XVII IMEKO World Congress
Metrology in the 3rd Millennium
June 22–27, 2003, Dubrovnik, Croatia

ROTATING MACHINES PARTS AND THEIR VIBRATION CONTROL

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Abstract – The development of new aggregates of mobile machine aims at the reduction of production and operational costs and, at the same time, at the increase of transmitted power when a sufficient reliability is provided.

Simultaneously, the real operational safety concerning maximum permissible stress is also rescued. This results in necessity of further more exact methods of design and strength control of aggregate elements.

Keywords: Vibration, gearbox, gearmesch

1. INTRODUCTION

Vibration signals from a simple epicyclical gearbox between a motor and compressor were used for all the controls presented. Higher up in the frequency range components originating from the tooth-mesh in the gearbox will be found and are in this context referred to as medium frequency components. They will be at a frequency corresponding to rotational speed multiplied by the number of teeth on the gear, and referred to as the tooth-meshing frequency.

Controls of vibrations and a consequent expression by means of the random magnitude characterised by a probability density present also a problem concerning the tooth gear reliability. It means that exact data concerning a loading spectrum are required.

This application note examines a particular set of measurements mainly in order to show what effect controls techniques have on the results obtained.

2. THE MEASUREMENT SYSTEM

A practical example of gearbox vibration frequency control is presented, which demonstrates the use of high-resolution frequency control using zoom FFT for diagnostic purposes. It is intended to show how to get and interpret good results from control, with particular reference to points, which arise gearbox applications.

Vibration signal from a simple epicyclical gearbox between a motor and a compressor were for all the controls presented.

A schematic drawing of an electric motor-driven gearbox, driving a ball-mill shows Figure1.

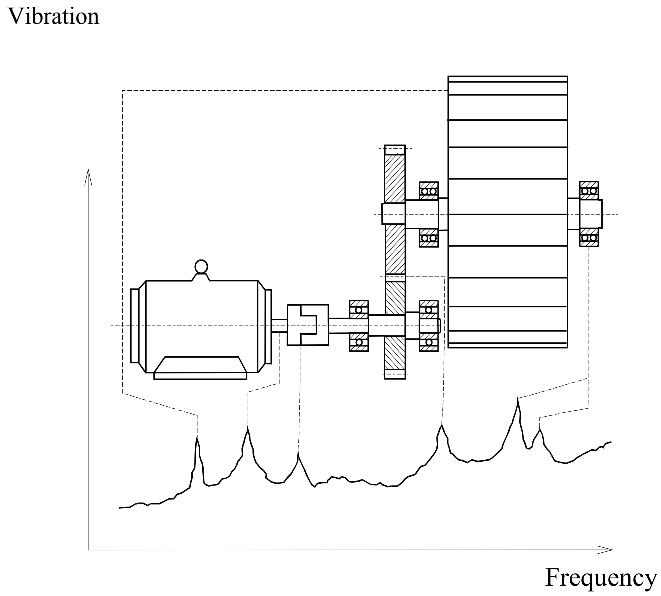

Fig. 1 Schematic drawing of an electric motor-driven gearbox, driving a ball-mill.

Vibration signals were recorded on site with instrumentation tape recorder and analysed on FFT analyser, using digital cassette recorder f or storage of analyses and digital data X-Y recorder to draw the grapes.

A spectrum made with FFT analyser was delivered with the gearbox, and after installation this was compared with a series of measurements made on the site to cheek for correct installation. Their measurements were made using a different resolution, in fact on a variety of analysis equipment.

The various results were sufficiently different to cause concern, but many of the differences in the results obtained originate in the differences between the analysis methods used.

It is necessary to understand the rezones for the apparent differences to make good measurements on signals from gearboxes.

In this unit a synchronies motor running at a nominal 0,42 r.p.s and the output from the sun wheel drives a compressor at a nominal 200 r.p.s drives planets.

3. INFLUENCE OF DISTORTION

Due to the transmission of torque, all parts of the gearbox are distorted and this affects also the meshing conditions of the gear. The changed meshing conditions may result in an increased noise, higher stress of the gear and, consequently, its shorter life in bending and contact, as shown in Figure 3.

The resultant mutual position of elements of the gear under loading is given by the sum of impacts of partial distortions.

The partial distortions may include:

- distortion of toothed wheel bodies,
- distortion of shafts,
- distortion of bearings,
- distortion of internal parts of the gearbox under bearings,
- distortion of the gearbox itself.

A new and healthy gearbox will clearly exhibit this frequency, but not just by it self. Due to mechanical loading the teeth will deflect, but they will deflect differently depending on how many teeth there are in mesh.

This is indicated in Fig. 2a. A simplified time signal from a new gearbox is shown containing not only the tooth-meshing frequency, but also it higher harmonic.

When the gearbox wears, the gear profile will gradually change due to sliding between two teeth in mesh at any point except at the pitch point, Fig. 2b.

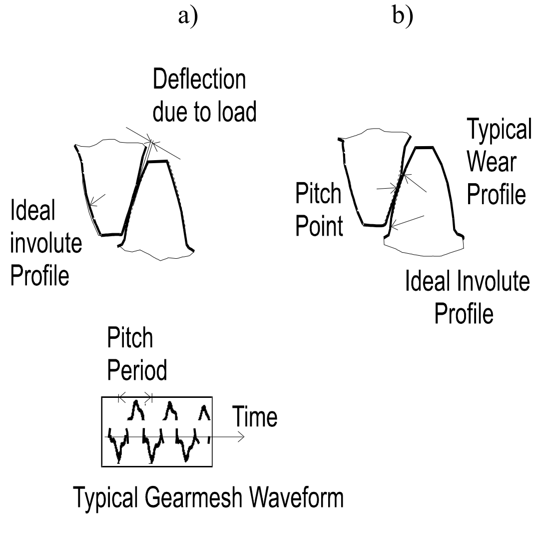

Fig. 2 Deflection of gear teeth in mesh together with a simplified time history from a new gearbox (2a). Changes caused in the teeth profile caused by wear (2b).

It is very difficult to determine mutual positions of elements of the gear only on the basis-calculated distortions. It is, therefore, necessary to have measured values of distortions as a starting point.

The measured values of distortions for all measured points are to be processed statistically into dependencies which embody regular properties of the measured distortions related to the torque and governing deflections which reflect random properties of measured distortions.

When the problem is approached from a statistical point of view, the following requirements have also to be satisfied when the measurements are carried out:

- the measurements should be taken at least three at levels of loading,
- when the measurement is carried out at a load level, it has to be repeated both under load and unload conditions,
- for each loading at least 15 values of distortions from the measured point should be taken.

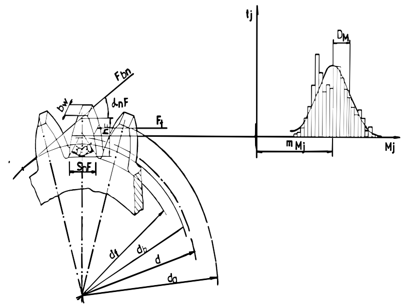

Fig. 3 The power conditions in the root of tooth

The character of the dependencies can be seen in Figure 4. The influence of distortions on the strain in the root of tooth can be represented by an arrangement of dependencies between the strain and torque, or in the strength calculation by means of lowering the fatigue limit and increase of the fatigue curve exponent.

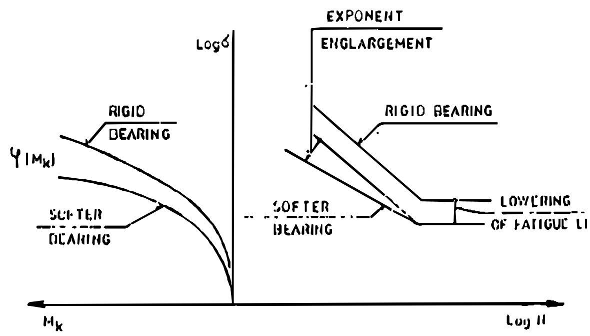

Fig. 4 Influence of distortion on the tooth system

4. A WAY OF THE VIBRATION CONTROL

Figure1, shown a scheme of the used was testing system. The signal of the gear vibration was recorded both digitally and graphically.

By means of a control of the vibration for simulated operating conditions we selected a sample to meet the required life of the testing gear system. The sample takes into consideration all the working activities which are characteristic for any operation of the mobile machine aggregate during the required life of its transmission section.

The basic values of the loading sample sets served as input data for the WMVM programmed , (Vavro, 1992), which enables the processing of statistical characteristics of the set as: a correlation function, a power spectral density and, further, a calculation of a distribution function, probability density, a function of the phenomenon occurrence intensity and characteristic life expressed by means of a function of failure-free probability for reliability estimation.

The output data expressing one of the statistical characteristics of loading in a graphical way can be seen in Figure 5.

It is a dependence of the reliability estimation expressed by means of the function of failure-free probability for the particular testing system.

Weibull's model, (Weibull, 1951), can serve a theoretical point for further solution. The dependence between the loading process of the testing system and life N_f, has to be extended by a variable R, which is a numerical guarantee in a form of probability:

$$R(N_f) = \exp.-(N_f - N_{min} / N_{sig} - N_{min})^{k} \qquad (1)$$

where: N_{min} is a minimum of the longevity,
N_{sig} is a modal value of the longevity,
k is a parameter of distribution.

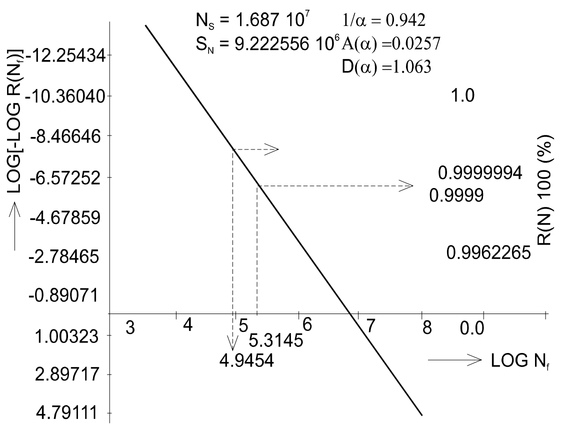

Fig.5 The graphical function of failure-free probability

The determination of the parameters k, N_{min} , N_{sig}, are achieved by the moments numerically.

Common value of n-th moment for variables

$(N_f - N_{min}) / (N_{sig} - N_{min})$ is:

$$m_n = \Gamma(1 + n/k)$$

The first and second central moments are:

$$m_1 = \Gamma(1 + 1/k)$$

$$m_2 = \Gamma(1 + 2/k) - \Gamma^2(1 + 1/k)$$

The coefficient of obliquity is definite with second and third central moment:

$$m_3 / (m_2)^{3/2} = [\Gamma(1 + 3/k) - 3\Gamma(1 + 2/k).\Gamma(1 + 1/k) + \Gamma^3(1 + 1/k)] / [(\Gamma(1 + 2/k) - \Gamma^2(1 + 1/k))]^{3/2} \qquad (2)$$

If we return to original variable N_f , the first moment is a reply to estimate the moment for basic random selection:

$$m_1(N_f) \cong N_S \qquad (3)$$

where: N_S is a middle value of longevity

The dispersion of original variable N_f may be expressed in second moment and the estimate of moment is:

$$m_2(N_f) \cong S_N^2 \qquad (4)$$

where: S_N is the standard deviation.

The coefficient of obliquity of variable N_f may be expressed in second and third moment and the estimate is:

$$m_3(N_f) / m_2(N_f)^{3/2} \cong (n^2 / (n-1).(n-2)).$$
$$.((N_S^3 - (3N_S^2).N_S + 2N_S^3)) / S_N^3 = $$
$$= B(k) \qquad (5)$$

From the second moment and eq.(4) is:

$$S_a . D(k) = b^{1/k} \qquad (6)$$

From the first moment and eq.(3) is:

$$N_S - (S_N . D(k)) . C(k) = a \qquad (7)$$

The values of function B (k), C (k) and D (k) which achieves eq.(2), are introduced for the practical application in eq.(1) for variables 1/k .

With parameters of distribution, we may define the result by the statistical curve of longevity, which in a form of probability characterised the longevity form eq.(1) :

$$\ln(-\ln R(N_f)) = k[\ln(N_f - a) - \ln b + \ln\ln e] \quad (8)$$

5. CONCLUSIONS

The results obtained from loading of the testing system show that the methodology selected is correct and offers possibilities for further generalisation.

It is obvious that a sample of the loading set can be arranged in compliance with user's requirements and it is also possible to assess expected reliability that may be achieved for any case under changed conditions.

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Acknowledgements:
The authors expressed there thanks to Slovak Agency for Research and Science for its support of this work (grant 1/9413/02).