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OIL INFLUENCE OVER DYNAMIC STABILITY OF ROLLING BEARING AND HYDRODYNAMIC BEARING TURBOCHARGERS

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Abstract: *The dynamic stability of rotating machines can be influenced by some functional parameters than can in some functional conditions, rise or decrease the running performances of the rotating machines. One of the main parameters that can majorly influence the dynamic stability of the rotating machines is represented by the oil film. The objective of this study is to highlight some aspects related to oil film influence over the dynamic performances of diesel engines turbochargers rotors sustained by rolling bearings or hydrodynamic bearings. The study brings into audience attention some experimental data related to turbocharger rotordynamic stability, data gathered from test rig testing of modern turbochargers that can reach functioning speeds beyond 250000 rpm.*
Keywords: *rotordynamics, vibration, turbocharger, oil film, unbalance.*

1. INTRODUCTION

Modern turbochargers use as sustaining elements rolling bearings which have the major advantage that in comparison with classic hydrodynamic bearings can reach speeds that in some functioning cases reach 300000 rpm. The other major advantage that results from rolling bearing usage is related to bearing durability. In comparison with hydrodynamic bearings the usage life time of rolling bearings is much higher with approximately 25% [3], [4].

In order to obtain functioning performances at high speeds the turbocharger rotor has to be perfectly balanced and the oil film parameters have to be at the indicated scale in order to supply cooling agent (oil) at the level of the turbocharger rotor and also in order to supply additional damping to the turbocharger rotor system.

The oil film parameters are also important because they influence the self-centering phenomena that occurs at high speed at the level of all functioning rotating machines that have rotors sustained on hydrodynamic bearings [5], [6].

The study of the oil film parameters can provide properly information regarding the functioning conditions of turbochargers, showing the bearing wear scale of the bearings.

2. CONTENT

In order to accomplish the objective of the study there had been developed several test in order to identify the level of vibration amplitudes, tests performed on GARRETT GTV 2600 hydrodynamic bearing turbocharger and on GARRETT GTB 2260V rolling bearing turbocharger.

The tests were accomplished using the Bruel&Kjaer Pulse 12 vibration platform. In figure 1 it is presented the 6 channel acquisition platform and accelerometer connections to the platform.

Figure 1. Acquisition platform and channel set up

In order to have a sufficient precision of the measurements there were used 6 accelerometers mounted on the turbocharger in the following order:

- on channel 1 accelerometer no.1 mounted on the intermediate turbocharger housing near to the compressor wheel on X axis;
- on channel 2 accelerometer no.2 mounted on the intermediate turbocharger housing near to the compressor wheel on X axis with 90^0 phase shift form accelerometer no.1;
- on channel 3 accelerometer no.3 mounted on the intermediate turbocharger housing near to the turbine wheel on X axis;
- on channel 4 accelerometer no.4 mounted on the intermediate turbocharger housing near to the turbine wheel on X axis with 90^0 phase shift form accelerometer no.3;
- on channel 5 accelerometer no.5 mounted near to the bearing outer ring;
- on channel 6 accelerometer no.6 mounted near to the bearing outer ring with 90^0 phase shift form accelerometer no.5;

The placement of the accelerometers on the GTV 2260V turbocharger is presented in figure 2.

Figure 2. Accelerometer montage on to the GTV 2260 V turbocharger

The two turbocharger rotors subjected to study are presented in figure 3 a and b.

Figure 3a. Turbocharger rotor sustained by hydrodynamic bearing

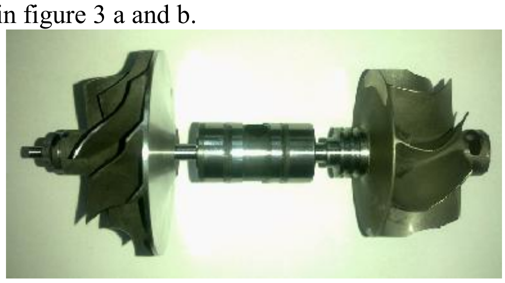

Figure 3b. Turbocharger rotor sustained by rolling bearing

In order to measure the amplitude given by the oil film whirl it had been performed several test at stabilized, accelerated and decelerated regimes at different rotor revolution speed like: 30000, 55000 and 90000 rpm considering these revolution speed to all of the above mentioned regimes.
The measurements performed on the rolling bearing turbocharger GTB 2260 V highlighted the fact that the oil film frequency is obtained at the frequency of 550 Hz, frequency obtained at measurements performed at 55000 rpm at stabilized regime.
In figure 4 there are presented the frequency obtained at 55000 rpm stabilized regime where we can observe the oil film frequency.

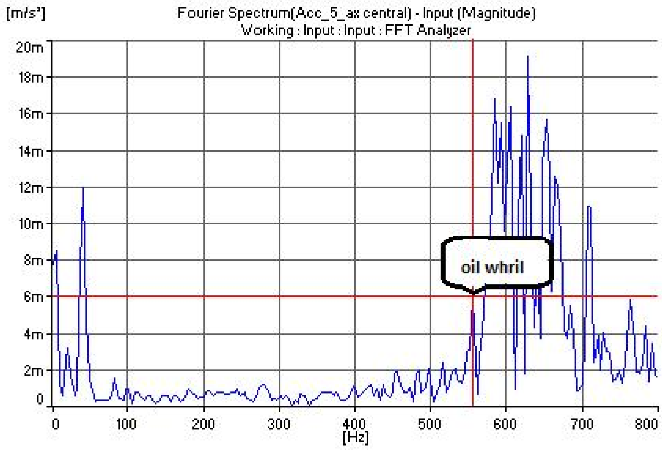

Figure 4. Oil film frequency at 55000 rpm stabilized regime for the rolling bearing turbocharger

Generally speaking the oil film frequency is obtained in measurements at 0.55X Hz from the fundamental frequency f_n given by the formula [1], [2]:

$$f_n = \frac{n}{60} = \frac{55000}{60} = 916.66\text{Hz} \tag{1}$$

In case of the measurements the oil film frequency is obtained at 0.6X from the fundamental frequency given by the revolution speed.
In order to determine the oil film frequency of the hydrodynamic bearing turbocharger rotor the measurements and the accelerometer montage on to the turbocharger where maintained the same with the ones considered for the rolling bearing turbocharger.
For the case of the hydrodynamic rolling turbocharger rotor the oil film frequency is presented in figure 5.

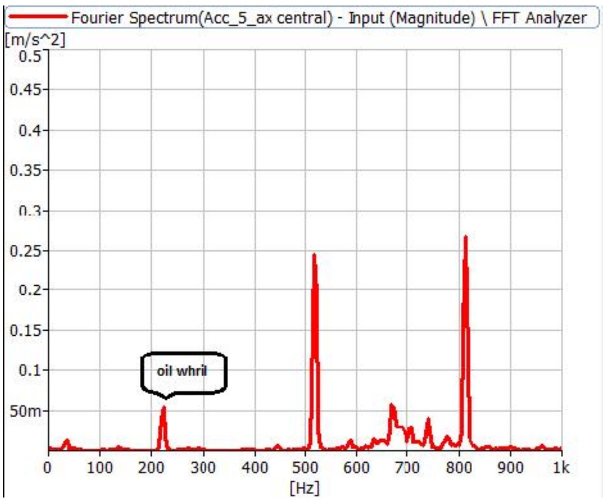

Figure 5. Oil film frequency at 30000 rpm stabilized regime for the hydrodynamic bearing turbocharger

In the case of the hydrodynamic bearing turbocharger the obtained oil film frequency was found at the value of 0.45X Hz from the fundamental frequency given by formula 1.
The measurements performed by specialists in the field of turbocharger rotordynamics found that oil film frequency is obtained at 0.55X Hz [7] from the fundamental frequency.

It is to be mentioned that the two turbocharger rotors subjected for analysis in this study where considered for the similarity between the two regarding mass, turbocharging properties and rotors geometric data.
The tests accomplished on both turbocharger rotors highlight the fact at only at certain functioning regimes the oil film frequency can be observed, because of the multitude of the vibration sources that can be tricky in real vibration source identification.

3. CONCLUSION

Oil film frequency can be found only on certain functioning regimes. It is very important to correctly identify the oil film frequency in order not to confuse the vibration sources that can be found during monitoring the rotating machines in this case the turbocharger. High vibration amplitudes denote some aspects related to malfunctioning of turbocharger rotor assembly including bearings (hydrodynamic or rolling bearings).
The measurements accomplished in this study are accurate, fact highlighted by the comparison of the gathered data with data sets obtained by other studies performed by specialist in the field of rotordynamics [7].
The oil film has major relevance in the self-centering phenomena that occurs at high revolution speed that turbochargers reach during functioning.
The self-centering phenomena is important for the hydrodynamic turbocharger because if the self-centering phenomena does not occur the rotor could function on semi viscous friction an unwanted friction domain because of the damages that this phenomena induces to the life time of the turbocharger rotor in general.
If we refer to rolling bearing turbocharger the oil film is important because the oil film influences the contact type between the ball and the outer/inner ring of the bearing. The contact type between these two elements is important because if the oil film does not exist the friction is dry and at the level of the bearing at high speeds can appear the micro welding phenomena when the bearing is rapidly and permanently damaged.
The study highlighted the fact that level of amplitudes of the oil film are strongly different for the two considered turbocharger rotors, fact highlighted in figures 4 and 5.

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