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INFLUENCE OF PERTURBATION ON OILWHIRL PHENOMENON GENESIS

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Abstract: *In this paper is surveyed the influence of the perturbation using model RK4. The perturbation was induced by centrifugal force. The measurement was made to evaluate influences of the single factors for future including to the mathematical model. There were used various combination of shaft speed and perturbation speed and the vibration spectra were recorded. It was found that the perturbation caused by even a small amplitude of centrifugal force could cause the very dangerous "oilwhirl vibration" even if the amplitude of vibration developed by perturbation itself is low. The simplified mathematical model suggested by Muszynska does not response the situation. This model was not in agreement with measured data. Another mathematical model should be used.*

Keywords: ***Oilwhirl, perturbation, threshold, spectra.***

1. Introduction

The oilwhirl phenomenon can occur under some circumstances in hydrodynamic bearing. This phenomenon could be very dangerous as the amplitude of vibrations is very high. It is a nonlinear phenomenon. The speed threshold of this phenomenon depends on many factors. The most important of them are the rotational speed, diameter of the journal, bearing gap, pressure of oil and its, viscosity etc. The amplitude of this vibration is very high and this phenomenon could cause severe damages.

2. Methods

The vibrations were measured on model RK4 rotor kit. The configuration can be seen in the picture. The shaft was loaded by two discs per 800 g located 60 mm from the bearing. There was a perturbation disc, which can rotate with the range 250 to 10 000 rpm as well as the shaft. The shaft diameter was 10 mm. The pressure in bearing is ensured by pump. The arranging is displayed in the Fig. 1.

Fig. 1: Rotor kit.

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Fig. 2: The bearing and perturbation disc.

The excitation was induced by rotating weight mounted in perturbation disc. The press in the bearing was 10000 Pa (=1,45 p.s.i). The journal-bearing diameter was 25 mm and the bearing gap was 0,25 mm. The signal was taken by eddy current sensors and using the datacollector MICROLOG CMVA 10 in was processed to proximity values in µm. (peak-peak) and the spectra were calculated by FFT (fast Fourier transformation). The signal from horizontal and vertical sensors was approximately the same, so the horizontal was chosen for processing. The bearing is displayed in the Fig. 2.

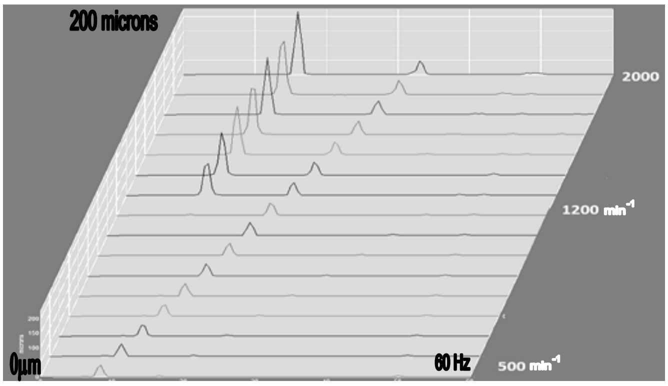

Fig. 3: Oilwhirl waterfall spectrum.

3. Measured data

First, the spectra were taken without any excitation by perturbation and waterfall of them can be seen in Fig. 3. The oilwhirl vibration arises at once at about 1300 revolution per minute. The amplitude of this vibration reaches 200 µm (almost the completely bearing gap). This amplitude comparing to the amplitude cased of imbalance, which was maximally 40 µm, was at least five times higher.

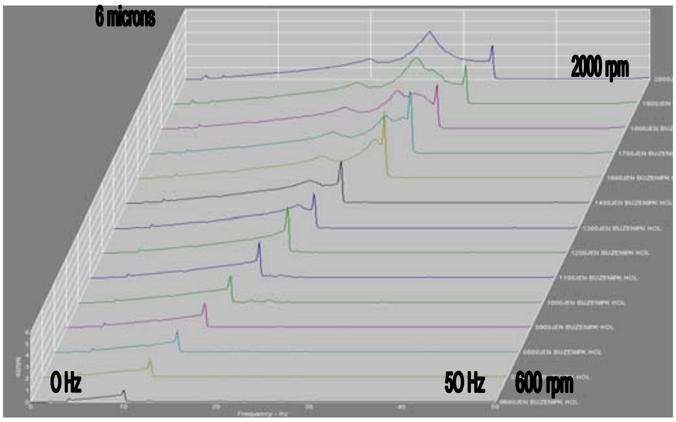

Fig. 4: Perturbation waterfall spectrum.

3.1. Perturbation

The speed of perturbation were run up and down slowly (acceleration 1000 revolution . min^{-2}) from 450 rpm to set value from 600 to 2000 rpm. The maximum amplitude was recorded on every frequency. When only the perturbation disc rotated and the shaft was stopped the highest amplitude of the vibration was only about 4 µm at most. The waterfall of series spectra caused only by ramping up perturbation could be seen in Fig. 4.

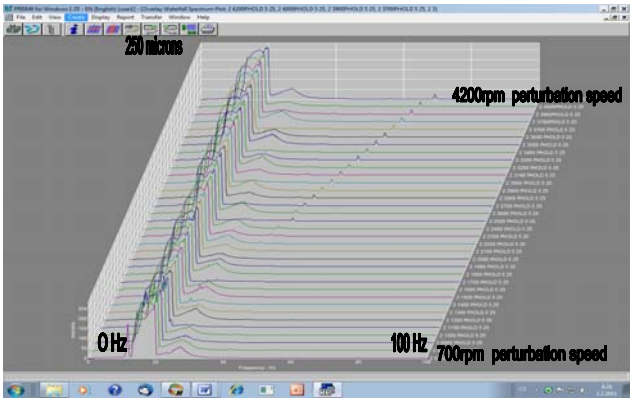

Fig. 5: Perturbation waterfall spectrum.

3.2. Perturbation with various shaft speeds

When the perturbation speed was set on, certain value and the shaft speed varied from 500 to 2000 rpm and only the pick values were hold on preset value. It is seen in the picture that perturbation has no significant effect when the oilwhirl phenomenon had already arisen no regardless its speed and amplitudes. From previous experiences, it is possible to suppress the phenomenon only when the perturbation amplitude is comparable with the amplitude of oilwhirl.

3.3. Combination of shaft speed with perturbation varied speed

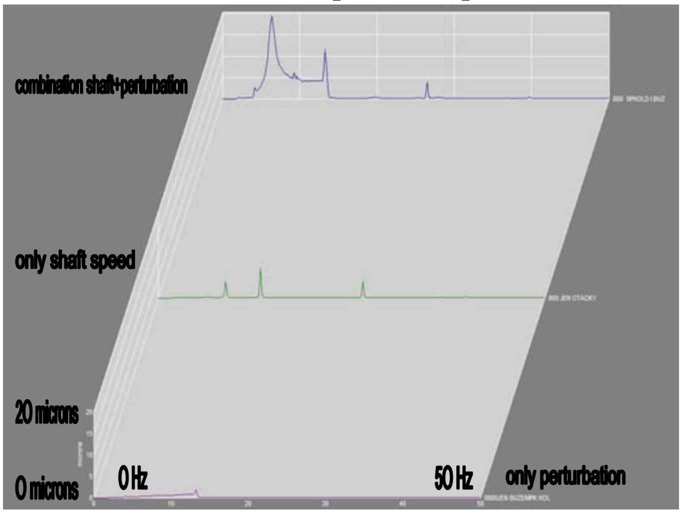

Fig. 6: Oilwhirl shaft speed 800 rpm.

The next measurements were done for given speed of shaft and varied speed of perturbation from 500 rpm of running shaft speed. The amplitude of perturbation was relatively very low. The shaft vibration without any excitation was also relatively low. The combination of perturbation and the shaft rotation led to uprising the vibration caused by oilwhirl phenomenon. This vibration occurs especially when the speed frequency of perturbation was approximately 0.48 multiply of the shaft running speed frequency. It even starts for much lower shaft speed.

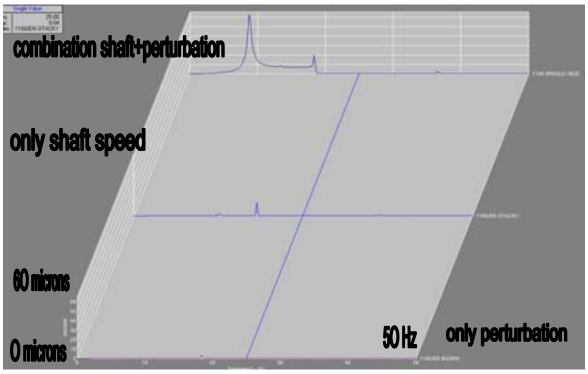

Fig. 7: Oilwhirl shaft speed 1100 rpm.

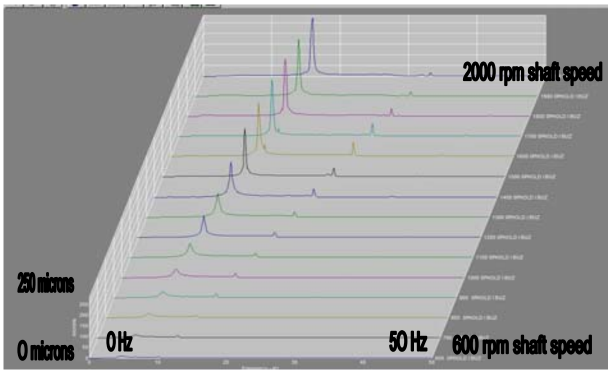

Fig. 8: Perturbation waterfall spectrum.

The waterfall spectrum, which could be seen in Fig. 8, shows the gradual genesis of the oilwhirl phenomenon, when the excitation using the perturbation is used.

4. Mathematical models

As the very first approximation was tested the equation of motion by Muszynska (2005):

$$-Kr+\left(D1\cdot\frac{dr}{dt}+i\cdot\lambda\cdot D2\cdot\omega s\cdot r\right)+ms\cdot rs\cdot\omega s^2\cdot e^{i\cdot(\omega s\cdot t+\delta)}+mp\cdot rp\cdot\omega p^2\cdot e^{i\cdot(\omega p\cdot t+\varepsilon)}+=M\cdot\frac{d^2r}{dt^2} \qquad (1)$$

Where: **K** is the spring stiffness coefficient (complex)
- **D1, D2** are coefficients of damping (complex)
- **ms**, is imbalance rotating mass with eccentricity **rs**
- **ωs** is angular speed of shaft
- **mp**, is rotating mass on perturbation disc with eccentricity rp
- **ωp** is angular speed of perturbation disc
- λ is fluid circumferential average ratio (usually about 0.48)
- **r** position of journal centre (complex)

The amplitude of r was assumed to be consist of to harmonic signals one with frequency of shaft speed and second with frequency of λ times shaft speed frequency. The determination of coefficients, which could be in good agreement with measured data, was impossible. So the different mathematical model should be used.

5. Conclusions

Oilwhirl is a phenomenon when oil film excites the vibration, when the relative eccentricity of shaft and the angle of shaft centre "push" the shaft circumferentially in bearing. The destabilization force in rotation direction causes the whirl. Oilwhirl is an unstable phenomenon as the centrifugal forces increase oilwhirl vibration, which again increase the centrifugal forces. This phenomenon can cause the destruction of machine.

The influence of various combination shaft speed and perturbation speed were tested and their influence on the oilwhirl phenomenon generation. It was found that when the frequency of perturbation is close to this of oilwhirl (approximately 0.48 times of shaft speed frequency) the vibration peak on this frequency occurs even for much lower shaft speed. This should be taken in account when there are other machines close the machine with hydrodynamic bearing which operate with speed close to the oilwhirl.

To understand the phenomenon it is necessary to suggest mathematical model, which could be in good agreement with measurement. The first suggested mathematical model was not convenient to describe the phenomenon.

Acknowledgement

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References

Muszynska, A.; Rotordynamic, (2005) Boca Raton Florida, ISBN 10-8247-2399-6.

Glenn D. White, (1997) Machine Vibration, DLI Engineering Corp., page 200. Bearing maintenance, Copyright SKF 1991, 332 pages.

Pochylý, F., Malenovský, F., Hlavoň, P. (1999) Hydrodynamic damper. National conference with international participation Engineering mechanics 99", Svratka 1999, pages. 199-202, (in Czech).

Malenovský, E. (1999) Computiona modeling of dynamic features for nonlinear rotor systems. Engineering mechanics, volume 6, pages. 411 – 426, (in Czech).