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Investigation of resonance frequencies of a rotor system with segmental sliding bearings

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Abstract

This paper is based on investigation of self-vibrations of rotary systems with segmental sliding bearings, having different frequencies of rotor revolution. The graph of resonant frequencies of operating rotary system obtained from experimental investigation is given. It can seen how frequencies of rotation are unacceptable the worst working rotary system by this graph.

The problem of this work is formulated, technical characteristics of primary elements of investigated system and operation principle are provided. Methodology of the experimental investigated is described.

The obtained results are presented in graphs and a comparison of obtained results and its discussion are given. General conclusions are presented at the end of the work.

Keywords: resonance frequency, segmental sliding bearing, rotor system.

Introduction

Sliding bearings are one of the primary elements of construction of rotary machines of a big power. Bearings hold the rotor together and rotate in the stream turbines of big power, in the compressors, in the pumps. According to EEI (Edison Electrical Institute) statistical data, breakdowns of sliding bearings form 23 % causes of all breakdowns of the system. Analogical research of thermo power stations done by EPRI (Electrical Power Research Institute) shows that outages are happening mostly because of problems of these bearings.

One unacceptable phenomenon that occur in rotary systems is in the resonant regime. The resonant regime is attributed to the crash bearing work regime, because working bearing in the resonant regime, may cause damages during snatch of the whole mechanism, in which the bearing is embeded.

Sliding bearings are stocks of rotors and at some workloads and frequencies of revolution they are characterized with a unstable work which different by its nature from an unstable regime of roll bearings. If those instabilities are asserted in the elastic (limp) rotor, that working to critic, resonant frequency of revolution, then breakdown of a machine is possible. Such breakdown is sudden, therefore catastrophic. Some mechanisms can excite phenomenon of instability.

A substantial difference is observed between vibrations of rotor that raises unstable work of sliding bearings of friction and between other vibrations that raises the rotor, for example a disbalance of a rotor, deflections of truths of rotors, rubs of turning parts over bodies and so on.

Vibrations that raise the lubricant of sliding friction are shown by spontaneous cross vibrations of rotor. In the case of the rotor it raises the vibrations in itself, when energy of vibrations of vapour or gas, liquid, or lubricant are carried to the rotor. These vibrations results for sucks and agitation of lubricant and for raising impact in the sliding bearing.

Dynamic parameters of the “rotor-lubricant-bearings” system and parameters of liquid taken together show step of stability of rotary system that is expressed with frequency of revolution of the rotor [1]. When this frequency of revolution of the rotary system is exceeded, it causes spontaneous cross vibrations of sub-synchronic frequency of the rotor, that is started by whirls of lubricant in the clearance of the bearing. It forms whirls of lubricant in the clearance of bearing that raises procession of rotor with much less frequency than its side of frequency of revolution [2, 3]. There is characteristic instability for whirls of lubricant, because they increase dynamic powers, and these enlarge the whirls. The rotor becomes unstable, when the lubricant cannot remain in its axle or when the frequency of whirls is coincident with the frequency of vibrations of the axle. The result of the above-mentioned phenomenon is a raised cross vibration of the rotor of a steady frequency [3, 4, 5] (Fig. 1). It depicts S_{pp} spectrogram – cascade of biases of spontaneous cross vibrations. It can be seen in spectrogram presented in Fig.1 – cascade that stable revolution of axle without vibrations ends at 2400 rev/min. [3, 4]. It is step of stability of a rotary system. Spontaneous vibrations of a rotor appear due to whirls of lubricant at 2400 rev/min and last up to 3300 rev/min. The frequency of these spontaneous vibrations is 0.47 of the frequency of rotor revolution. Increasing the frequency of rotor revolution increases proportionally spontaneous vibrations. When the rotor increases the 3300 rev/min frequency of rotation, spontaneous cross vibrations of rotation disappear. Spontaneous vibrations of the rotor do not occur in the interval from 3300 rev/min to 4000 rev/min.

When the frequency of rotor revolution goes beyond 4000 rev/min, the amplitude of vibrations of the synchronic frequency 1X begins to decrease, because of decrease of its dynamic eccentricity.

Increasing the frequency of a rotor revolution further from 6200 to 8000 rev/min, spontaneous cross whirls of the rotor that raises the stirring of lubrication come into being again; they are of a stable frequency and of significant amplitude.

However, the spontaneous cross vibrations spring up in different frequencies of rotor revolution, than simple slide bearings [6]. Additional experimental investigation is needed to set lines of spontaneous self excited vibrations in these bearings.

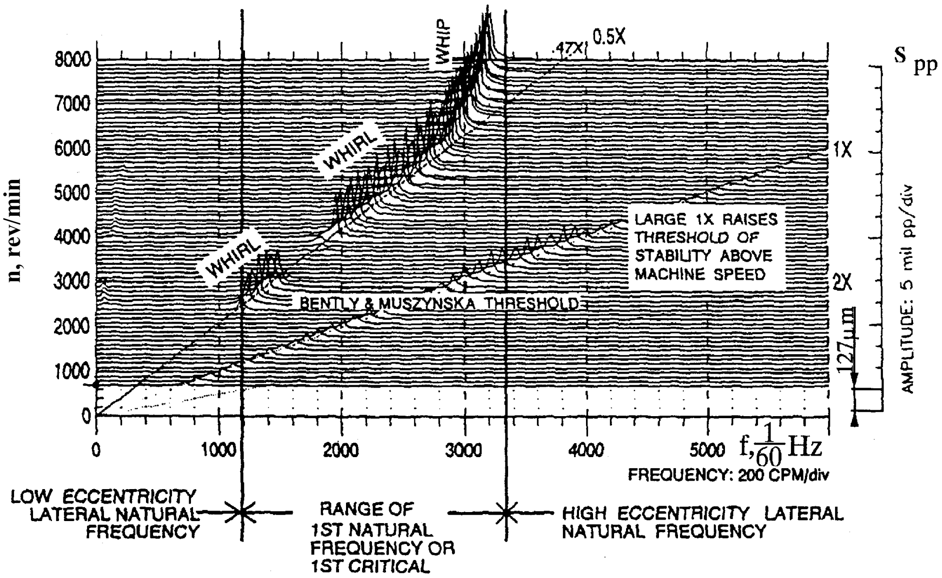


Fig. 1. **Spectrograms of axle vibrations changes of rotary systems that are rising lubricant of sliding bearing – graph of cascade with "Step of Bently and Muzcynska" [3, 4]**

Basis of research

The system under investigation (stand of research) consists of four several subsystems: the investigated system (the rotary system with segmental sliding bearings); the stepless system of regulation of the rotor revolution frequency; lubrication system of the rotary system, of measurement system and analysis system of measurement results.

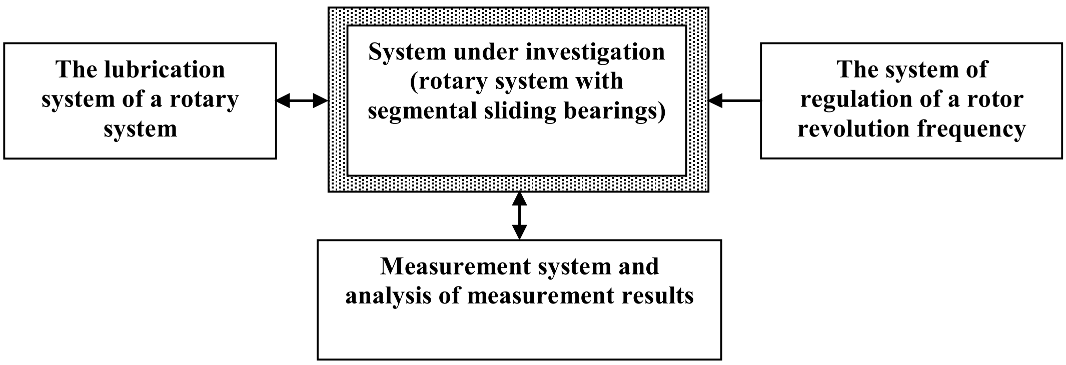


Fig. 2. **Principal scheme of the testing system**

The system of regulation of a rotor revolution frequency

The stepless system of regulation of a revolution frequency of the German firm "INDRAMAT" is used for rotation of the rotary system with bearings of sliding bearings, that primary technical data:

- The power supply of the system 380 V;
- The power of the electriccal engine 6.5 kW;
- The frequency of revolution of stepless regulation 0-8000 rev/min.

The stepless system of regulation of the rotor revolution frequency consists of asynchronous three-phase electrical engine and its control unit. It helps the start and stop of the engine, settings of fixed or stepless frequencies of revolutions.

The programmable module AS31 is installed to regularize the control unit with the asynchronous engine. The module has a programmable supply and it keeps necessary parameters of compatibility in the memory.

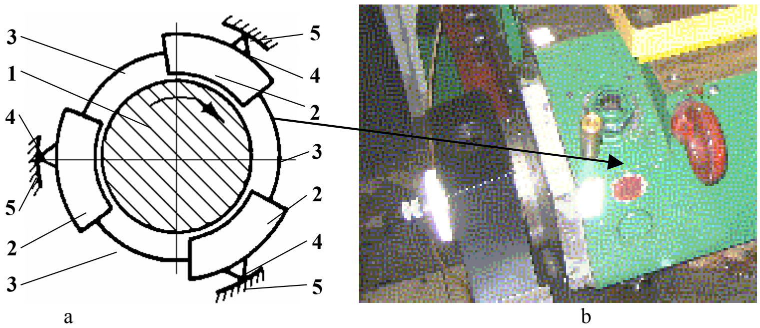


Fig. 3. **Investigated system: a - segmental sliding bearings 1 - rotor, 2 - segments, 3 – elastic coupling, 4 – adaptive thrust, 5 – spindle head; b – photo**

Programming is done with the help of KDA keyboard. The view of the programming module with the keyboard and display is presented in Fig. 4.

The lubrication system is used for functions of lubrication and refrigeration of the rotary system.

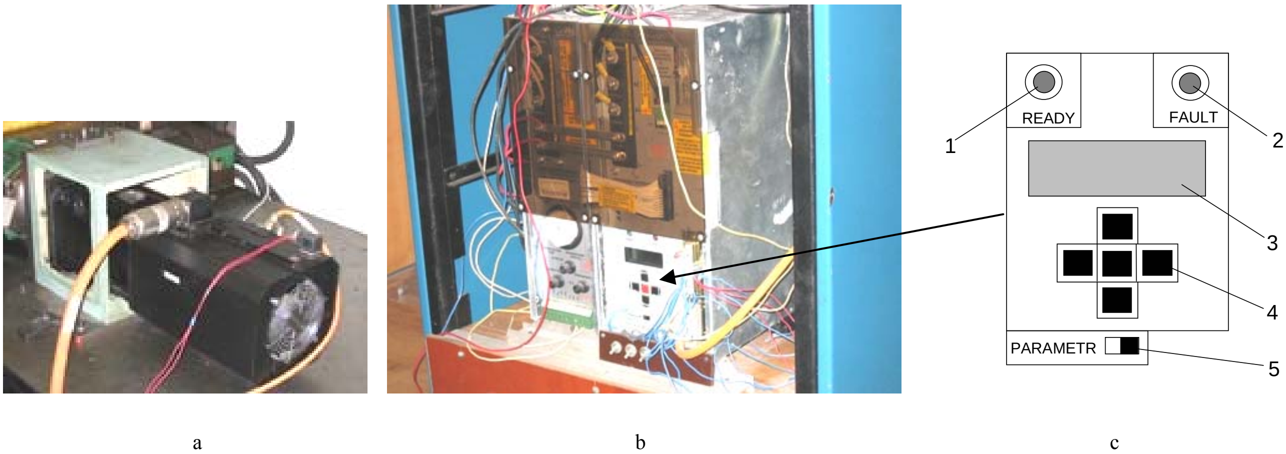


Fig. 4. **Keyboard and display of the programming module AS31: a - photo; b – picture: 1-signal indicator, that system is making for work, 2-signal indicator, that caused mistake, 3-screen, 4- keyboard of gear's control and programming, 5-adapter for of change parameters**

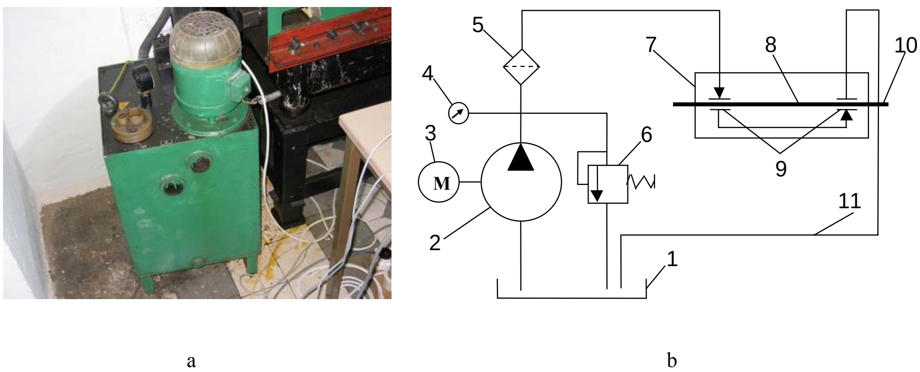
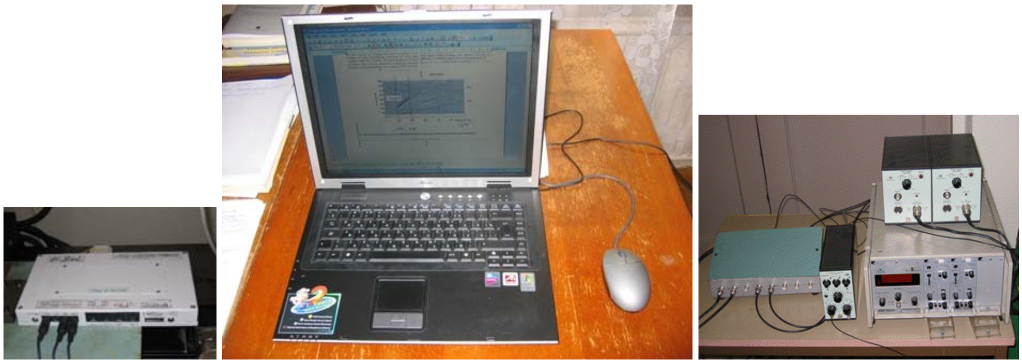


Fig. 5. **Lubrication system: a – photo; b – principal scheme of the lubrication system: 1-reservoir of lubricant; 2- hydro pump; 3-electrical engine; 4-manometer; 5-filter of lubricant; 6-protective valve; 7-frame; 8-rotor, 9-segmental bearings of sliding frequency; 10 – rotor, 11-manifolds.**

Analysis of measurement and results of measurement

The measurement system and analysis of measurement results consists of different measurement transducers, boosters and supply units and computer with the special plate DAD 1210 that is installed in the computer. Non-contact displacement transducers Tr.102 and of the Bruel & Kjaer accelerometers 4370 were used for measurements. All measurement results are obtained and stored in the computer with the help of the special board. The results of measurement are analyzed with the help of different programming batches.



a b c

d e

Fig. 6. **Analyses system of measurements and measurements results: a - special plate DAD1210, b – computer, c- amplifiers, d – non-contact induction displacement transducer, e – accelerometer**

Methodology of experimental investigation

Measurements of resonant frequencies of the rotary system with segmental sliding bearings were carried out using the described system (Fig. 2).

Preparative works of regulation and coordination and calibration of special thermometers were done before performing diagnostic investigation.

This investigation was carried in the following steps:

1. Coordination of the system and calibration of measurements;
2. Measurement transducers (Fig. 6d, 6e) are fixed on the stand;
3. Provided clearance between the neck of the rotor and the segment of a sliding bearing (50 μm clearance) is tested during experiment;
4. Lubrication system is actuated, which given lubricant to the chambers of segmental sliding bearings (Fig. 5);
5. Electrical engine is actuated, which rotates the system, provided frequency of rotor rotation is ascertained (Fig. 4);
6. Amplifiers are actuated and proportionated (Fig. 6c);
7. Computer is switched on (Fig. 6b);
8. The special computer programme is used.
9. Measurement data are incorporated into made-up data and informative files;
10. Analysis of all obtained results during measurements is carried out.

The frequency of the rotor rotation was changed during the experiment. The frequency was changed by the step 50 rev./min from 0 to 8000 rev./min because the system of regulation of rotor revolution frequency enable to change the frequency of rotor rotation. The results of measurements at each instants were fixed changing the frequency of a rotor rotation.

Results of measurement and its discussion

The graph of resonant frequencies of a rotary system with segmental sliding bearings is obtained from analysis of results of measurements (Fig. 7).

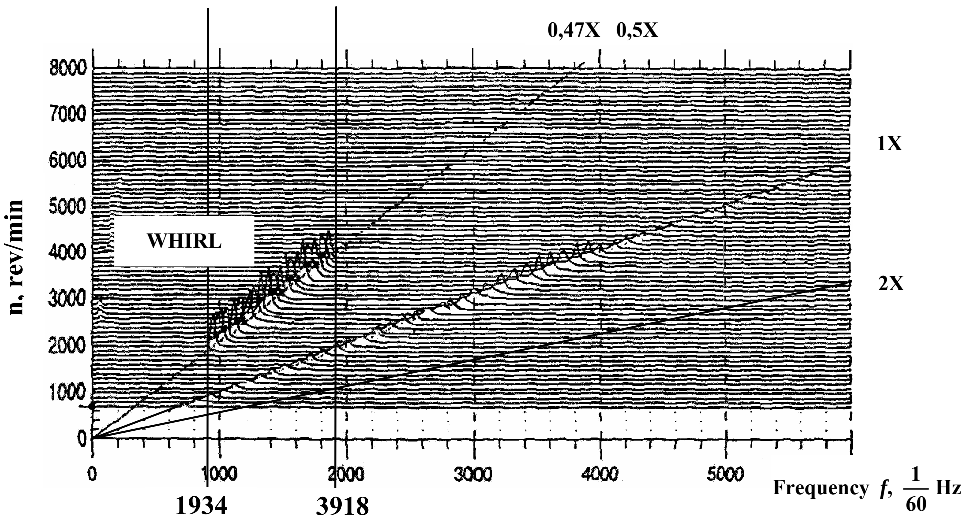


Fig. 7. **Resonant frequencies of a rotary system with segmental sliding bearings, when clearance between the rotor and the bearing is 50 μm**

The resonant frequencies of a rotary system with segmental bearings of sliding are shown in the graph too. The system beginning to work from 0 to 1934 rev/min system is working keel and exceeding 1934 rev/min spontaneous vibrations of the rotor start, that continue until 2921 rev/min. At the frequency of a rotor revolution 2921 rev/min spontaneous vibrations decrease and that are going when the rotor rotates up to 3918 rev/min. In the range from 3918 rev/min to 5500 rev/min there are no spontaneous vibrations again.

Rotary systems with segmental bearings are recommended when the clearance between the rotor and the bearing is 50 μm and they do not work with the given frequencies.

Comparing the obtained results with the "Step of Bentlis and Muzcynska" graph can be seen that there is a difference of resonant frequencies between rotary systems with simple sliding bearings and segmental bearings.

Conclusions

Resonant frequencies of rotary systems with simple and segmental sliding bearings are different.

Changing clearance between the rotor and the sliding bearing (decreasing or increasing) changes range of system spontaneous vibrations.

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Rotorinių sistemų su segmentiniais slydimo guoliais rezonansinių dažnių tyrimas

Reziumė

Tiriami rotorinių sistemų su segmentiniais slydimo guoliais rezonansiniai dažniai esant įvairiems rotorinės sistemos sukimosi dažniams. Atlikus eksperimentinius tyrimus gautas rotorinės sistemos darbo rezonansinių dažnių grafikas. Iš jo matyti, kokie rotoriaus sukimosi dažniai labiausiai nepageidautini rotorinei sistemai.

Suformuluota tyrimo problema, aprašyti tiriamosios sistemos elementai: techninės charakteristikos ir veikimo principas, pateikta eksperimentinių tyrimų metodika.

Tyrimo rezultatai pavaizduoti grafiškai, palyginti ir aptarti.

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