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# Experimental research of rotor axis revolution orbit in rotor systems with adaptive and sleeve sliding-friction bearings

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## 1. Introduction

Most researchers [1, 2] of rotating systems appls orbits of rotor for Tilting – Pad Journal Bearings to estimate their operation quality. The orbits of vibrations show vibration biases of rotor bolsters, relative and absolute phases relative frequency, that is amplitude of the change of biases of relative vibrations of the rotor in radial direction and the frequency with respect to the frequency of rotor rotation and the frequency of radial vertical vibrations with respect to the frequency of radial horizontal vibrations, trajectory of vibrations, trajectory of precession of the rotor with respect to its trajectory of rotation, configuration of deflection of a roller [3-8]. Bias of configuration of the orbit describes the change of dynamical workloads on the rotor, what indicates perfection of the bearing construction, accuracy of its mounting.

Practice has shown [9, 10] that graphs of orbits are informative especially for quality research of the bearings operating at high speeds.

Working quality of a bearing researching graphs of rotor orbits at different frequencies of rotation is analyzed in this work.

## 2. Testing systems

Relative body wise displacements of the rotor *1* (Fig. 1) are measured by noncontact induction displacement transducers *3*. The direction of rotation and angular velocity of the rotor are measured from the mark *6* by photoelectric phase transducers *5*. The phase converter synchronizes signals of the displacement converters *3*. Absolute vibrations of the rotor's body are measured by accelerometers *4* which signals amplified by the primary amplifiers *8* are sent to the measurement signal input/output board *10* of the computer *9*. Signals of induction displacement transducers *3* and the phase converter *5* are also sent to the board. The computer *9* processes the signals registered with the versatile board *10* by using Origin, Data Master and Statistika, Excel or other software packages. Noncontact induction displacement transducers have been selected to determine deviation (beating) of the rotary motion of the rotor. Two transducers mounted at 90° angle are used to determine the rotary trajectory (orbit) of the rotor's pivot.

The functional diagram is presented in Fig. 1.

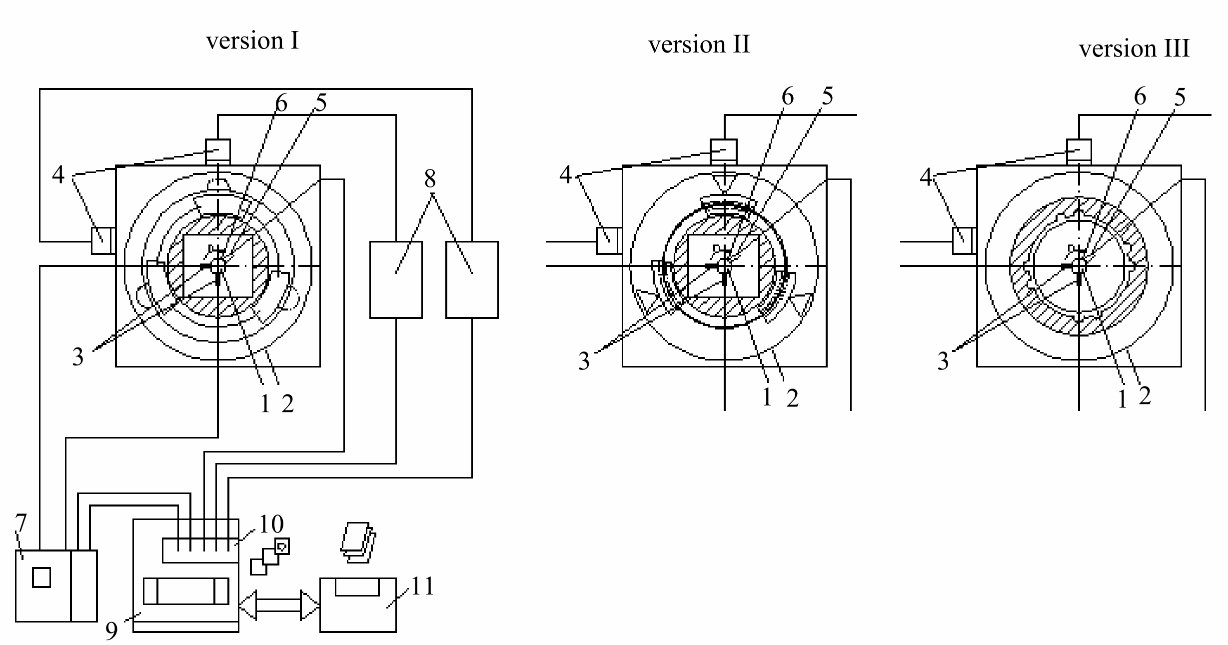



Fig. 1 Testing system of a rotor system with adaptive viscous-friction bearings: *1* - rotor; *2* - spindle head, *3* - noncontact induction displacement transducers, *4* - accelerometers, *5* - photoelectric phase transducers, *6* - mark, *7* - amplifier, *8* - primary amplifiers, *9* - computer, *10* - measurement signal input/output board, *11* - printer

## 3. Diagnostic measurements

Diagnostic measurements of adaptive (version I and sleeve (version III) sliding-friction bearings are performed as follows: after mounting the bearings of adequate structure on the spindle head and connecting the drive motor, the converters are mounted, amplification of measuring channels is adjusted and calibration is performed. The rotor's driver is switched on and the desired angular velocity of the rotor is set. The angular velocity regulation range is as follows: 0.5...8000 rev/min. When the rotor reaches a stable preset rotary velocity the Experiment application is run in the computer.

Measurement signals from both displacement transducers, accelerometers and the strobe converter are registered within 10000-15000 interval limits.

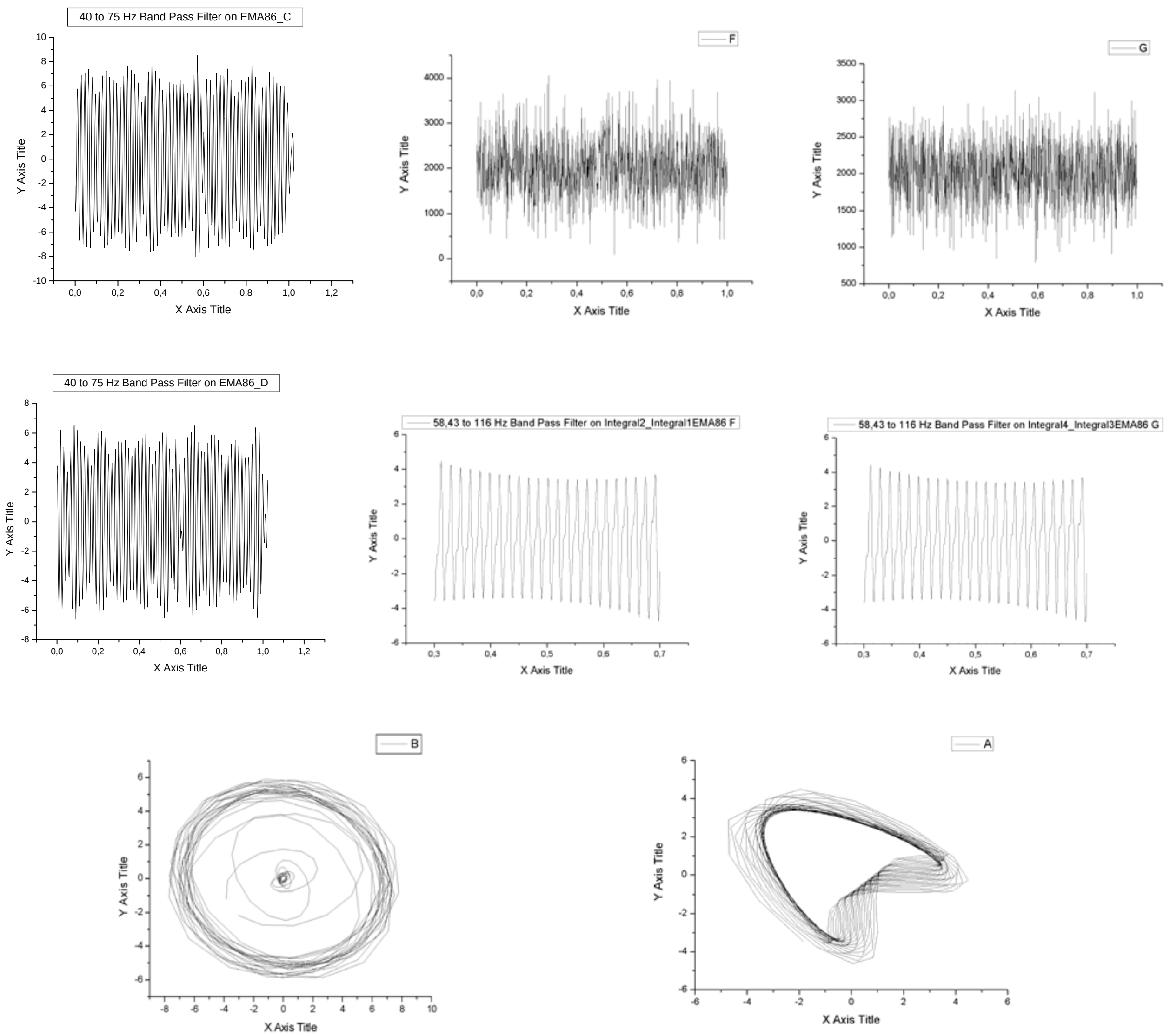



Fig. 2 Results of measurements

The data is recorded into the created data file and information files. A text file with a specified file name is created from these files. Further it is processed by means of Origin, Statistika or other software packages in accordance with respective methods (Fig. 2). By varying angular velocity of the rotor it is possible to take readings and to analyze the interrelation of the rotor orbits at different angular rotary velocities, types of adaptive and sleeve sliding-friction bearings, and absolute vibrations of the spindle head body in different directions and at different locations.

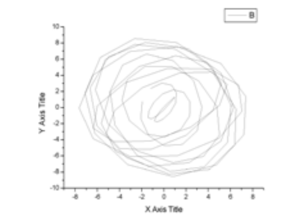
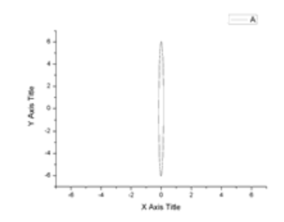
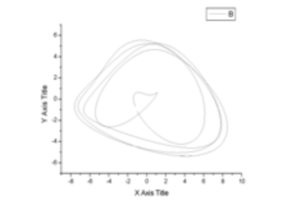
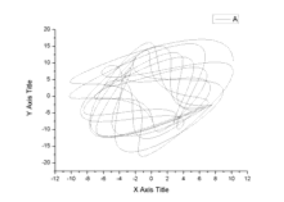
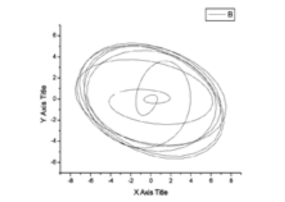
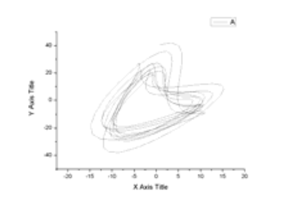
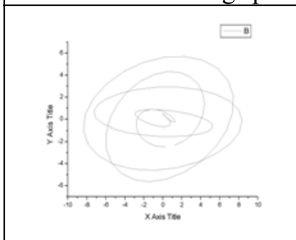
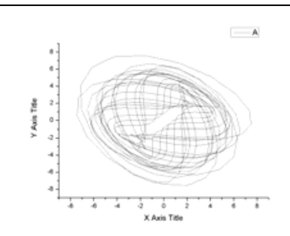
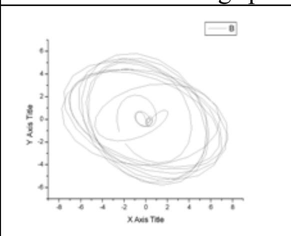
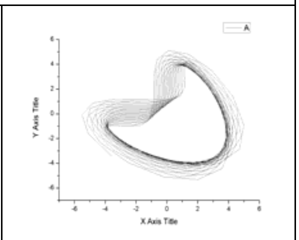
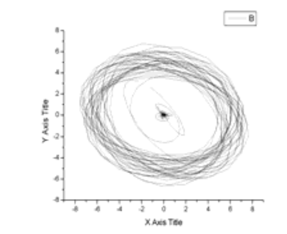
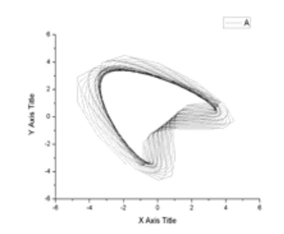
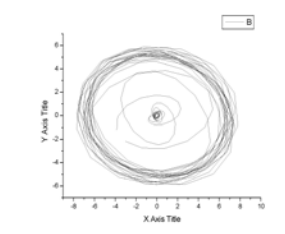
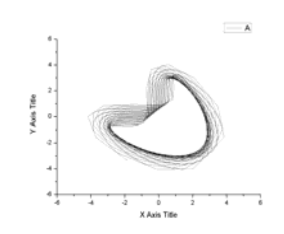
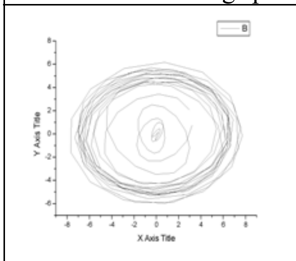
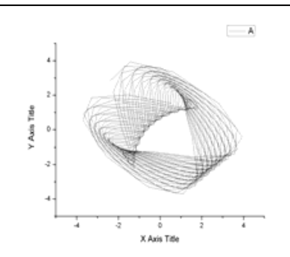
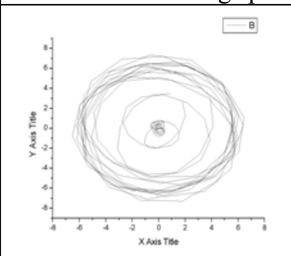
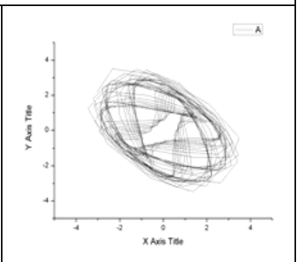
## 4. Analysis of results

From the analysis of the rotor axis revolving orbits, measured and calculated according the signals of vibro-displacement transducers and the signals of accelerometers at different rotation frequencies when the rotor revolves in two adaptive and sleeve sliding-friction bearings (see Fig. 3), it is possible to notice the following regularities.

At the increase of revolution frequency (1550; 2512; 2553; 3092 rev/min to see Table) forms of the orbits stabilize and become more constant. At the revolution frequency 3506 and 4077 rev/min the form of orbits is the most stable. At further increase of the frequency (4529; 5102 rev/min to see Table) they again become less stable because of temperature influence on the lubricant. At further increase of revolution frequency it would be necessary to increase synchronously the clearance in the bearing.

Table

The summary table of experimental data

| Type of bearing | The orbits of the rotor axis | | | |
|---|---|---|---|---|
| | According to signals of vibration displacement transducers | According to signals of accelerometers | According to signals of vibration displacement transducers | According to signals of accelerometers |
| Sleeve sliding-friction bearing | Rotating speed 2070 rev/min | | | |
| |  |  | | |
| Adaptive sliding-friction bearing | Rotating speed 1550 rev/min | | Rotating speed 2512 rev/min | |
| |  |  |  |  |
| | Rotating speed 2553 rev/min | | Rotating speed 3092 rev/min | |
| |  |  |  |  |
| | Rotating speed 3506 rev/min | | Rotating speed 4077 rev/min | |
| |  |  |  |  |
| | Rotating speed 4529 rev/min | | Rotating speed 5102 rev/min | |
| |  |  |  |  |

Difference of orbit forms, received by measurement using vibro-displacement transducers and accelerometers with double integration of later signals and filtration by special methodics prepared by the authors, could be explained due to not enough quality of signal filtration and not compatible signal scale of vibro-acceleration and integrated vibro-displacement. At a set of constant coefficients and correction of calibration methodics this noncompatibility can be decreased.

Revolution orbits of the rotor in a bush type sliding bearing were measured only at revolution frequency 2070 rev/min. They are more stable, but difference between them is higher and further research is necessary to explain the reasons. Fig. 2 shows the orbits received by measurement with vibro-displacement transducers and accelerometers after double integration and filtration of the signals later, when the revolution frequency was 3506 rev/min.

At measurement by accelerometer the signals are not decoded in full. The orbits are not fully informative and to conclude the reliability of diagnostics from them additional research is needed.

At further improvement of the methodics of measurement and analysis it would be necessary to receive the measurement signals together with the revolution frequency transducer (stroboscope) signals and to search for connection between these signals that is to define non coincidence of the phases and relation between the phases received by measurement with different transducers.

## 5. Error analysis

Rotary system with hydrodynamic bearings is not strong straight but it could be linearised. In this case it is necessary to find such value of operator, that the function of error would be close to zero [3].

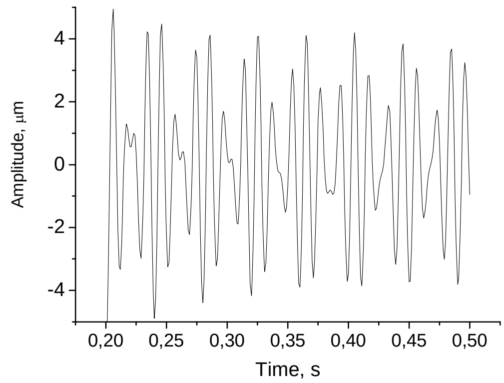
$$\Delta_d(t) = Y(t) - AX(t) \quad (1)$$

here $X(t)$ is revolution fluctuations of the rotor (Input signal); $Y(t)$ is frame fluctuations of the rotor (Output signal); $A$ is operator; $\Delta_d(t)$ is function of error.

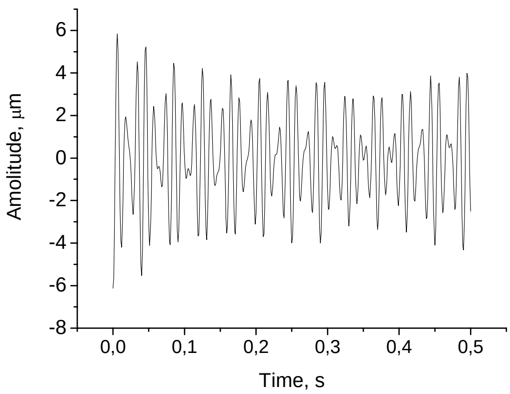
Operator

$$A = A(\sigma_x) = \frac{1}{\sigma_x^2} K_{yx}(0). \quad (2)$$

Results of errors counts are given in the graphs (Fig. 3, a and b). The results - graphs of counts of measurement transducers that are fixed horizontally: error $\Delta_d(t)$ (Fig. 3, a). The results - graphs of counts of measurement transducers that are fixed vertically: error $\Delta_d(t)$ (Fig. 3, b).




a




b

Fig. 3 Rotor rotation frequency 4500 rev/min, error $\Delta_d(t)$; a - horizontal converter, b - vertical converters

## 6. Conclusions

1. Dynamic error $\Delta_d(t)$ (Fig. 3, a and b) shows that practice of accelerometers is possible and expedient being confusing constructions of rotors systems.

2. Dynamic standard deviation of error $\Delta_d(t)$ between oscillations is 2.1514 µm (Fig. 3, a) and 2.3053 µm (Fig. 3, b). Right measurement results are got at measurement by noncontact induction displacement converters.

3. It is necessary to do researches improving measurement methodology of rotor revolution orbits using accelerometers.

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V. Vekteris, A. Čereška, M. Jurevičius, V. Striška

ROTORINIŲ SISTEMŲ SU ADAPTYVIAISIAIS IR ĮVORINIAIS SLYDIMO TRINTIES GUOLIAIS ROTORIŲ AŠIŲ SUKIMOSI ORBITŲ EKSPERIMENTINIAI TYRIMAI

R e z i u m ė

Straipsnyje nagrinėjamas rotorinių sistemų su adaptyviais ir įvoriniais slydimo guoliais rotorių ašių sukimosi orbitų tikslumas, matuojant vibracinius poslinkius bekontakčiais poslinkių keitikliais (tiesioginis matavimo būdas) ir vibracinius pagreičius akcelerometrais (netiesioginis matavimo būdas). Atlikti rotorinių sistemų eksperimentiniai ir teoriniai tyrimai. Iš gautų matavimo rezultatų sudarytos rotorių ašių sukimosi orbitos bei kiti analizei reikalingi duomenų formatai. Nustatytos rotorių ašių sukimosi orbitų netaisyklingos formos susidarymą įtakojančios priežastys bei priklausomybės tarp adaptyvių ir įvorinių slydimo guolių tyrimo rezultatų, bei rezultatų, gautų matuojant tiriamąją sistemą tiesioginiu ir netiesioginiu matavimo būdais.

Atlikta gautų rezultatų analizė ir pateiktos išvados, apie rotorinių sistemų rotorių ašių sukimosi tikslumo diagnostinių tyrimų rezultatus.

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EXPERIMENTAL RESEARCH OF ROTOR AXIS REVOLUTION ORBIT IN ROTOR SYSTEMS WITH ADAPTIVE AND SLEEVE SLIDING-FRICTION BEARINGS

S u m m a r y

The accuracy of revolving orbits of rotor axes in rotor systems with adaptive and sleeve sliding-friction bearings is analyzed in the paper measuring vibration displacements by contact less displacement transducers (straight measurement method) and vibration accelerometers (nonstraight measurement method). Experimental and theoretical research of rotor systems was performed. On the basis of received measurement results rotational orbits of rotor axes and other data formats necessary for analysis were formed. Reasons influencing the formation of irregular form of rotor axes revolving orbits and dependencies between the research results of adaptive and sleeve sliding-friction bearings and the results received by measurement of the searched system by straight and nonstraight methods were defined.

Analysis of the received results is made and conclusions are presented about the diagnostic of revolution accuracy of rotor axes in rotor systems.

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ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ ОРБИТ ВРАЩЕНИЯ ОСЕЙ РОТОРОВ В РОТОРНЫХ СИСТЕМАХ С АДАПТИВНЫМИ И ВТУЛОЧНЫМИ ПОДШИПНИКАМИ ЖИДКОСТНОГО ТРЕНИЯ

Р е з ю м е

В настоящей работе приведены результаты исследования точности орбит вращения осей роторных систем с адаптивными и втулочными подшипниками скольжения, измеряя перемещения бесконтактными датчиками (метод прямого измерения) и виброускорение акцелерометрами (метод косвенного измерения). Проведены экспериментальные и теоретические исследования роторных систем. Из полученных результатов измерений сформулированы орбиты вращения осей ротора и другие форматы данных необходимые для дальнейшего анализа. Установлены причинны влияющие на форму орбит, установлена взаимосвязь между характеристиками адаптивных и втулочных подшипников скольжения, а также между результатами, полученными измеряя прямым и косвенным методами.

Проведен анализ полученных результатов диагностических исследований точности вращения оси ротора и сформулированы выводы.

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