DEFECTS DETECTION IN GEAR USING DIRECT SPECTRUM ANALYSIS OF VIBRATION

ОБНАРУЖЕНИЕ ДЕФЕКТОВ В ЗУБЧАТОМ КОЛЕСЕ, ИСПОЛЬЗУЯ АНАЛИЗ ПРЯМОГО СПЕКТРА ВИБРАЦИИ

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Abstract: *This article provides a way to detect fatigue cracks in welded gearwheel at reinforcement dimensional cutting mechanism (flying shears) of rolling mill by analyzing the direct spectrum of vibration. This method is progressive and allows through regular vibration measurements to assess equipment condition and predict performance.*

Keywords: *FLYING SHEARS, ROLLING MILL, MONITORING, DIRECT SPECTRUM, SENSOR, VIBRATION DIAGNOSTICS.*

1. Introduction

Modern industry development produces the promoted requirements to reduction gearboxes reliability. Therefore on most industrial enterprises, possessing some park of gearboxes the vibration monitoring and diagnostics systems are implemented. Different firms can make these systems, which could have different configuration, but task for them one is looking after a working equipment, to expose the already present defects of gearing (basically gears, gearwheels, rolling bearings and journal bearings), and also to make the equipment capacity prediction.
Machines and equipment condition monitoring is one of the most effective methods to decline accident rate and increase technical systems reliability. For the reduction gearboxes vibration monitoring is very important, because in the process of condition irreversible change there always is a chain of defects and even one of them really changes the equipment vibration background.
The monitoring and diagnostics systems can be both stationary and portable. Functionally these systems do not differ practically. A difference is only in mobility. Application of these systems is gives another very important advantage: due to these systems, equipment repair conducted now on the real condition only.
Using the monitoring and diagnostics systems could easy to detect fatigue cracks in welded gearwheel at reinforcement dimensional cutting mechanism (flying shears) of rolling mill by analyzing the direct spectrum of vibration. This method is progressive and allows through regular vibration measurements to assess equipment condition and predict performance.

2. Nature of gear's vibration

The most frequently used diagnostic parameters of parallel-shaft reduction gearbox is shown in Table 1. [1] Table1.

Nr.	Type of defect	Diagnostic features	
		Vibration direct spectrum	Envelope spectrum of high frequency vibration
1	Pulsation of driving shaft	f_{rot1}, $kf_z \pm f_{rot1}$	kf_{rot1}, $k \leq 3$
2	Pulsation of driven shaft	f_{rot2}, $kf_z \pm f_{rot2}$	kf_{rot2}, $k \leq 3$
3	Distortion of driving gear	$2f_{rot1}$, $kf_z \pm 2f_{rot1}$	$2kf_{rot1}$, $k \leq 3$
4	Distortion of driven gear	$2f_{rot2}$, $kf_z \pm 2f_{rot2}$	$2kf_{rot2}$, $k \leq 3$
5	Teeth defect of driving gear	kf_{rot1}, $kf_z \pm kf_{rot1}$	kf_{rot1}, $k>5$
6	Teeth defect of driven gear	kf_{rot2}, $kf_z \pm kf_{rot2}$	kf_{rot2}, $k>5$
7	Toothing defect or toothing grease defect	kf_z	-
8	Defect of bearing	***RMS*** *increasing (medium frequency* ***MF****)*	*the appearance of shock pulses on* ***MF***
9	Bearing grease defect	*RMS increasing* ***(UHF)***	*the appearance of shock pulses on* ***UHF***

Note: f_{rot1} - rotating frequency of driving shaft, f_{rot2} - rotating frequency of driven shaft, f_z - tooth frequency, ***RMS*** - root mean square vibration, ***MF*** - medium frequency, ***UHF*** - ultra high frequency, $k=1,2,3,4,\ldots$ [1]

3. Industrial vibration monitoring and diagnostics systems.

In world industry is used the enormous amount the rotating equipment vibration monitoring and diagnostics systems of different firms.

2.1. Stationary systems.

The stationary monitoring system is needed above all things for a multimode strength equipment, guided an auxiliary personnel. Exactly personnel errors is more frequent than all are the defects multiplying reason of the guided equipment, which it must find out practically instantly (for a few turns of rotor) for failure timely prevention.
On Figure 1 the simplified structure of the vibration monitoring and diagnostics stationary system is shown.

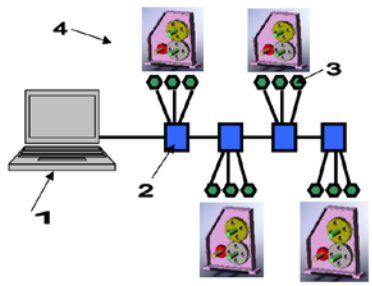

Figure1 *Structure of the vibration monitoring and diagnostics stationary system.*
1 - The computer with special software; **2** - The Signals transformation card in digital form; **3** - Vibration sensors; **4** – Supervising equipment.

2.2. Portable systems.

Equally with the stationary systems wide application is found the portable monitoring and diagnostics systems (Fig. 2), equipped by expert or automatic troubleshooting routines. These systems can be divided into two basic classes are the extended monitoring systems, including with the expert programs, it means, that diagnostics is executed by the prepared expert, and mass diagnostic systems with the standard rotating equipment automatic condition diagnostic and prediction programs. Such system consists of:

- A portable device (devices), providing vibration measuring and analysis in heavy industrial terms;
- Computer with the program of monitoring, containing a database and fulfilling operations row of signals analysis and processing of analysis results;
- Expert or automatic diagnostic program, processing obtained diagnostic information.

***Figure 2**. Vibration portable set on the vibration analyzer СД-21 base, produced by company BACT (Russia) [2]*

4. Description of the equipment which was under control.

Method of fatigue cracks detection in welded gears and gearwheels with the help of the direct spectrum of vibration analysis can be applied in the study of all gears. This method has been tested on flying shear of steel plant's rolling mill.

Flying shears is a machine for cutting the continuous length rolled product that does not require a stop rolling. These shears (Fig.3) are composed of housing, a drive shaft with a driving gear (4) and the working shafts with the driven gear wheels (5 and 6) on which are mounted blades for cutting the reinforcement. Positions 1, 2 and 3 are places for vibration sensors mounting.

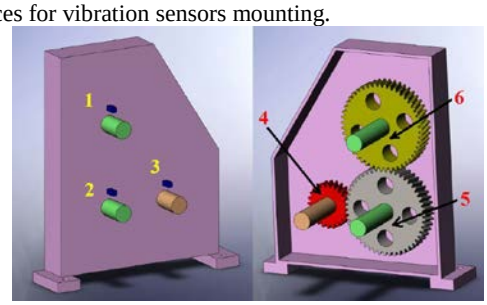

***Figure 3**. The scheme of flying shear under control.*

For a complete research on the state of flying shears, it is necessary to organize the 6 points of vibration control (Fig.4).

***Figure 4**. The scheme of the 6 points of vibration control.*

Reading data from the sensors is occurring remotely. To do this you must create a remote monitoring system (Fig.1)

The most effective way to monitor the status of welded gearwheels is direct spectra of vibration analysis, which is necessary to carry out about once a week.

5. The detection of a fatigue crack in a welded gear

Here is an example of the real detection of a fatigue crack in a welded gear. In comparison are given the spectrums: before appearance of cracks (black graph), when the crack has been formed (red graph) and after repair (blue graph) (Fig.5).

Since a crack formed in the top gearwheel, and the spectra are also obtained at the control point #5.

The direct spectrum (Fig.5), was obtained under the following conditions: measuring units: dB (A); cutoff frequency: $F_b = 800\,Hz$; spectrum lines - 1600 averages - 8.

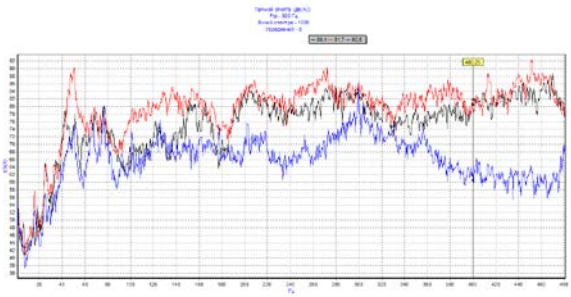

***Figure 5**. Direct spectrum – (dB(A)), $F_b = 800Hz$, Spectrum lines: 1600, Averages: 8.*

As seen from obtained direct spectrum, the red spectrum (corresponding to the already formed crack) has a clear excess of the level ranges from 40 to 180 Hz, from 240 to 280 Hz, from 330 to 390 Hz and so on.

In order to reduce the probability of error, it is necessary, after detecting a deviation in the spectrum, to conduct repeated measurements. And only on the basis of repeated measurements, to make conclusions about the state of the equipment.

One of the cracks, which was detected by analyzing the direct spectrum of vibration shown in Fig.6.

***Figure 6.** The photo of the real welded gearwheel, with the cracks.*

As can be seen, due to this method, was sufficiently prevented a serious accident and were spared a lot of resources.

Conclusions

Vibration diagnostics of metallurgical or any rotating equipment is very important. This makes it possible to significantly reduce the costs of the equipment, to extend the term of its operation, as well as improve the quality of products. The company must have a diagnostic service that provides vibration monitoring and forecasting the state of the equipment. It is also necessary to establish the system of remote monitoring equipment. The cost of equipment and software for the diagnosis is usually recouped within a year at its regular use.

Literature

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[2] http://www.vibrotek.ru/russian/