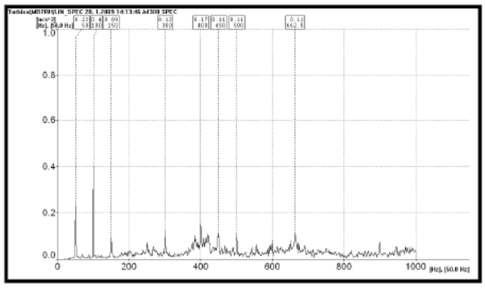

Fig. 5 Frequency spectrum of rms values of vibration acceleration

4.2. Temperature Analysis

Measured data are stored in a memory card of thermocamera Fluke for subsequent data processing. The analysis of temperature fields of sliding bearings is done by means of software SmartView 2.0. In software SmartView, a correct ambient temperature, emissivity and resolution for accurate identification must be set.

For the analysis of thermovision images, the following parameters of software SmartView were set (Fig. 6): high contrast colour palette, colour alarm disabled, emissivity of 0.95 and background temperature depending on the place where we just were; the temperature ranged from 38° to 55°C. As needed, the range was also changed. Furthermore, temperature cursors for easy temperature orientation can be utilized. Also the function “image in image” can be used for a quick orientation of image being measured. One has a possibility of utilizing items of menu, namely information on image, marker data, function of graph and its 3D display, histogram, and last but not least, a visible picture of the whole image.

After image processing, it is possible to begin reading the increased temperatures of the bearings.

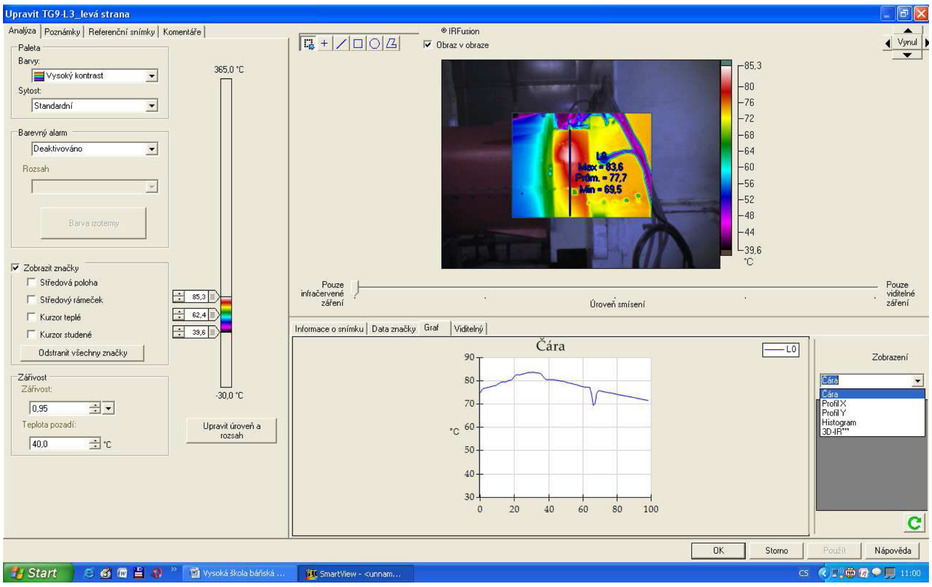

Fig. 6 Software necessary for the evaluation of thermovision images

5 FINDING THE DEPENDENCE OF VIBRATION ON TEMPERATURE

When evaluating the dependence of temperature of sliding bearings on vibration, we use the analysis of total values of vibration and frequency components in vibration frequency spectra as a basis. In the framework of analysis of vibration total values, measured data on bearing temperature and vibration in H,V,A in the horizontal, vertical and axial directions are processed to a so-called temperature rise factor $\zeta_{H,V,A}$ according to the following relation

$$\zeta_{H,V,A} = \frac{T_{ložiska}}{v_{H,V,A}}$$

where H, V, A stand for the relevant measurement planes.

The temperature rise factor ζ expresses a ratio of vibration [mm/s] on temperature of sliding bearings [°C]. Figs. 7, 8, 9 illustrate the dependence of this factor on vibration magnitude in relevant measurement planes.

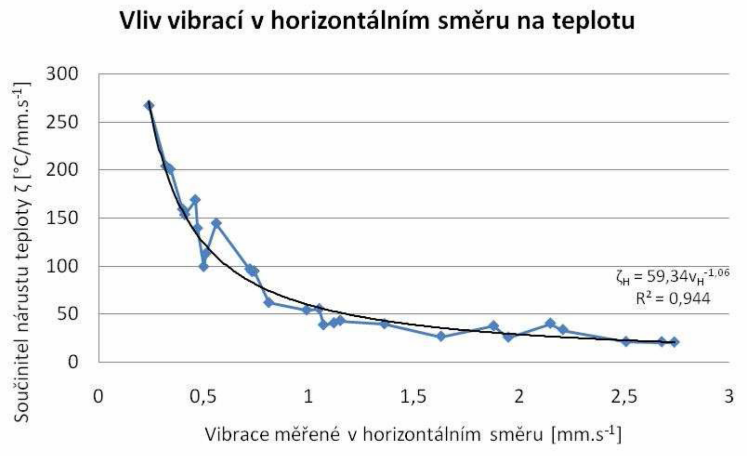

Fig. 7 Graph of vibration in horizontal direction

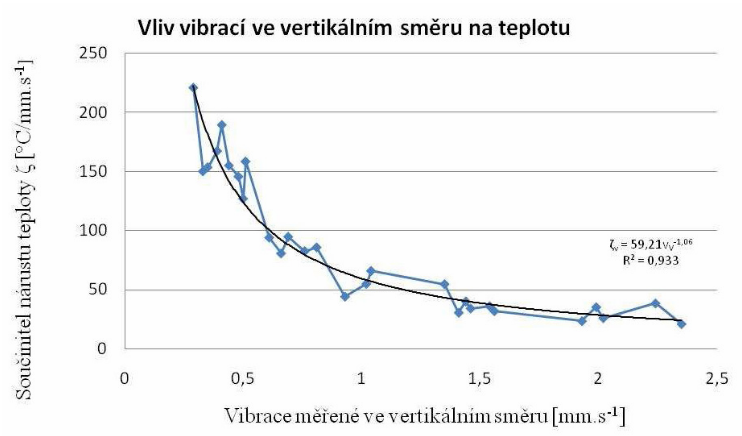

Fig. 8 Graph of vibration in vertical direction

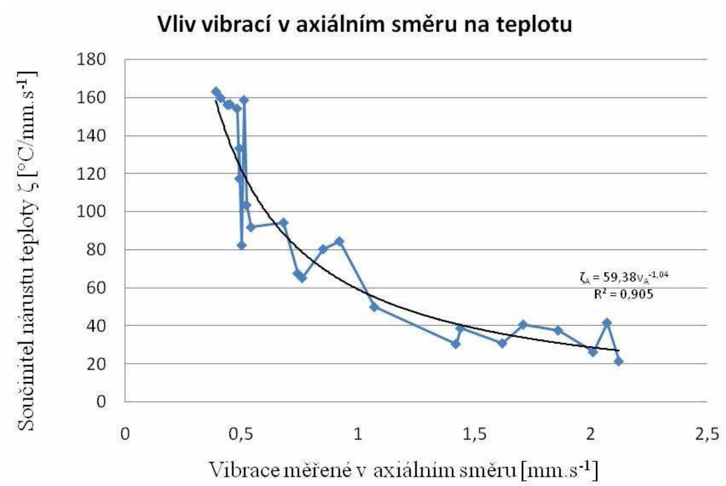

Fig. 9 Graph of vibration in axial direction

The factor is further compared with the total values of vibration in individual measurement planes of bearings measured. Subsequently, graphs for finding the dependence of temperature on vibration were constructed from the measured and the calculated values.

From the graphs, created using the Excel editor, expressing the dependence of temperature rise factor on vibration of sliding bearings (Figs. 7, 8, 9), the same exponential behaviour of a curve fitted to the analyzed data is evident, and subsequently the value of reliability described by the following relation is obtained:

$$\zeta_{H,V,A} = 59{,}3 . v_{H,V,A}^{-1{,}05}$$

The factor is sensitive to a change in either parameters, because in the case of change in total vibration, bearing temperature will change as well.

The graph given below in Fig. 10 represents the total values of vibration in the horizontal, vertical and axial directions. By the analysis of plotted data, any dependence of vibration on measurement direction was not found. Differences in these values are given by different stiffnesses of bearing boxes and different operating parameters of measured machines.

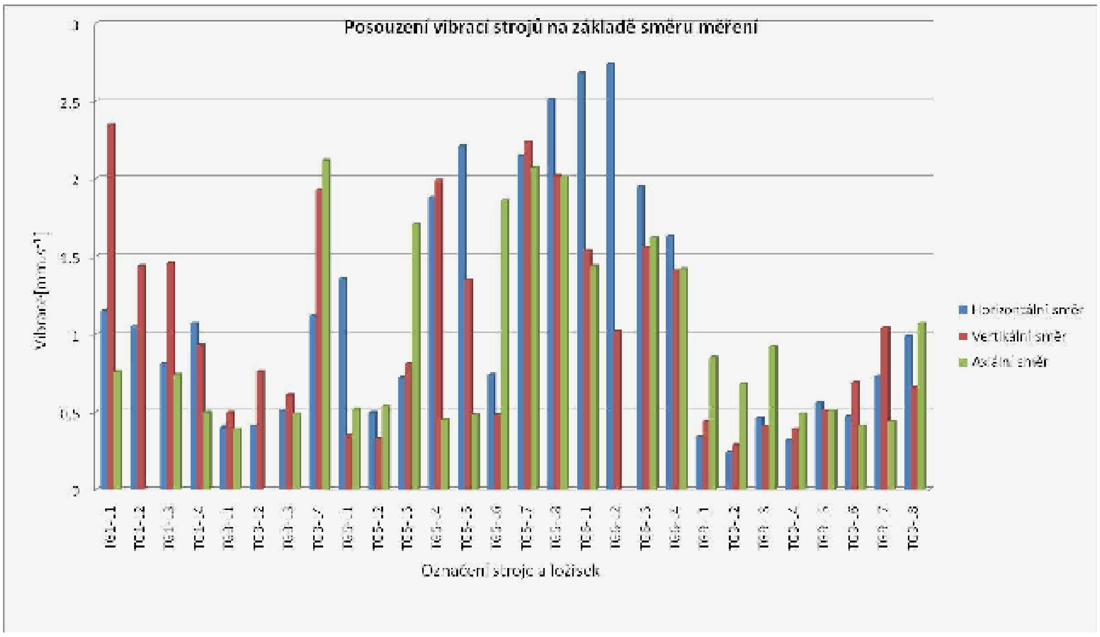

Fig. 10 Magnitude of total vibration measured in horizontal, vertical and axial directions

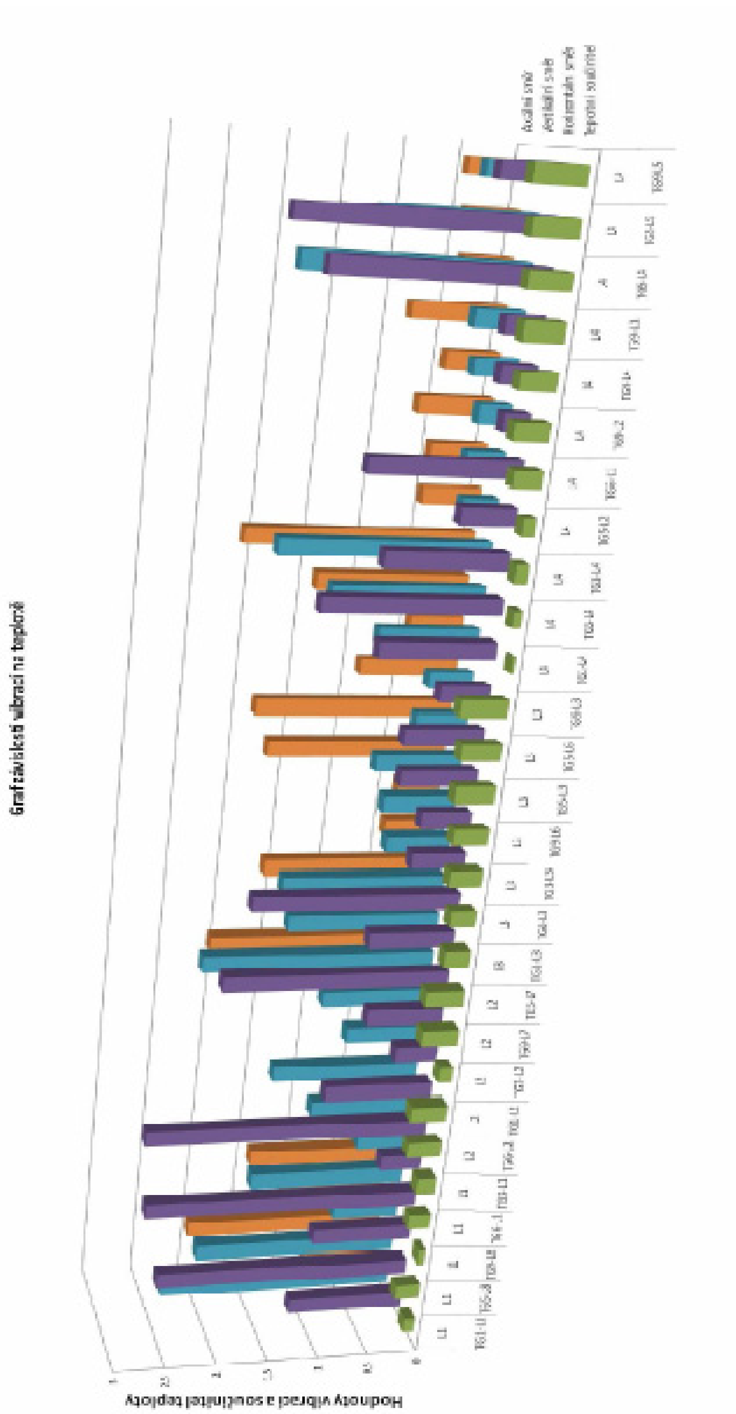

Fig. 11 3D graph of dependence of vibration on temperature

As follows from the detailed analysis of graphical representation of dependence of factor ΔT on vibration (Fig. 11), this dependence shows itself most sensitively in the horizontal direction of vibration measured.

6 CONCLUSION

The influence of vibration on temperature of sliding bearings expressed on the basis of factor $\Delta T = \frac{T_{lož} - T_{okoli}}{T_{lož}}$ manifests itself most sensitively in the horizontal direction of measurement. The dependence of temperature rise factor ζ on vibration of sliding bearings (Figs. 7, 8, 9) can be described in all directions of measurement by an exponential curve the shape of which is for all the measurement directions given by the equation given below

$$\zeta_{H,V,A} = 59{,}3 . v_{H,V,A}^{-1{,}05}$$

This factor is sensitive to a change in either parameters, because if any change in vibration total values occurs, bearing temperature changes as well and vice versa.

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