

## MECHATRONICAL SYSTEM FOR TESTING OF HYDRODYNAMIC BEARINGS

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**Abstract:** Diagnostic apparatus with measuring transducers of changes and accelerations widely use for measuring and for research of rotors of vibrations, which rotation in hydrodynamic bearings. There does exist a little data, in with base we can estimate functioning quality of hydrodynamic bearings.

*Mechatronic testing system of hydrodynamic bearings presents in this work, this system lets estimate functioning quality of rotor system, loading to bearing and geometry of change of bearing, according to distance between pintle of rotor and change of segment of bearing.*

*Graphics of rotor orbits present for some cases, according to which we can estimate rotor system.*

Key words: mechanical system, hydrodynamic bearings, rotor, testing, transducer, measuring.

### 1. INTRODUCTION

In rotor systems serious mechanical problems emerge sometimes due to the rotor instability and coaxial misalignment of bearings (Адамс & Пойандех, 1983, Вектерис, 1989, Adams & Макоу, 1981, Челомей, В. Н. 1981, Пуш et al., 1987). The increasing velocity of these systems and other reasons made the problem of regulating the characteristics of the rotor – bearing system more complicated. Seeking to minimize the instability of this system on the basis of self-adjustment, are variety of bearing structures have been worked out, including those with a floating spacer, elliptical bearings, tilting – pad bearings, as well as elliptical tilting – pad bearings (Vekteris & Čereška 2002, Vekteris 2000). The latter enabled to obtain the most – successful results due to the changed natural frequency of the system (Адамс & Пойандех, 1983, Вектерис, 1989, Vekteris & Čereška 2002). Therefore, they are successfully applied in high power turbines, in spindle units of grinding machines, centrifugal compressors, the principal pumps of boiler plants, steam and gas turbines, generators, powerful electro motors (megawatt ones), turbo-blowers, ventilators, turbo drills, high-speed ship drives, etc (Vekteris, 1993). However, normal radial tilting-pad bearings with flood lubrication have insufficient damping and reduced carrying capacity due to the non-uniform load distribution among separate segments; an intensive fatigue cracking occurs sometimes in the Babbitt filling close to the front edge (in the direction of lubricant flow) of statically unloaded (upper) segments (in case of a horizontal rotor) (Адамс & Пойандех, 1983, Adams & Макоу, 1981). In addition, errors in mounting and adjustment operations cause distortions in the initial geometry of the bearing, thus creating conditions for a non-uniform load distribution among the segments. Attempts to overcome these shortcomings of segmental bearings were successful only in regard to thrust bearings. This problem is existed in radial segmental bearings up to now, and then it is necessary to test bearings according to size of interval between segments of bearing and rotor.

### 2. THE MECHATRONICAL SYSTEM OF THE TESTING

The mechatronic scheme of hydrodynamic bearings of testing systems is represented in fig. 1, photograph stand fig. 2. It contains the systems of rotor with hydrodynamic bearings, transducers of improvements, accelerometers and phase, the original plate of input-output of signal of measuring, computer, printer, block of feeding, boosters, the analyzer of two canal signals, plotter.

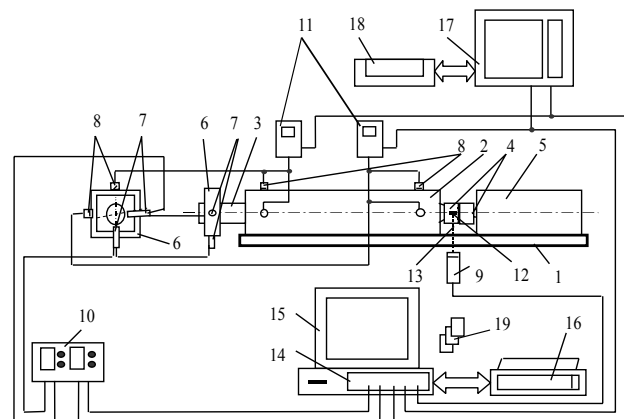


Fig. 1. The scheme of mechatronic system  
 1-foundation; 2-frame, in which are assembled bearings of sliding; 3-rotor; 4-muff; 5-asynchronous electrical motor; 6-holder of measuring of transducer; 7-noncontact transducers of improvements of measuring; 8-transducers of acceleration of measuring (accelerometer); 9-transducer of phase (strobe); 10-block of improvements measuring of transducers feeding and “0” establishment; 11-opening boosters; 12-excellent; 13- radius of phase transducer (strobe); 14-input-output plate of measuring signals; 15-computer; 16-printer; 17-analizer of two canal signals; 18-plotter; 19-program packet.

Transducers of rotor are measured of non-contact transducers, inductive improvements in the bearing 7. Transducers are feeding, are adjusted and their opening strength is carry out of and “0” equipment of establishment 10. Direction of rotor turning and speed are measured with transducer of photoelectric phases 9 from mark 12. The transducer of phase is synchronized 7 signals of transducers of improvements. Absolute vibrations of rotor frame are measured with accelerations their signals are strengthened with opening boosters 11, they are given to input-output plate 14 of computer 15 of measuring signals, signals 9 of induction transducers of improvements are analyzed by computer 15 employing program packets 19 (“Origin 6.0”, “Statistica”, “Excel”) and others. Results of measuring and analyses are represented with printer 16.

Signals of acceleration are strengthened with opening boosters 11 and signals are given for analyzer of two canal signals directly 17 results of data analyzing with analyzer are represented with

plotter graphic 18. Direction information was received about process, when signals were machined by Danish firm “Briuel & Kjaer” with analyzer signal mod. 2034 of two canal signals. When signals have analyzed, it could establish those functions and parameters: the function of instant time; the function of medium time, the function between correlations; orbits; instant spectrum; its own spectrum and spectrum between them; statistic function, characteristics  $H_1, H_2$ , of frequency; the power of signal of coherence and non coherence sing of going-out, auto correlation functions and functions between correlations; impulsive characteristic, using Hilbert transformation.

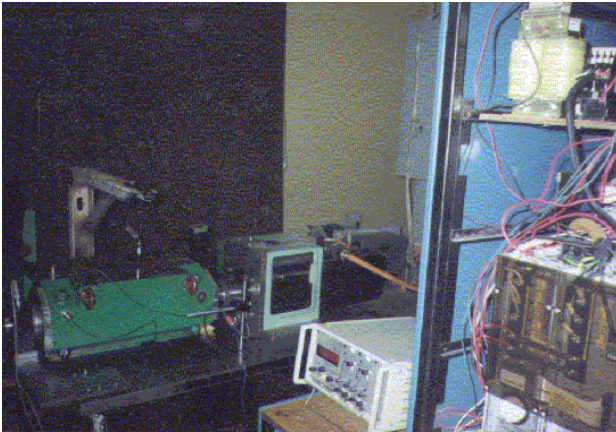


Fig. 2. Mechatronic system of testing

### 3. THE SYSTEM OF MEASURING AND GOVERNING

The system of measuring form: non-contact transducers of measuring improvement (Barzdaitis & Činikas, 1998), transducers of measuring vibroacceleration (Barzdaitis & Činikas, 1998), photoelectrical transducer of measuring phase (Barzdaitis & Činikas, 1998), different boosters and feedings block and it can be used transducers of speed measuring.

For measuring of rotors rotation defections mechatronic systems had applied firm Germany Hettinger Baldwin Messtechnik CMBH (HBM) transducers of non-contact inductive improvement mod. Tr. 102.

Transducer of improvement consists of two large sensitiveness inductive reels installed in one frame scheme. Reel of measurement is strengthening in the part of lost cylindrical frame and compensatory reel is inside of frame. Carrying frequency is 5 kHz or 50 kHz.

Sensitiveness of transducer belongs from elementary interval  $L_A$  and from its banquet  $\Delta L$ . When small bridge is balance wheel, inside interval  $L_R$  is equal exterior elementary interval  $L_A$ .

Accelerometers distinguish itself the widest interval of measuring vibrations signals frequency compare witch transducers of changes and speeds.

For measuring of absolute vibrating accelerations are used firm of Danish “Briuel & Kjaer” piezoelectric accelerometers (mod. 4370) (Barzdaitis & Činikas, 1998). It’s the main characteristics are: sensitiveness according to change 10...10.12 pC/ms<sup>-2</sup>, or 99.0...99.4 pI/g; sensitiveness according to voltage 8.84 mV/ms<sup>-2</sup>, or 86.9 mV/g; capaciousness in common with hook is 1144 pF; resistively – 2000 MΩ min in room temperature.

Accelerometer is statement on the frame of rotor. Witch disposition of strengthening lets to fix accelerometer in any point of measuring.

To establish phase is used photoelectrical phase’s transducers of original construction. The special plate DAD1210 of loading-withdrawal is feeding transducer.

In diagnostically transducers all transducers of measuring except (strobe) are lay out 90° corners of phases in one plane of shafts transverse.

Such exposition of transducers lets to measure the position of shafts neck sliding bearing of rotor turning including and zero. Orientation of transducers not necessarily has to be vertical or horizontal. It’s choosing most comfortable position of mechanism position.

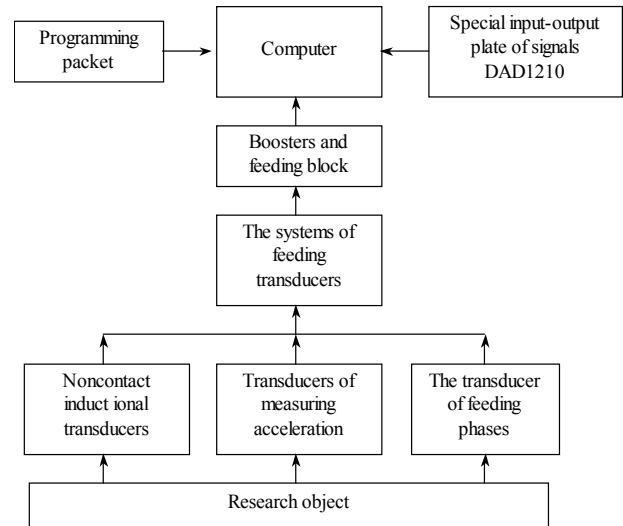


Fig. 3. Principal block scheme of measuring system

The plate of input-output DAD1210 of universal electric signals is used for transmissions information to computer, for strengthen of transducers signals and for government of experiment.

The plate of input-output of universal electric signals is realized:

- Input-output function of programming of universal information;
- Function of time intervals formatting of programming length;
- Exchange of numerical signal to analogue function;
- Function of strength of programming analogical signal;
- Exchange of analogical signal to function of numerical code;

The blocking scheme of universal input-output plate of electrical signals is presented in fig 4.

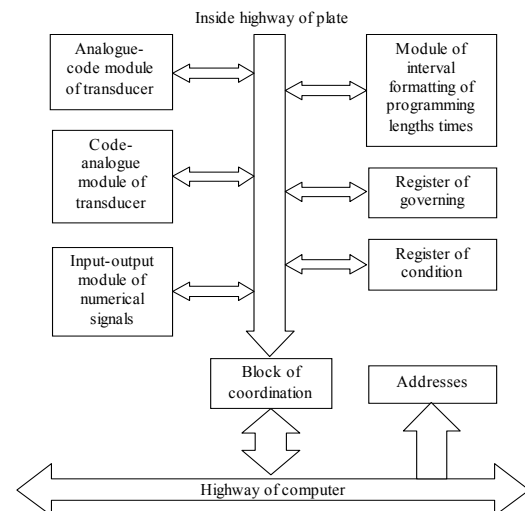


Fig. 4. The blocking scheme of input-output plate of signals

Plate is connected block of apportionment of address, which is formatted signal of contrivance engaging of every plate, buffering of plate with computer highway, registers of governing and condition, which are configured plate and are reflected effect of mechanism of plate, which are programming module of intervals formation of time length, changing of analogical signal to numerical module, which consists of two electrical commutator of analogue signal, programming booster and analog code transducer (ADC), module of changing of numerical code to analogue signal, which consists of government scheme of two-code-analogue transducers and commutations of analogue signal. Mechanisms of plate are occupied 24 addresses in the space of address of exterior mechanisms of computer.

*Input-output module of programming of numerical information.* Two 8 lobes numerical lines use in this module, information would be inscribed to computer across them or information would be pass to exterior numerical mechanism (Block of impulsion boosters, of electromagnet cal relays). Input-output module of programming of numerical information would be used to information of transducers are assemble theirs of going-out are coordinated with levels of entrance module. Error of times length is  $\pm 5 \times 10^{-5}$  s.

*Formatting module of programming lengths of time internals.* This module consists of 2 MHz quarts generator and programming of 48 lobes. Module would generate intervals of time, which the smallest length is 4  $\mu$ s, the biggest length – some years. The smallest programming change of time interval is 0.5  $\mu$ s. Signal of going-out of formatting module of time intervals of programming length governs register condition or forms signal of interapt to one interapt line from computers highway dependently from establishments of government register.

*Module of numerical signal changing to analogical.* Two code analogue transducers (DAC) use in this module. Opening-10 lobes use to generate signal. It could make up generating signal 1024 meanings of voltage; they change dependently from second 8 lobes code-analogue transducers (DAC) establishments. The second transducer set interval of changing of going-out powers. It is possible 256 intervals of going-out powers, then  $\pm 10$  V intervals select, when code 255 has written in two code analogue going-in of transducers. The time of module changing of code –analogue transducer is  $10 \mu$ s  $\pm 0.05$  %. Filters do not use in the going out of transducer code-analogue, but they could attach, dependently from employment cases. Signal could distribute to 8 canals over electronically analogical commutator in going-out of code-analogue transducer module.

*Module of changing analogical signal to numerical code.* Analogue-code module consists of two commutator of electronically analogical signals, they allow program to choose 18 differential or 16 with general earth leak canals of going-in, booster witch program governing coefficient of strengthen (it can program 256 coefficients of strengthen) and transducer of 12 lobes analogue-code, it is time of changing 2,7  $\mu$ s. The biggest power belongs from selecting coefficient of strengthen in the goings-in of canals module and when coefficient of strengthen is 1, it is flat  $\pm 5.00$  V  $\pm 0.0125$  %, or when coefficient of strengthen is flat 1024 -  $\pm 4.88$  mV. This interval is quantuated to 4096 discrete levels. Ending signal of transducer of analogical changing to numerical code is given to register of condition or to one inter apt lines from highway of computer dependently.

#### 4. TESTING

Result presents in fig. 5 are given testing hydrodynamic bearings according to orbit of rotor (Bently, 1994). Orbit of

rotors axle have shown how is changed accuracy of revolution when the size of oils wedge (distance) and speed of revolution are changing.

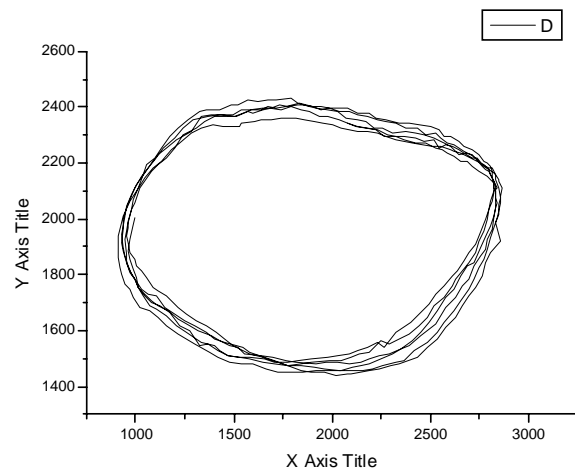


Fig. 5. Orbit of rotor when distance is 25  $\mu$ m and speed is 2000 rev/min

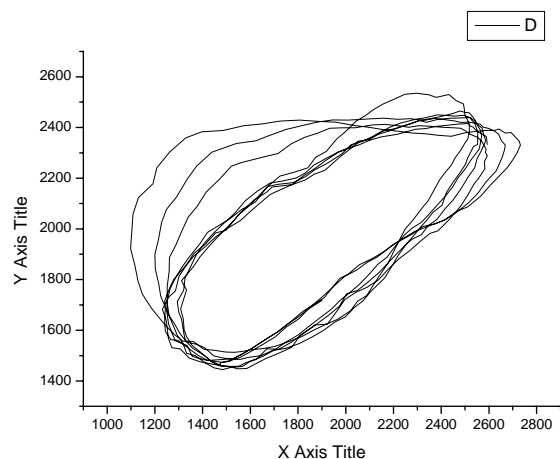


Fig. 6. Orbit of rotor when distance is 75  $\mu$ m and speed 2000 rev/min

Trajectory of orbit become worse when distance become bigger, this we could see from presenting graphics of orbit and this orbit trajectory is shown decrease of revolving accuracy due to used wearing sliding bearing. It can be get diagrams of Bode, to represent relative position of shaft in the bearing of sliding or with respect of packers or to present graphics of spectrogram-cascade of vibrations and others, testing according to others parameters, for example letting and stopping rotor.

#### 5. CONCLUSIONS

We can establish industrious limits of rotor systems when distance is changed imitating used wearing of bearing.

We can see visual change of orbits trajectory of size and form when the speed 2000 rev/min of orbit trajectories is the same and intervals are different 25  $\mu$ m and 75  $\mu$ m.

The made-up system is thawing to research spatial state of rotor in bearings of sliding, excited vibrations of oil, nicks of antifriction metal in top of radial bearings, boost of openings between pintle of rotor and bearings, disbalance and others.

This system can be usable of different makes and this system is bit for bearings of rolling.

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