IDENTIFICATION OF FAULTS IN ROLLING BEARINGS THROUGH VIBRATION AND SHOCK IMPULSES ANALYSIS

Mariana NICODIM[1], Horia GHEORGHIU[2]

Articolul are ca scop identificarea şi localizarea defecţiunilor din lagarele de rostogolire, din componenţa maşinilor-unelte şi a utilajelor dinamice industriale.

Cercetările experimentale sunt prezentate prin studii de caz unde se va demonstra că supravegherea maşinii-unelte şi a utilajului doar prin măsurari şi analize de vibraţii nu ar fi sesizat nimic anormal in funcţionarea lor. Folosind analiza FFT a impulsurilor de şoc s-a semnalat apariţia uzurilor în faza incipienta, cu mult înainte de apariţia vibraţiilor.

The purpose of the article is to identify and track faults in bearings as components of machine-tools and dynamic industrial equipment.

Following experimental research it was shown through case studies which demonstrated that monitoring machine-tools and the equipment just through measuring and vibration analysis nothing anormal would be shown. When using the FFT analysis of the shock impulses the appearance of wear in the initial phase was signaled, long before the appearance of vibrations.

Key words: vibrations, shock impulses, bearing, monitoring, amplitude spectrum.

1. Introduction

Following a complete and detailed analysis of the current status of research regarding vibration-diagnosis of machine tools and dynamic industrial equipment, it was noted that the rolling bearings present the highest failure rate.

From this perspective, the purpose of the article is not only to present solutions regarding fault diagnose in rolling bearings in optimum conditions and time, but also to anticipate the appearance of faults from early stages, offering the possibility to plan interventions in due time.

The article presents the results of measuring with a machine-tool analyzer and with a dynamic industrial equipment, thus emphasizing the promptness of the analyzer to capture the moment when the working conditions of the bearing are modified. Thus, a severe technical accident, which might produce production losses and large repairing costs, could be prevented.

[1]PhD. Student, Departament of Strength of Materials, University POLITEHNICA of Bucharest, e-mail: mariananicodim@yahoo.com

[2]Professor, , Departament of Strength of Materials, Faculty of Engineering and Management of Technological Systems University POLITEHNICA of Bucharest, E-mail: hgheorghiu@yahoo.com

The analysis of the technical state of machine-tools or dynamic industrial equipment by means of mechanical vibrations and shock impulses leads to reducing costs related to their maintenance and repair, but also those related to assembly stationing, through production failure, when they are part of a system [1]. In addition, identification and localization of faults due to vibrations and shock impulses leads to the elimination of useless operations of dismantling and checking components, also with benefic effects in reducing costs [2].

The article presents and emphasizes the manner in which mechanical faults in bearings, from machine tools/dynamic industrial equipment, manifest and are identified, in mechanical vibrations spectrum and SPM spectrum of shock impulses.

2. Description of the principle and method to identify faults through vibration and shock impulses analysis

A study was made to diagnose rolling bearings in machine-tools due to the fact that this assembly presents the highest rate of faults.

The measurements were made periodically with an analyzer, its purpose being to acquire information regarding vibrations coming from different points of the machine-tool and dynamic industrial equipment, stored for their analysis and diagnose.

The analyzer records, measures and analyzes shock impulses coming directly from the rolling bearing, since bearing deterioration represents the most common cause of bearing breakdown [1].

It acquires a sample of shock impulses signal, decomposes it by FFT (Fast Fourier Transformation) resulting in a SPM spectrum that emphasizes on the frequencies at which the impulses coming from the rolling bearing are manifested.

The main advantage of the shock impulses method is its specialization in tracing shocks produced when a ball/roll hits a faulty area on the ball groove and propagates in the metallic mass of the bearings' body.

The analyzer and the SPM shock impulses method are so sensitive that they measure the well-being state of the bearing, due to the fact that the device measures the thickness of the film of lubricant. Any change in the working conditions, which would lead to the thinning of the film (increase of bearing temperature, alteration of lubricant quality, diminution of clearance, axis decentration, increase unbalance, and so on), determines an increase in the level of the signal.

If necessary corrections are not made, wear begins, then pitting, thus vibrations will appear [3] – see figure 1, where:

- ❖ black represents the evolution of vibration amplitudes;

- orange represents the evolution of signal amplitude from bearing to seizing, if necessary correction methods are not taken;
- purple represents the evolution of signal amplitude from bearing to maximum life span, if corrections at moment T1 are made. But, if the necessary corrections are made in due time, the state of functioning comes back to the initial conditions, thus the bearing can be used up to the fatigue of the material, as close to 100% from its normal life span.

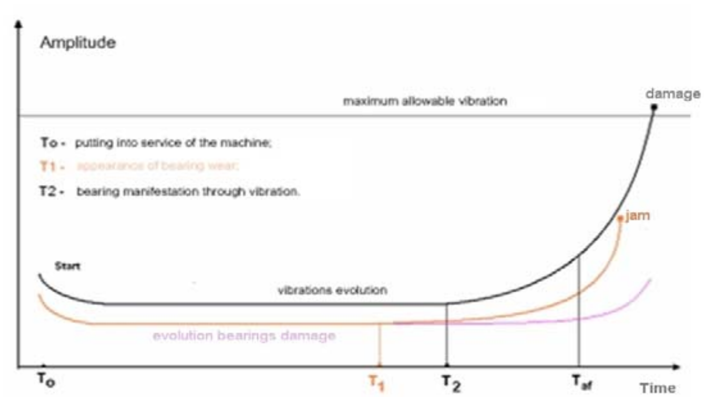

Fig. 1. The evolution of the state of the faulty bearing [3].

The SPM method of shock impulses emphasizes failures due to pitting, material fatigue and assembling errors, having the diagnose error under 10%. But, more important is the fact that the SPM method tracks the moment when the bearing working conditions change, changes that might lead to wear and pitting.

A sample of signal from a SPM transducer for shock impulses is analyzed according to FFT. This analysis provides a spectrum that is compared to the rotation frequencies of the bearings' components. Moreover, this can identify other sources of periodic shock impulses in the rolling bearings of the machine-tool (friction, shocks, etc.) [3].

The size of the shock impulse is quantified at a scale in decibels with values of dBm/dBc. This is a parameter by which the degree of bearing wear is evaluated. The quality of lubrication, thus the technical state of the bearing. LR/HR is a parameter that enables a more complete and exact evaluation of the technical state of the bearing.

3. Description of the solution to identify faults in rolling bearings of the machine-tool AFP 160-CNC

Any machine-tool vibrates while operating. The vibrations measured on the bearings are generated as follows: approximately 99% by dynamic forces that occur due to the movement of machine components, 1 % from shocks and 0.1% from friction forces [4].

The analyzer presents sufficient accuracy in collecting data. The spectrum of vibration and shock impulse is analyzed in order to diagnose the rolling bearings of the machine AFP 160-5CNC that generated them.

The machine characteristics are the following: column range X axis = 15 000 mm; frontal traverse Y axis = 5 000 mm; boring spindle Z axis = 1000 mm; ram W axis = 1 200 mm; speed range (adjustable continuously): max 2000 up to 2500 rpm for periods of working of 30 minutes up to 1 hour of the machine, in accordance to the conditions mentioned in the instruction manual of the machine; the power of the main engine = 60kW.

For the analysis of this spectrum, the software Condmaster is used in order to facilitate data analysis and interpretation.

A special transducer is used to collect vibrations data, its role being to take the spectrum of vibration and transform them in electrical information transmitted to the data collection system. This transducer evaluates vibration amplitudes and speeds or accelerations.

After the experimental tests, it was noted that wear appeared at the acting motor bearings after 2500 up to 3000 hours of operation.

All through the operation of the motor, the amplitude of the radial vibrations was maintained at relatively low values [5], [6].

Approximately during the middle of the interval, when the first signs of an increase in vibration amplitude were noted, the FFT analysis of the vibration signal has not shown any problem with the bearings (Fig. 2, a), but the FFT analysis of the shock impulse signal, coming from the second motor bearing has clearly shown components of frequency produced by a wear in the initial phase, from the outer tread – BPFO (Fig. 2, b).

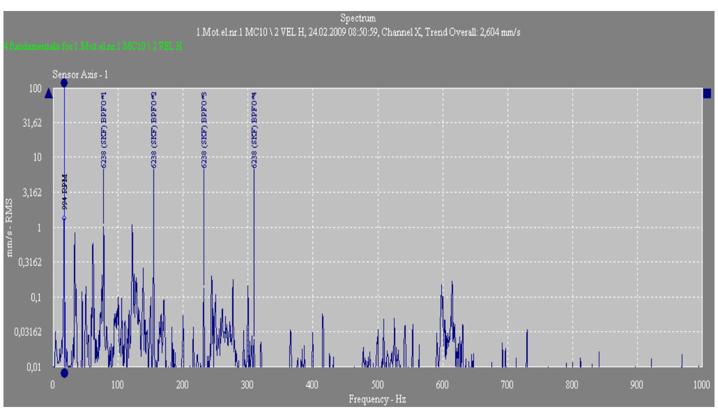

Fig. 2 a) The FFT analysis of the vibration signal

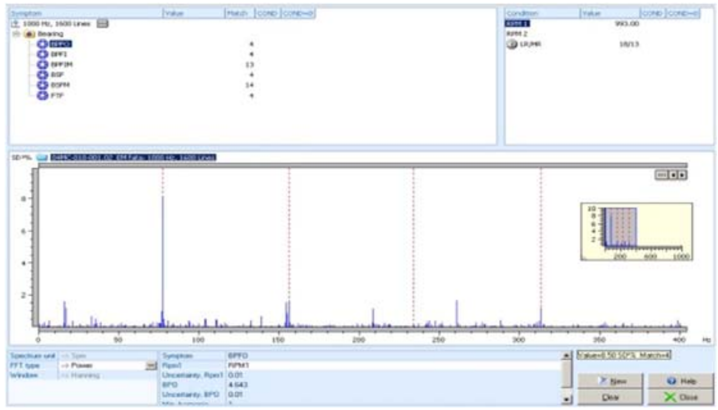

Fig. 2 b) The FFT analysis of the shock impulse signal

The FFT analysis of the vibration signals, just before the stop and replacement of the bearings has pointed out components of frequency between the range of 200÷400 Hz and the software CONDMASTER identified them as coming from wears in the interior and exterior rolling paths – BPFI, BPFO – see Fig. 3.

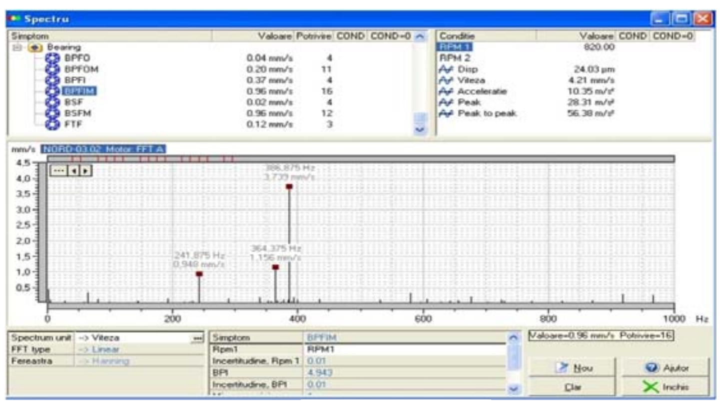

Fig. 3. Spectrum Analysis

After dismantling the rings presenting special wear, the rolling path looked like after a warp operation – see Fig. 4 (a and b).

After replacing the bearing behind the engine with a bearing of ceramic isolation, the phenomenon disappeared [7].

a)

b)

Fig. 4. Wear rings

4. Description of the solution of identifying faults in rolling bearings as components of a dynamic industrial equipment

This case study presents the results of measurements made on a rolling bearing as a component of a dynamic industrial equipment. The measurements were made with an analyzer and a shock impulse transducer with probe - see Fig. 5 (a) [8], [9].

In Fig. 5 (b) the evolution in time of the vibrations amplitude from a rolling bearing is presented. The evolution of the LR/HR signal, monitored with an on-line CMS system, during 7 months of operation in tough conditions, can be observed.

Fig. 5 a) Shock impulse transducer with probe

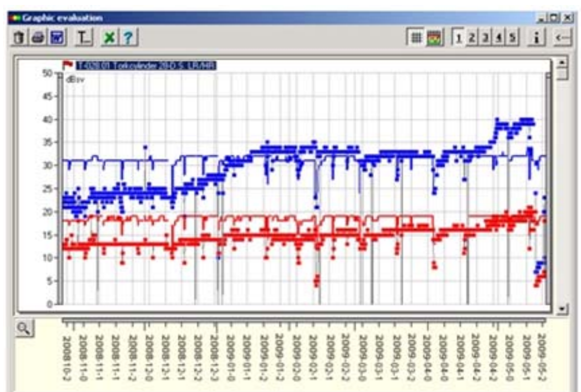

Fig. 5 b) SPM spectrum, the evolution of LR/HR signal

The frequency analysis of the vibration signal did not indicate any problem regarding the safety in operation of the rolling bearing, the amplitude of the vibrations being extremely small, Fig. 6 (a), also, the enveloping analysis did not signal anything dangerous, Fig. 6 (b).

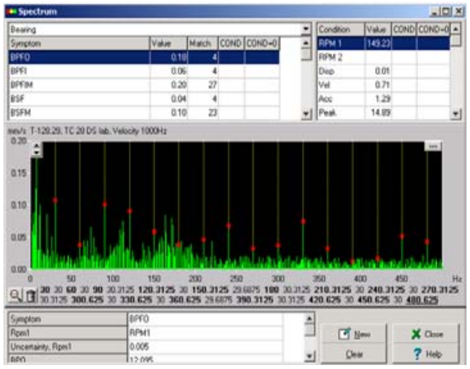

Fig. 6 a) Frequency analysis of the vibration signal

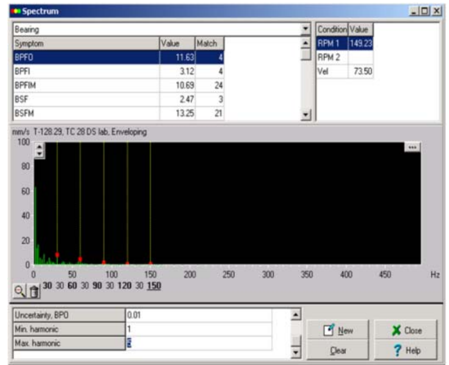

Fig. 6 b) Enveloping analysis

The analysis in frequency of the shock impulses signals wear on the exterior rolling path of the bearing, is presented in Fig. 7. It can be noticed that the frequency analysis of the vibration signal did not indicate anything in particular [10].

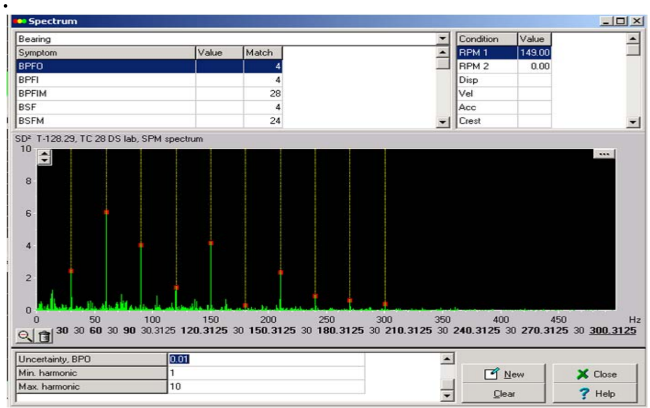

Fig. 7. Frequency analysis of the shock impulse signal

The bearing continued to function another 700 hours in conditions of dynamic critical load after the moment of diagnose.

For the manager of a company whose equipments rolling bears work continuously, it is very important to receive quality information in due time, in order to take correct decisions regarding both safety in operation and maintenance cost reduction.

5. Conclusions

It was proven through case studies that, just by measuring and frequency analysis of the vibration signal of machine-tools or dynamic industrial equipment, nothing unusual would have been noticed in their operation, but through the FFT shock impulse analysis wear is noticed in the initial phase, long before the appearance of vibrations.

Diagnosing faults at the optimum time can lead to both reduced maintenance costs of machine-tools/dynamic industrial equipment and wear in the bearings, as well as in other elements functioning in relation to these, also to reduced time of stationing for machine-tools/dynamic industrial equipment, as a consequence of unplanned interventions.

Furthermore, it was proven that the correct application of predictive maintenance principles increases safety in working. The intervention done in due time can prevent collateral damage and maintenance costs are significantly dropped.

Finally, this article covered the essential stages of equipment monitoring, identifying the fault in time, leaving room for development of some principles and new methods for machine-tools vibration diagnosis.

All the above reflects in the increase in quality of finite products and in the decrease in production price.

R E F E R E N C E S

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