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Mechatronics technology in predictive maintenance method

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Abstract. This paper presents recent mechatronics technology that can help to implement predictive maintenance by combining intelligent and predictive maintenance instrument. Vibration Fault Simulation System (VFSS) is an example of mechatronics system. The focus of this study is the prediction on the use of critical machines to detect vibration. Vibration measurement is often used as the key indicator of the state of the machine. This paper shows the choice of the appropriate strategy in the vibration of diagnostic process of the mechanical system, especially rotating machines, in recognition of the failure during the working process. In this paper, the vibration signature analysis is implemented to detect faults in rotary machining that includes imbalance, mechanical looseness, bent shaft, misalignment, missing blade bearing fault, balancing mass and critical speed. In order to perform vibration signature analysis for rotating machinery faults, studies have been made on how mechatronics technology is used as predictive maintenance methods. Vibration Faults Simulation Rig (VFSR) is designed to simulate and understand faults signatures. These techniques are based on the processing of vibrational data in frequency-domain. The LabVIEW-based spectrum analyzer software is developed to acquire and extract frequency contents of faults signals. This system is successfully tested based on the unique vibration fault signatures that always occur in a rotating machinery.

Keywords. Condition monitoring, lab-VIEW based spectrum, signal analysis

1. Introduction

Mechatronics engineering involves multidisciplinary branches of engineering studies that is capable of providing the necessary skills to install, calibrate, modify, troubleshoot, repair and maintain automated systems [1]. In industrial applications, most of the equipment or machinery are exposed to external vibration, especially in rotating machinery. Machine condition monitoring is the process of monitoring the condition of a machine with the intention to predict mechanical failures. Vibration is a key indicator of the state of the machine and widely used for predictive maintenance. Hence, a simulation rig, incorporating mechatronics technologies such as sensors, actuators, signal processing and control, is vital to understand and implementation predictive maintenance[2].

The basic maintenance strategies can be divided into three parts which are breakdown maintenance, preventive maintenance and predictive maintenance [3]. No actions or maintenance will take place until the design life is reached in breakdown maintenance. It is a reactive process and thus, it is unable to prevent downtime from happening. On the other hand, preventive maintenance is performed on a schedule basis. However, predictive maintenance focus on periodic or continuous equipment



condition monitoring which can eventually help in reducing the cost. It aims at knowing the earliest possible occurrence of damage to a unit in order to prevent equipment breakdown that could lead to stagnation of a production process [4].

Vibration signals produced by rotating machinery contains information on the nature of the fault [5]. The parameters needed for vibration indicator are listed in Table 1 [6].

Table 1 Parameter needed for machine health assessments

Fault	Parameters				
	Temperature	Pressure	Flow	Oil Analysis	Vibration
Out Of Balance					x
Misalignment Bent Shaft	x				x
Damaged Rolling Element Bearings	x			x	x
Damaged Journal Bearings	x	x	x	x	x
Damaged Or Worn Gears				x	x
Mechanical Looseness					x
Noise					x
Cracking					x

Effective vibration analysis starts with obtaining an accurate signal from standard vibration transducer with the help of an accelerometer. The analog signal is then converted into digital signal using analog to digital converter. The digital signals can be processed directly or using formula defined by the user.

In this paper, Vibration Fault Simulation System (VFSS) is introduced to further improve the understanding of vibration fault signals. Here, Vibration Fault Simulation Rig (VFSR) is developed to study the different maintenance techniques as well as for further development of vibration faults system. LabVIEW software is used to acquire the experimental data. This paper is organized as below: Section 1 provides the introduction to mechanical health whereas Section 2 discusses on the Vibration Fault Simulation System (VFSS). Sections 3 and 4 presents the experimental setup and results.

2. Vibration Fault Simulation System (VFSS)

The design proposed in this paper aims at detecting the unique vibration faults signatures of a rotating machine. To facilitate the detection of mechanical defects in digital format, the mechanical vibration of the motor is converted to electrical analog signals by a sensor. This model of vibration faults can be used for the purposes to study vibration pattern in various faults and as a training equipment for technical staff and engineering students in vibration monitoring and analysis of rotating machinery [6].

The fault simulation that occur in a rotating machinery are imbalance, misalignment, mechanical looseness, bearing fault, bent shaft, missing blade, balancing and critical speed. The system is divided into four subsystems, which are:

- i. Main shaft system - to simulate imbalance, angular misalignment, parallel misalignment, mechanical looseness, bearing fault and missing blade.
- ii. Bent shaft system - to simulate bent shaft faults.
- iii. Balancing mass system - can simulate balancing faults.
- iv. Critical speed system - to simulate critical speed in rotating machinery.

2.1. Main shaft system setup procedures

The setup of the main shaft system can be describe in the following steps:

1. Insert rotor disc through the shaft (10 mm diameter) and slot the shaft through the bearing 1 and bearing 2 as shown in Figure 1.
2. Before tightening its setscrew, slot flexible coupling to the shaft.
3. Tighten the setscrews of rotor disc after placing it in the middle of shaft.
4. The propeller was slotted at the end of the shaft and tighten its setscrews.

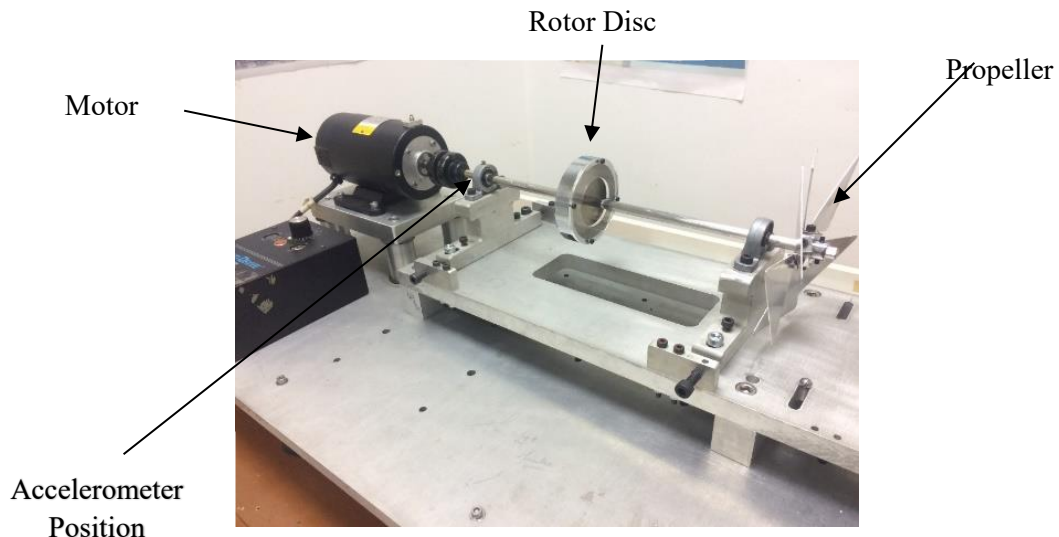


Figure 1 Main shaft system.

3. Methods of simulation

Vibration fault signals will be sent into Data Acquisition (DAQ) device where it will be used to interact or to read the accelerometer signal before being analyzed and displayed by the LabVIEW software. Every fault in the rotating machine has its own unique signature that can be detected and analyzed. For every fault, the result recorded is in the form of frequency analysis. All the simulations were done using the procedures explained in the Table 2.

Table 2 Methods of simulation.

Machinery Faults	Procedures
Imbalance	<ol style="list-style-type: none"> 1. The accelerometer will be mounted to the bearing 1. 2. Then, run the motor and view the spectrum display. 3. While the motor is running, drop the ball into rotor disc to create the imbalance faults. 4. Lastly, view the new spectrum display and record the new data.
Mechanical Looseness	<ol style="list-style-type: none"> 1. Run the motor at some speed and view the spectrum display. 2. To create the mechanical looseness, slowly loose the screws at the bearing base stand. 3. Lastly, view the new spectrum display and record the new data.

4. Results and analysis

1. Normal Spectrum:

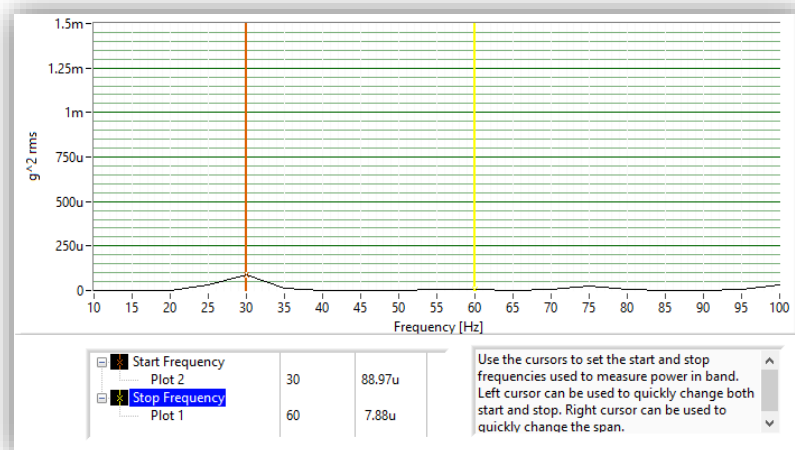


Figure 2 Spectrum analysis for normal spectrum.

Figure 2 shows the result for normal spectrum of the VFSR when there is no faults occurs on the VFSR. The motor is run at 52% of its maximum speed (3450 rpm) which is at 1794 rpm. In frequency domain, 1794 rpm is equivalent to 30 Hz. It can be observed from the graph that the first peak exists at 23 Hz (which means 1 time running speed), while the second peak exists near 60 Hz (2 times running speed). The peaks are found not accurately at the 30 Hz and 60 Hz due to noise disturbance from the surrounding during experiment.

2. Imbalance:

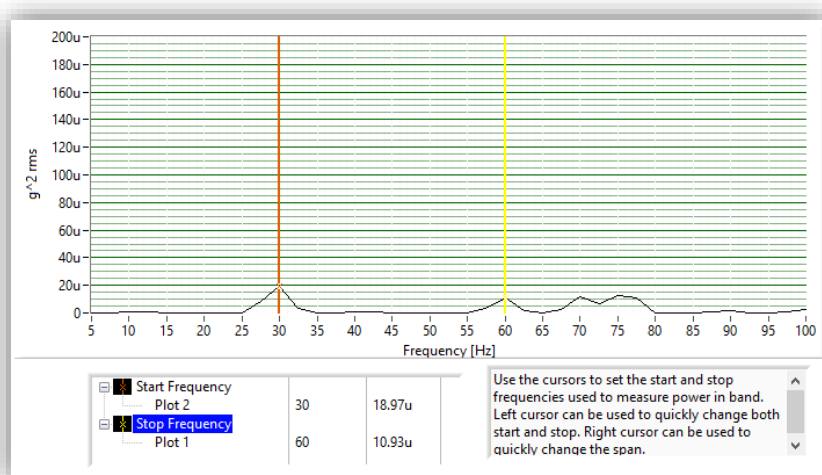


Figure 3 Spectrum analysis for imbalance (rotor disc).

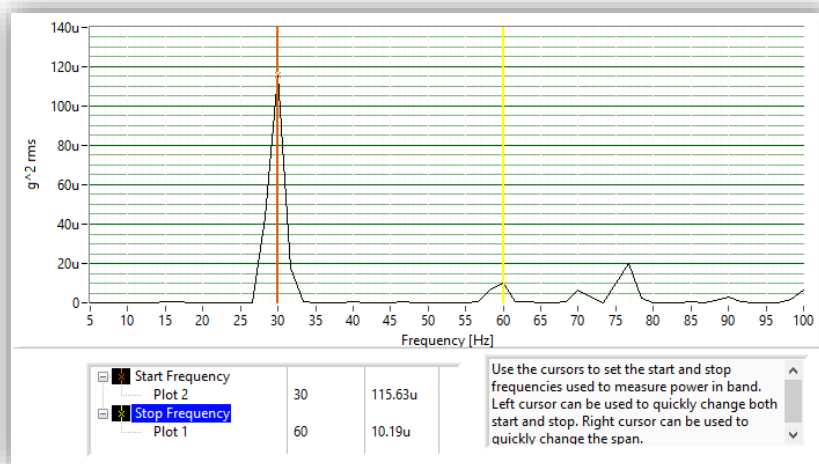


Figure 4 Spectrum analysis for imbalance (rotor disc and ball).

Figure 3 shows the spectrum for imbalance with rotor disc only. It can be observed that the peaks are found at 30 Hz (1 time running speed) and 60 Hz (2 times running speed). When the ball is drop into the rotor disc, the ball allocated itself at the hole inside the rotor disc during rotation. This causes unbalance force and the spectrum is shown in Figure 3. The amplitude due to unbalance compared to Figure 4. Theoretically, the peak at 1 time running speed always present and dominates the spectrum.

Mechanical Looseness:

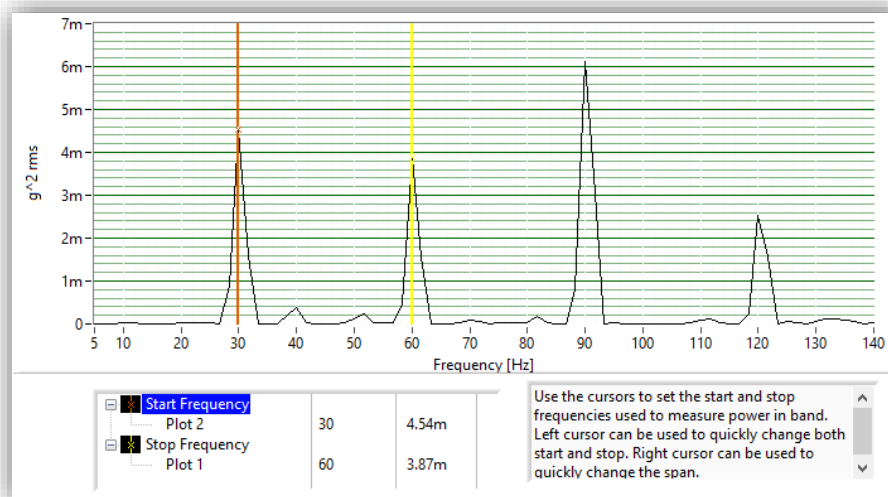


Figure 5: Spectrum analysis for mechanical looseness.

Figure 5 shows the spectrum of mechanical looseness. From the spectrum analysis above, the signal produced harmonically when there is some mechanical looseness occurs at VFSR. The signature occurred due to the improper fit between the bearing base and the plate base cause due to non-linear response of loose parts to the dynamic forces from the motor. From the figure above also, the harmonics

occur starting from 30 Hz (1 time running speed), 60 Hz (2times running speed), 90 Hz (3 times running speed), 120 Hz (4 times running speed) and etc.

5. Conclusion

Condition monitoring is the best way to monitor and observed the condition of a machine, especially for rotating machine. Vibration of the rotating machine is the best parameter to be monitored as each fault has its own unique signature. The early stage of a failure can be detected and the real failure of certain part of rotating machine can be predicted. Vibration Fault Simulation System (VFSS) is an application of mechatronics technology, which can be used in predictive maintenance. This paper presents the unique vibration fault signatures that occur in a machine by using a sensor to detect the spectrum of rotating machine. Also, the design of the Vibration Faults Simulation Rig (VFSR) has been proven to work well. In addition, t LabVIEW software is used to simulate common vibration faults.

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