Resonance Analysis

A Vertical Pump Case History

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Key words:
Resonance, pump, vibration, impact test, stiffness, structure

Background:

The case history in this article is for a vertical cooling water pump delivering seawater from a bay to a power plant's heat exchangers. The maintenance activities implemented based on vibration analysis were quite inexpensive and brief in time which could not be achieved without the proper vibration tests.

The vibration technician reported vibration increasing trends on this machine from the periodic survey. The machine had a PM a few months ago while the standby pump is planned to have the PM soon. This put some constrains on both analysis and the recommendation. Operation parameters of the pump and motor, including pressure, flow and current were normal. No abnormal sounds were noticed. A schematic drawing for the machine structure is given in Figure 1 along with the points at which the data was collected. The synchronous speed of the motor is 600 rpm.

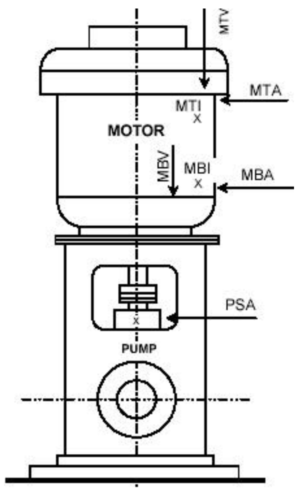

Figure 1 Schematic of the machine

Vibration Data:

Table 1 summarizes the unfiltered vibration reading on six points, as their locations are indicated in Figure 1. A trend of the highest vibration point (MTA) is given in Figure 2. From the trend it can be noticed that the majority of the vibration signal is synchronous (1x Rpm) vibration. This was confirmed also by corresponding spectrum of the same point in Figure 3.

Table 1 Unfiltered vibration data on 26 May

Motor Top In-line (MTI), ips 0-p	Motor Top Across (MTA) , ips 0-p	Motor Top Axial (MTAx) , ips 0-p
0.20	0.41	0.04
Motor Bottom In-line (MBI) , ips 0-p	Motor Bottom Across (MBA) , ips 0-p	Motor Bottom Axial (MBAx) , ips 0-p
0.12	0.12	0.04

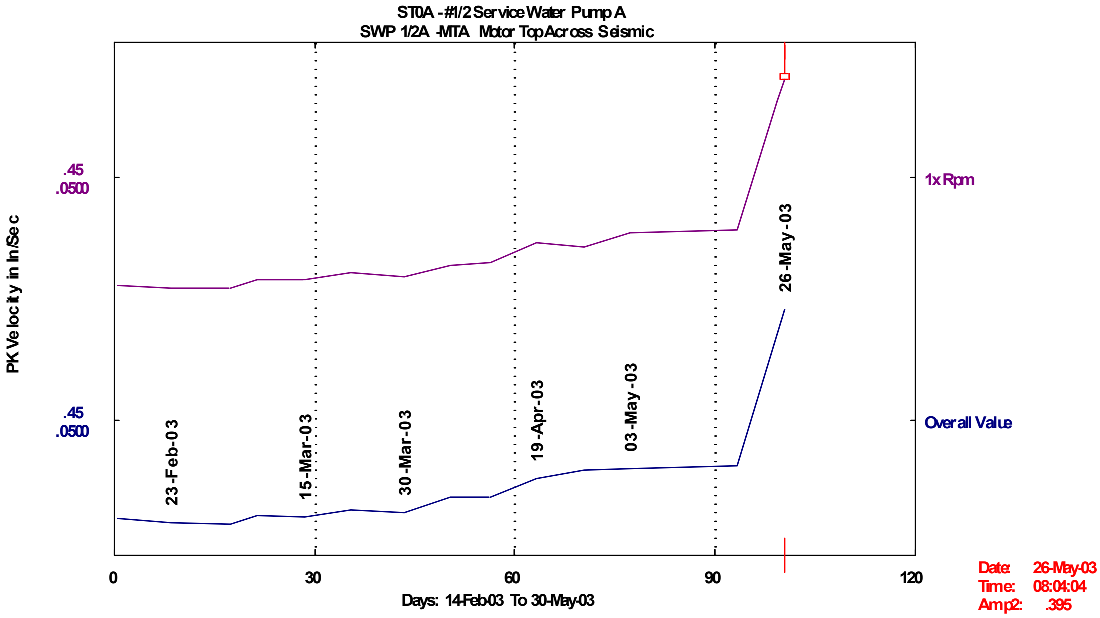

Figure 2 Unfiltered and 1x vibration trend

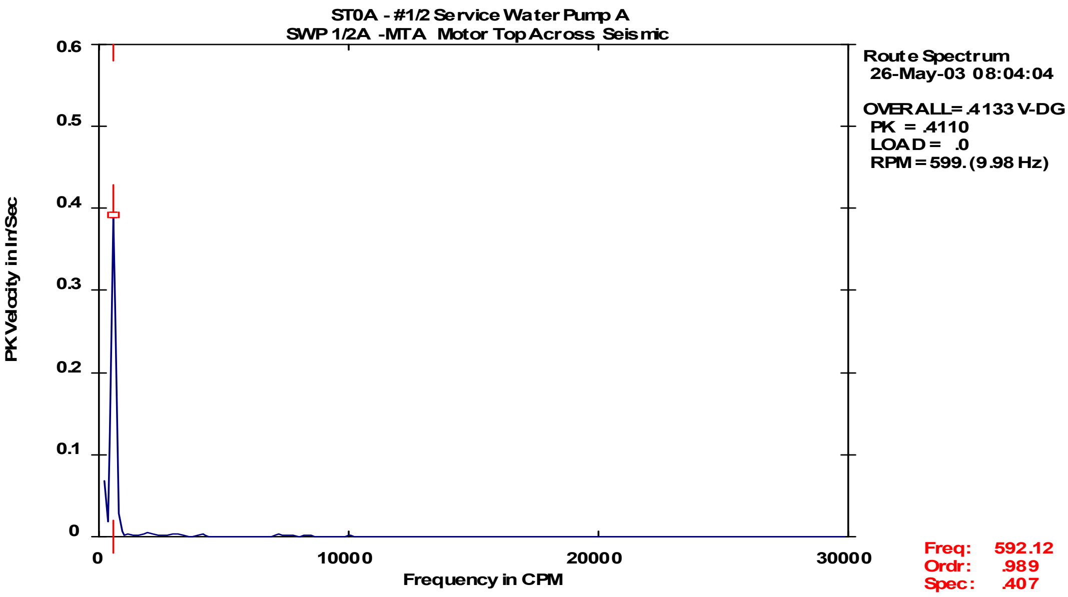

Figure 3 Vibration spectrum from routine survey

Analysis:

Vibration reading was collected on the monitor mode to check the stability of the signature and no abnormalities were noticed. To confirm the exact frequency at which the vibration is taking place and examine the existence of any other significant frequencies, a high resolution data was collected with 3200 lines, as shown in Figure 4. The resultant spectrum showed single amplitude at the running speed.

The amplitude difference between the response of the two radial readings (MTI and MTA) gave a hint for a problem related directional force or stiffness. Coupling alignment as per Maintenance records were within tolerance after installation. Motor bottom bearing and coupling temperatures were normal (measured using a temperature gun). So realignment was not considered as a first action. Rather, motor was shut down for visual inspection and impact test.

No abnormalities were found after the visual inspection and the impact test spectrum is given in Figure 5. It is very clear from the impact test that the structure natural frequency was coinciding on the running speed casing vibration amplitudes to magnify due to resonance. Engineering reports recorded that this pump after the current installation had a natural frequency of 700 cpm and cautioned that the natural frequency of the sister machines is higher (800 cpm). The conclusion that could be drawn is that the stiffness of the structure was initially low and gradually decreased and pushing the natural frequency down closer to the running speed 600 rpm, as described by the basic formula:

$$Natural\ Frequency = \sqrt{\frac{Stiffness}{Mass}}$$

Corrective Action:

The corrective action was to raise the natural frequency above the running speed by identifying the location of the low stiffness parts of the structure. These locations are typically the "joints" like the motor-motor stool bolts and the motor stool-ground studs. By tightening the bolts and studs, the problem was found to be corroded and loose studs and nut as can be seen from the picture (Figure 6). A temporary solution was to replace the studs and nut while the permanent solution was recommended to perform a civil work in the concrete foundation. The foundation was physically deteriorated because of the more water contamination and settlement than sister machines in the same. After replacement, vibration dropped to about 15 % of the previous readings.

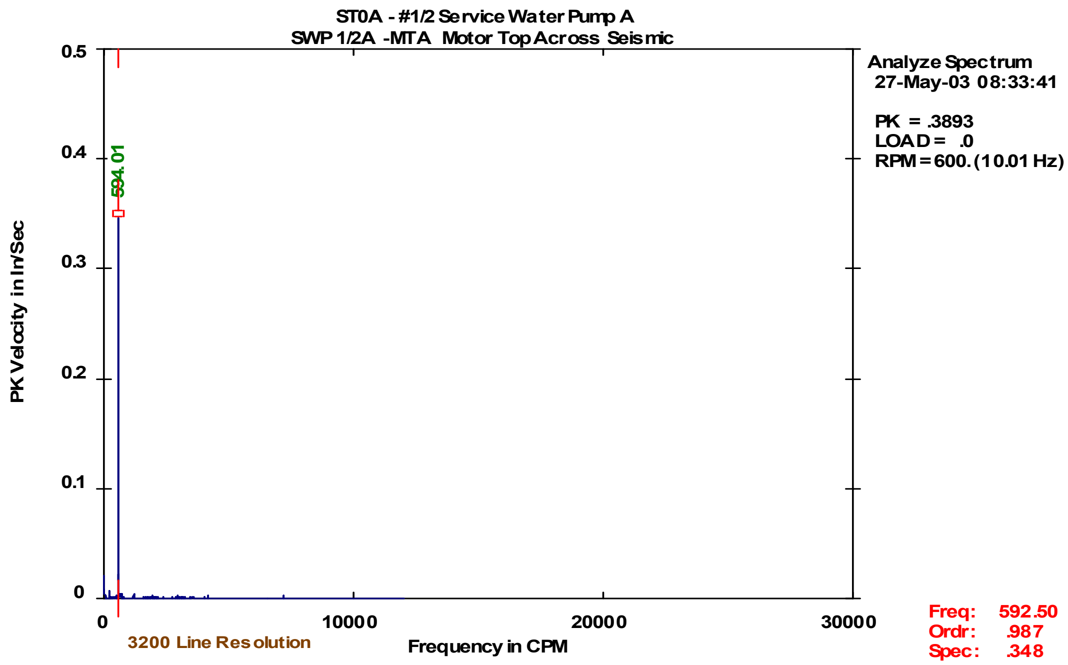

Figure 4 High resolution spectrum showing exact 1x vibration response

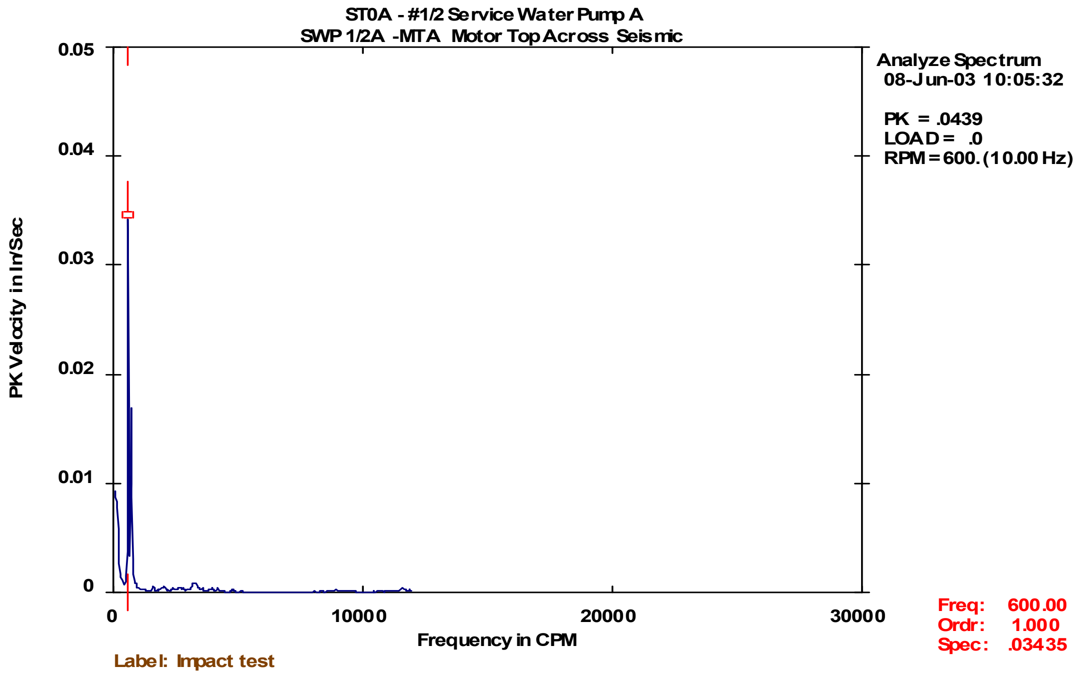

Figure 5 Spectrum of impact test showing 600 cpm natural frequency

Figure 6 Physical deterioration in the foundation, bolts and nuts