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DYNAMICS MODEL AND MONITORING IN ROTATION MACHINES

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ABSTRACT
The digital signal processing based on new microprocessor technology allows us great success in machines protection, with very acceptable economic investments today. Additionally, including vibration-diagnostics monitoring of machines in addition with analytics methods, it is possible monitoring and quantification dynamics parameter of machine. By means analysis dynamics behavior of rotor, it is possible diagnostics defect which relating on rotor and other parts of machine, and solve it.
In last time, vibrations analysis and monitoring are become the most wide spread and softest part of machines diagnostics. Detection, identification and removing of problems about work of machine is simpler if we modeling few dynamics solution. When forming model which oriented on discovering defect by means sensors measured vibrations, which almost located in bearings, mathematics model is presented as elastic rotor with concentrated weight. Experimental results from test tables leading company in the world Bentley Nevada Co. USA used as base for development of this model. As note, mathematics model in the most cases based on radial oscillation of rotor and torsion oscillations in someone cases. Torsion vibration are not detect without special sensors even if they are his magnitude near destruction level.
The reliability of this model and accuracy of vibrodiagnostics analyses is affirmed for long time experimental results which observed on real machines during exploitation.
Key words: rotors dynamics, modeling, vibrations, vibrodiagnosis, monitoring

1. INTRODUCTION

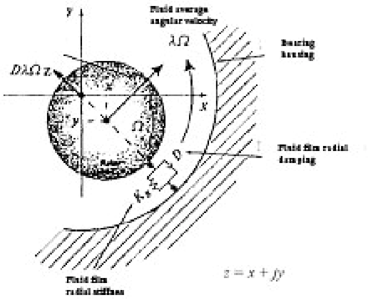
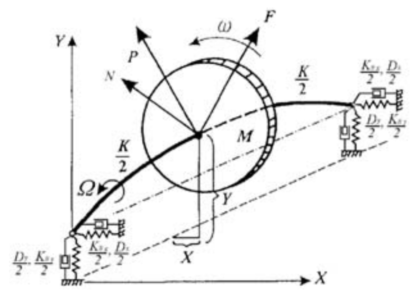
Modern world is inconceivable without electric current, oil, chemical or process industry. In order to produce all that the most important role is given to rotary machines. We should keep in mind that today's rotary machines can develop enormous power (even over 1000 MW), that they make rapid revolutions (even over 50000 revolutions a minute), and that process parameters (pressure, temperature) are very high and they processing very explosive and toxic media. For all we've said it is necessary to understand and predict possible disorders in the work of rotary machines. Modern resources (vibration sensors, devices for collecting dynamic and static data of machine, computer programs for analyses of vibration signals and converting them into appropriate formats, dynamic models of machines…) enable tracking and quantification of dynamic parameters in the work of a machine. By analyzing the dynamic behavior of rotor (or the whole machine) it is possible to predict damages connected to rotor or other parts of the machine and to eliminate them on time. The most important characteristics of the system that we establish by modeling are:

- natural frequencies of system
- conditions of stability
- main forms of oscilation
- frequent characteristics (amplitude and phase angles of response)
- response of system in case of various defects

The purpose of this work was not discovering new methodology of construction models nor discovering description of new phenomenon of dynamic impulses, but to give mathematical models whose purpose is interpreting and understanding of these phenomena through sensor model.

2. SENSOR ORIENTATED DYNAMIC MODEL OF ROTOR

Forming the dynamic model is directed to discivering defects on basis of vibrations detected by sensors, which are mostly placed in bearings.
In order to understand the dynamic of rotor system in general, it is extremely important to understand and to model actions in fluid bearing, where interaction happens between hard body (branch of rotor) and fluid (oil in bearings, steam, pumped media in slits of pumps…) [4].

Picture 1. Dynamic model of shaft in bearing *Picture 2. Dynamic model of elastic shaft with bearing*

Let's analyze response of linear isotop rotor with one radial mode that rotates in fluid surrounding, with different dynamic incentives.
In classic model, vibrational movement is in one direction, which is not the case in processional movement of rotor. Here force of coil stiffness K and buffer force rotate in some rim speed $\omega = \lambda_0 \Omega$, where λ_0 is usually smaller than 0.5, but can vary from 0,005 to 1.
Differential equations of movement in this model have the form:

$$M\ddot{x} + (D_{xs} + D_x)\dot{x} + K_x x + D_x \lambda_0 \Omega y = F\cos(\omega t + \delta) + P\cos\gamma + N(x,t) \quad (1)$$

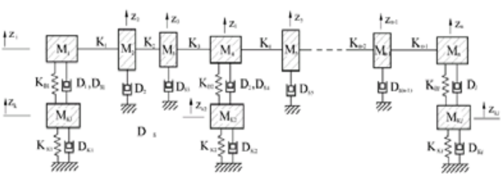
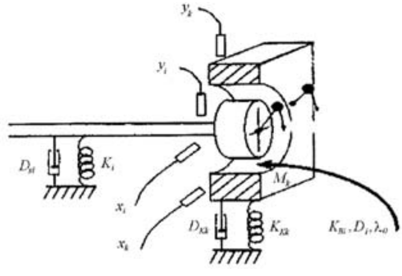
$$M\ddot{y} + (D_{ys} + D_y)\dot{y} + K_y y - D_y \lambda_0 \Omega x = F\sin(\omega t + \delta) + P\sin\gamma + N(y,t) \quad (2)$$

In complex shape, the equation of movement has the form:

$$M\ddot{z} + (D_s + D)\dot{z} + Kz - jD\lambda_0 \Omega z = Fe^{j(\omega t + \delta)} + Pe^{j\gamma} + N(z,t) \quad (3)$$

3. MULTIMODE MATHEMATICAL MODEL

It is shown here the sensor orientated mathematical model of the system rotor/bearings with elastic rotor and elastic leaned bearings. Model is based on modal characteristic of rotor and rotational characteristics of generalized fluid force. [5].

Picture 3. Model of multimode rotor leaned on elastic bearings *Picture 4. Sensor system in bearings*

Differential equation of observed model can be written as:

$$M_i \ddot{z}_i + D_{si} \dot{z}_i + K_i (z_i - z_{i+1}) + K_{i-1}(z_i - z_{i-1}) + F_{fli} = m_i r_i \Omega^2 e^{j(\Omega t + \varepsilon_i)} + P_i e^{j\gamma_i} + N_i (z_1, z_2, .. z_n, t)$$

$$i = 1,..n; \; z_1 - z_0 = 0; \quad z_n - z_{n+1} = 0 \tag{4}$$

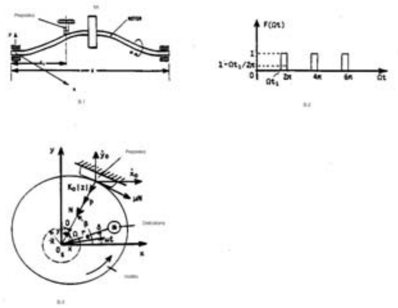
$$M_{Kk} \ddot{z}_{Kk} + D_{Kk} \dot{z}_{Kk} + K_{Kk} z_{Kk} + F_{flKk} = F_{Kk} \qquad k = 1,..l$$

4. MODELLING AND DIAGNOSTICS OF CERTAIN DYNAMIC DISORDERS

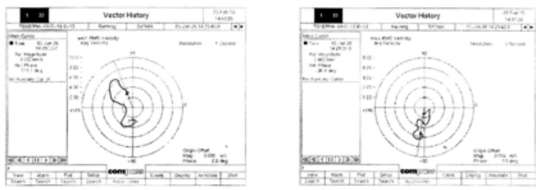
When modelling certain defects as: contact of rotor and stator, oil unstability, slack of stationary and rotating parts, cracks in rotor etc. it is necessary to model effects of stiffness, effects of friction, shock, additional unstabilities and eccentricities etc. [4]. In this work it is given the example of mathematical model of rotor when there is partial contact of rotor and stator.

4.1. Mathematical model with partial lateral rotor to stator rubs

Let us watch the system rotor/bearings of multimodal rotor with existing disbalance and direct force as an effect (disaxis, electric defects etc.) which has the contact of rotor to stator [6]



Picture 5. Modelling of contact of rotor to stator



Picture 6. Polar trend presentation 1X accordion vibrations during contact of the rotor branch and white metal in steam power plant Gacko

System of differential equation of movement is :

$$M_i \ddot{z}_i + D_{si} \dot{z}_i + K_i (z_i - z_{i+1}) + K_{i-1}(z_i - z_{i-1}) + F_i(\Omega t)\left[K_{di}|z_i| + N_i(1 + j\mu)\right]e^{j\beta_i} + F_{fli} = m_i r_i \Omega^2 e^{j(\Omega t + \varepsilon_i)} + P_i e^{j\gamma_i}$$

$$i = 1,..n; \; z_1 - z_0 = 0; \quad z_n - z_{n+1} = 0 \tag{5}$$

Expressions $K_{di}|z_i|, N_i, \mu N_i$ describe effects of modification of stiffness, shock and friction. Force $F(\Omega t)$ can be modellated by periodical step function [6]:

$$F(\Omega t) = 1 - \left\{ \Omega t_1 / 2 - \sum_{i=1}^{n} \frac{2}{i} \sin(i\Omega t_1 / 2)\cos[i\Omega(t - t_1/2)] \right\} / \pi \tag{6}$$

Characteristical sensor responses that follow this defect are the changes of amplitude and phase 1X accordion vibrations, shown on picture 6.

5. CONCLUSION

In this work, forming the very model of rotor is directed to detecting defects on basis of vibrations recorded by sensors, which are based in bearings. So the mathematical model is developed as elastic rotor with concentrated masses. It can be concluded that the phenomenology of defects imposes certain hypothesis to the model and makes it, unavoidably, more complicated. But, the purpose of this work was not discovering new methodology of construction of rotor dynamic model, nor discovering description of new dynamic impulse phenomena, but the development of mathematical model whose intention is to interpret and understand the dynamic impulse phenomenon on basis of response in sensor system.

The mathematical models are highly connected with results of experimental platforms of leading world companies. Results of these researches are systematized and mathematical models that follow phenomenology of diagnostics are shown.

Reliability of diagnostic analyses on base of developed model of sensor system is confirmed in researches on real machine objects during their exploatation.

Notation

Ω - *rotative speed*

ω - *complex eigenvalue.Also rotor self-excited*

λ_0 - *fluid circumferential average velocity ratio*

M – rotor modal mass

K – rotor modal stiffness

D_S *-rotorgeneralized (modal) external damping coefficient*

D–fluid film radial damping

F– synchronic rotating disturbance force (most often because of disbalance)

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