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Condition Monitoring and Diagnostics of Rolling Bearings of High-voltage Electric Motors during Their Operation

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ABSTRACT

During the operation of high-voltage motors at hazardous industries, it has been proved that, bearings do not work out the operating time assigned by the manufacturer. The report covers issues on the condition monitoring and diagnostics of the defects in rolling bearings of a high-voltage motors during theirs operation, defines the causes of a premature emergence and development of the defects as well the measures worked out for ensuring safe and prolonged operation of the rolling bearings of high-voltage motors.

The collection and analysis of vibration parameters of electric motors during their operation is performed by means of the real-time condition monitoring system. A spectral matrix of defects frequencies has been developed on the basis of the analysis of rolling bearings vibration source. The spectral analysis of vibration parameters showed the presence of frequency components that reveal defects of the bearings. As a result of vibration analysis, a number of defects in the rolling bearings have been revealed and proved during the motor repair and inspection of its bearings for likely defects.

The condition monitoring and diagnostics of the rolling bearings during the operation of the electric motors have allowed:

- timely decommissioning of the motor with the damaged bearings as well as prevention of accidents which may have occurred with the unit that dispenses fire explosive products;

- detection of the principal cause of frequent failures of the rolling bearings, which is application of the bearings in inappropriate working conditions and non-fulfillment of auxiliary measures recommended by manufacturers of bearings to prolong lifetime of the equipment;

- submitting of recommendations on use of the bearings in the motor.

Keywords: rolling bearings, high-voltage motors, monitoring, diagnosis, vibration, real-time monitoring

1. INTRODUCTION

The bearing is the main element determining the operability of all units because operating life of the unit is limited by reliability of the bearing.

The use of condition diagnostics instruments at all stages of the equipment life-cycle (manufacturing, installation, operation, repair) enables timely detection of mistakes and defective parts, parts with critical condition (or close to critical). The use of such instruments also enables to take action on the increasing of equipment reliability.

2. THE EXAMPLES OF EQUIPMENT DIAGNOSING

The paper is devoted to the diagnostics of equipment and rolling bearings during their operation.

Methods of diagnostics of rolling bearings in different frequency bands of audio-frequency range and supersonic range enjoy wide application (Kostyukov, V.N. 2002).

Vibration acceleration measurement in the frequency band up to 10-12 kHz enables not only condition control of bearing units but also condition control of an overall mechanism. In a certain frequency range a general vibration level or frequency band levels are standardized and the equipment is sorted according to its condition: 'TOLERABLE', 'ACTION REQUIRED', 'INTOLERABLE' (State standard of Russian Federation R 53565-2009. 2010).

For condition detection of units and their assemblies, it is expediently to control changes of vibration parameters.

To determine validity of used methods of diagnostics vibration acoustical characteristics of high-voltage electric motor of type MAFE560M2, which operates on the unit producing benzene hydrocarbons, have been analyzed.

Before analysis technical information on the engine construction has been collected, spectral frequencies, on which defects of bearings, electric motor and mounting are showed up, have been analyzed. In addition, a spectral matrix has been constructed.

During the research RMS values of vibration acceleration (Ae), vibration velocity (Ve) and vibration displacement (Se) were under control. In addition, vibration signal spectrums and their envelopes have been analyzed. Vibration characteristics of an electric motor has been analyzed by the measurement of vibration in three courses (X - horizontal, Y- vertical, Z - axial) from the direction of a front end bearing and tail bearing of an electric motor. Spectral components of a vibration signal were analyzed as well.

The measured parameters of a motor vibration (TABLE 1) show that according to a general level of RMS values of vibration parameters (vibration acceleration, vibration velocity and vibration displacement) the motor condition corresponds with 'TOLERABLE' category (State standard of Russian Federation R 53565-2009. 2010).

TABLE 1. The measured parameters of a motor vibration

Type of bearing	Direction	Ae, m/s²	Ve, mm/s	Se, μm
Tail bearing	X	2,26	0,92	0,72
	Y	2,37	3,10	5,77
	Z	11,30	1,63	2,11
Front end bearing	X	1,83	1,04	1,09
	Y	2,25	2,47	6,23
	Z	2,20	0,63	0,83

The analysis of spectral components of vibration signals enabled to presume the following (concerning a tail bearing of an electric motor):

- In vertical direction (Y) in a vibration acceleration spectrum range up to 1 000 Hz there are a number (in the region of 15) of harmonics of a rotational frequency F_{ro}. This fact indicates a high probability of the bearing unit loosening. The harmonic of the defect frequency of the bearing outer ring "BPFO" (277 Hz) reveals an early stage of development of defect of the bearing outer ring (FIGURE 1a). In vertical direction (Y) in a vibration acceleration spectrum range more than 1 000 Hz a predominant harmonic is the frequency of passing of stator slots F_{st} modulated by a binary supply frequency. That may reveal electromagnetic defect of a motor – magnet gap eccentricity (FIGURE 1b).

- In a vibration velocity spectrum of a tail bearing of the motor the peak of the second harmonic of rotational frequency (99.2 Hz) is more than twice as large as the peak of the first harmonic of rotational frequency (49.6 Hz), which may show that a tail bearing has been installed with axis shift. In addition, this spectrum contains 8 harmonics of a rotational frequency, which indicates the loosening of a tail bearing unit (FIGURE 1c).

- In a spectrum of envelope of a tail bearing signal in horizontal direction a binary supply frequency predominates (100 Hz), its harmonics (200 Hz, 300 Hz) are present as well (that indicates a high probability of an electromagnetic defect of the motor) and the frequency of defect of "FTF" retainer (19.9 Hz) and its "2FTF" harmonics (38.7 Hz) and the frequency of defect of "BPFI" inner ring (414.1 Hz) (FIGURE 1d).

Regardless of the fact that according to the general level of vibration parameter RMS values (TABLE 1) the motor condition corresponded with 'TOLERABLE' category, the assembly was decided to stop and detect faults of its parts in order to confirm the diagnosis (based on a vibration analysis) indicating the following:

- a tail bearing has growing defects of the retainer, outer and inner rings;

- a tail bearing has been installed with axis shift, a tail bearing unit is loosen;

- the motor has an electromagnetic defect.

Fault detection of electric motor assemblies showed the following:

- on the outside surface of the outer ring of a tail bearing there are dark traces indicating that the bearing rotated in end shield. In addition, it shows that there is an electric discharge lesion focus (FIGURE 2a, 2b).

- on the inner surface of the cone there is a dark strip wide enough to confirm that the inner ring and the shaft of an electric motor are not in full contact throughout the whole area (FIGURE 2c). On the inner surface of the inner ring there is an electric discharge lesion focus as well. On the raceway of the inner ring there are two apparent narrow rings of inceptive defects. Fourteen rollers each have roll traces.

After the bearing dismantling four clear crosscut lines, which denote the layout of rollers in lower position, have been detected on a work surface of the outer ring (FIGURE 2d). This fact allows us to conclude that for a long time the unit was held in reserve without rotor cranking.

Thus, electric motor bearings have been changed, bearing shields and stator have been repaired. The lubrication has been changed as well.

This case confirms that vibration acoustic analysis is a very sensitive method of equipment diagnostics, which enables detection of defects on early stages of their development.

3. CONCLUSION

1. The used method of machinery condition monitoring according to RMS values of vibration acceleration, vibration velocity and vibration displacement as well as diagnosing ones according to amplitude spectrum of vibration and selection of envelope spectrum enabled detection of electric motor failures at their early stage.

2. This method of diagnostics enables detection of vibration signal spectral components connected with the construction and condition of the unit in whole, not just rolling bearings..

3. The use of the described method enables standardization of a general vibration level or frequency band levels as well as sorting of equipment according to its condition: ‘TOLERABLE’, ‘ACTION REQUIRED’, ‘INTOLERABLE’ (State standard of Russian Federation R 53565-2009. 2010).

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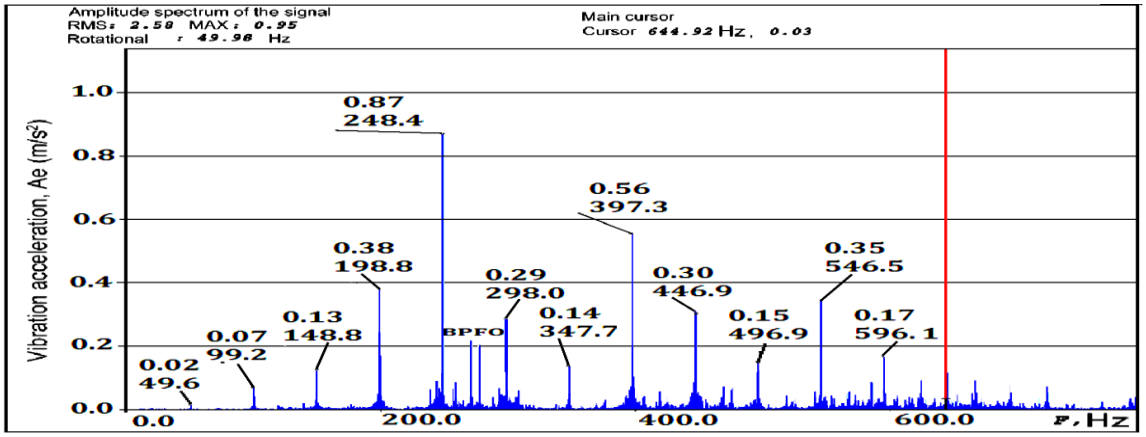
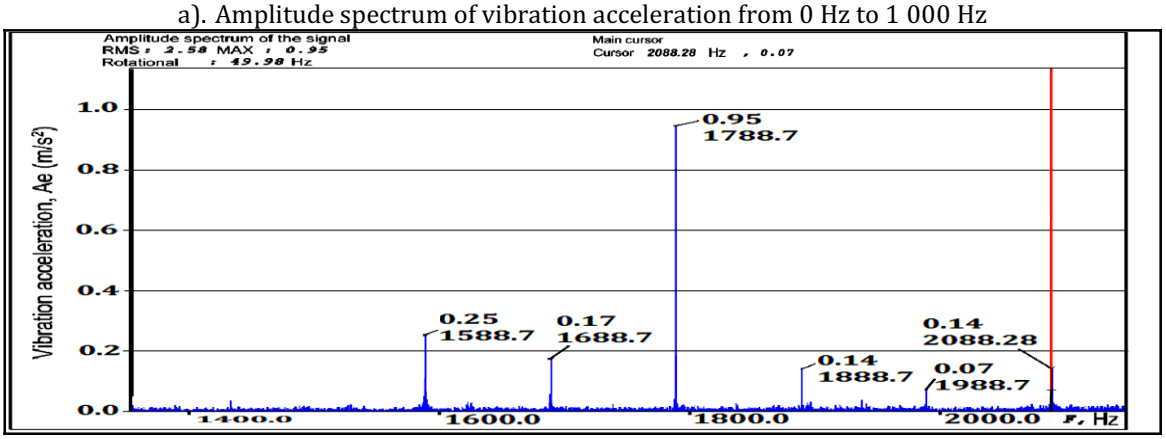
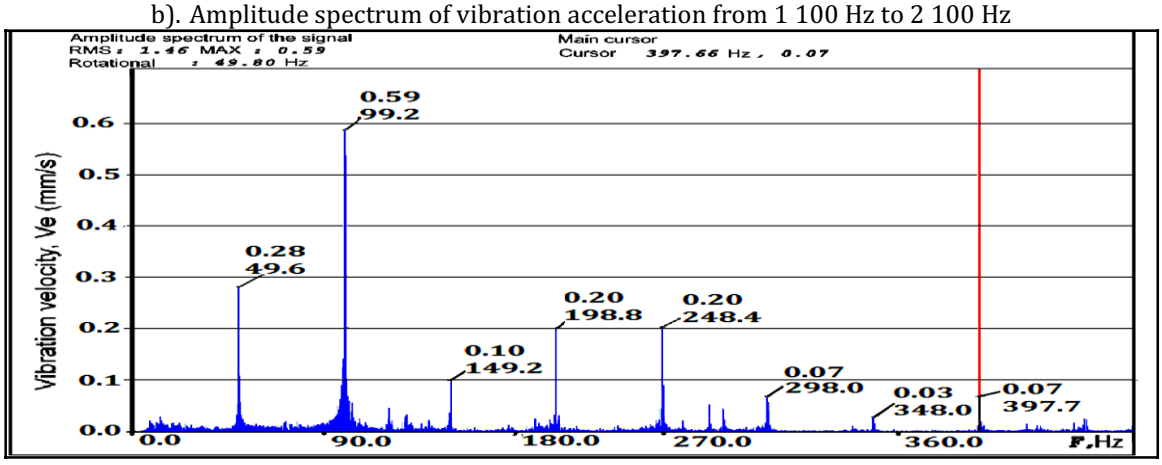


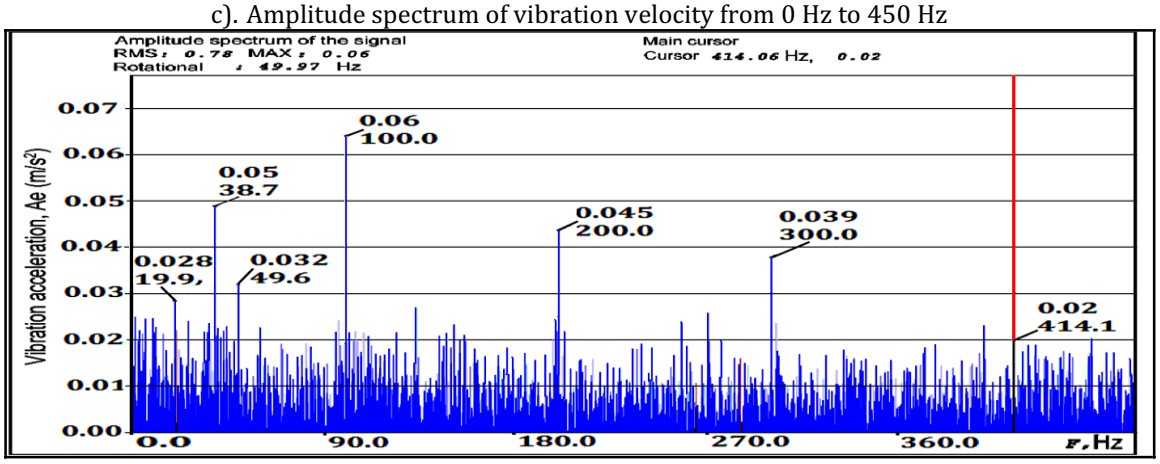
a). Amplitude spectrum of vibration acceleration from 0 Hz to 1 000 Hz



b). Amplitude spectrum of vibration acceleration from 1 100 Hz to 2 100 Hz

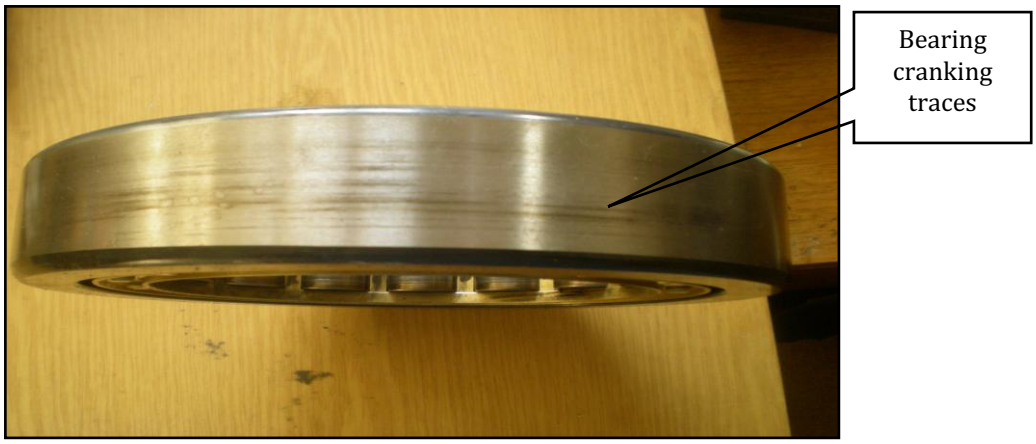


c). Amplitude spectrum of vibration velocity from 0 Hz to 450 Hz

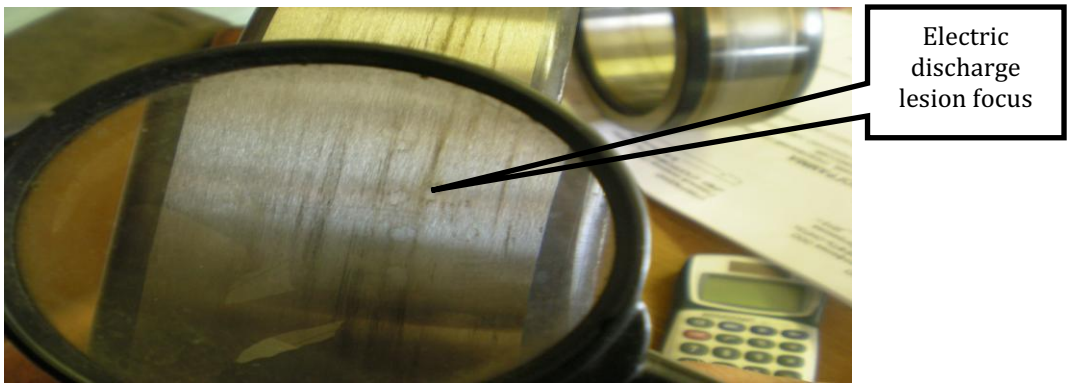


d). Envelope spectrum of a vibration acceleration signal from 0 Hz to 450 Hz

FIGURE 1. Spectra of the tail bearing of the electric motor

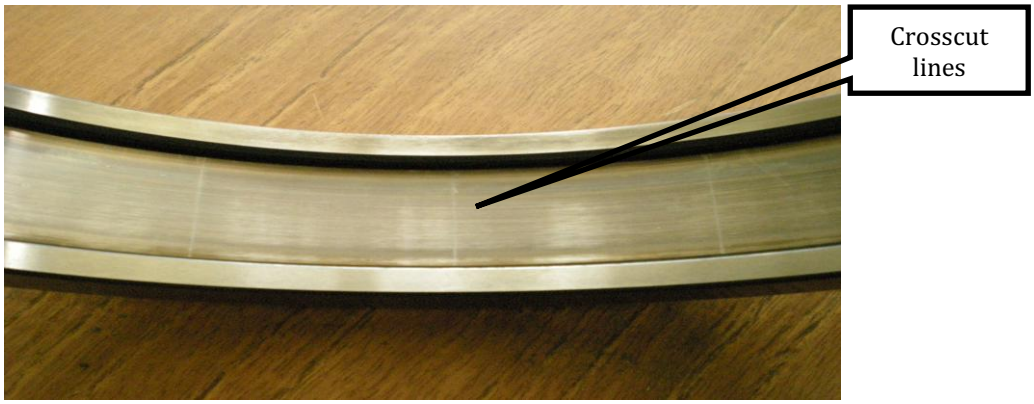


a) Outside surface of outer ring of electric motor tail bearing



b) Electric discharge lesion focus on the outside surface of outer ring

C) Inner surface of the cone of electric motor tail bearing



d) Inner surface of the outer ring of electric motor tail bearing

FIGURE 2. Photos of the tail bearing of the electric motor