Analysis of Whirl Speed of Rotor-bearing System Supported on Fluid Film Bearing

by

Usamah Azman

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

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(Dr. Varaha Venkata Lakshmi Narasimha Rao Tad)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

Sept 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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USAMAH AZMAN

ABSTRACT

This proposal outlines the background of the project “Analysis of whirl speeds for rotor bearing systems supported on fluid film bearings”. Most of high speed rotating machinery such as turbines and rotary compressor use both journal and thrust bearing configuration. However, in practice, only journal bearings play a significant factor in rotor whirling and vibration. When bearing fails or shows sign of distress, it is important for the engineer to recognize and make corrective adjustment before catastrophic failure of the entire machinery occurs. This explain the purpose of this study which is to provide analysis of whirl speeds for rotor bearing systems supported on fluid film bearings. Further details are explained in Chapter 1.

Literature reviews regarding the above project are presented in Chapter 2. The history and various types of motor and bearings are discussed. The perusal of literatures indicate that most studies on whirl speeds for rotor bearing systems supported on fluid film bearing use Finite Element Methods and test bench simulations. However, in this study the approach is based solely on test bench simulations. Based on the availability of test bench provided by the Universiti Teknologi PETRONAS, few simulations are conducted and tested. The methodology used is based on literature review and method proposed by software and hardware manufacturer of the related test bench. The results produced by the simulation indicate that few diagnosis and analysis can be obtained.

ACKNOWLEDGEMENT

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Finally, the author would like to extend her appreciation to Universiti Teknologi PETRONAS for providing the facilities and many learning opportunities, and to his family especially his parents and friends who constantly support her throughout the project.

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CHAPTER 1

INTRODUCTION

Problems usually associated with high performance rotating machinery can be traced either to rotating elements and rotor support system, faulty bearing designs or misapplication of bearing configuration. Most of high speed rotating machinery such as turbines and rotary compressors use both journal and thrust bearing configuration. In practice, as stated by Courtney and Todd (2009), only the journal bearings play a significant factor in rotor whirl and vibration. When bearing fails or shows sign of distress, it is important for the engineer to recognize and make corrective adjustment before catastrophic failure of the entire machinery occurs. Therefore, it is important to have proper understanding on how fluid film bearings such as journal bearing works and some basic principles that underline their operation.

Fluid film bearings which are also known as hydrodynamic bearings constitute one of the most critical components of all rotating machinery. There are two types of fluid film bearings; fluid dynamic and hydrostatic bearings. Fluid dynamic bearing consists of stationary cylindrical body (sleeve) which supports the bearing's load such as rotor solely on thin layer of liquid or gas. Fluid dynamic bearings rely on the high speed of the journal (the part of the shaft resting on the fluid) to pressurize the fluid in a wedge between the shaft or rotor and bushing, thus preventing metal to metal contact. Hydrostatic bearings, on the other hand, rely on externally pressurized fluid bearing done by a pump.

Literature suggested that there are several classification of rotor whirls in many rotating machinery. Among causes associated to the whirling rotor are due to different motor forces such as centrifugal force due to its unbalance rotors, the oil film force on the lubricated journals bearing, the work fluid applied on the disk of rotor, the internal damping force in the rotor shaft and the rubbing friction applied on the tip of rotor. Literature also classified rotor whirls into two types; synchronous whirls and non-synchronous whirls.

Some of the fluid film bearings configuration are susceptible to large amplitude, lateral vibration due to a “self-excited instability’ known as oil whirl (Figure 1.1). Oil whirl is independent from centrifugal force of rotor unbalance or misalignment. The oil whirl is caused by the forces generated in the fluid oil film due to the hydrodynamic action. During self-excited instability the rotor orbits in its bearing at a frequency approximately half of the rotor angular speed. If this condition left untreated, this non-synchronous rotor whirl will lead to rotation speed exceeding the threshold speed and, eventually may lead to catastrophic bearing failure.

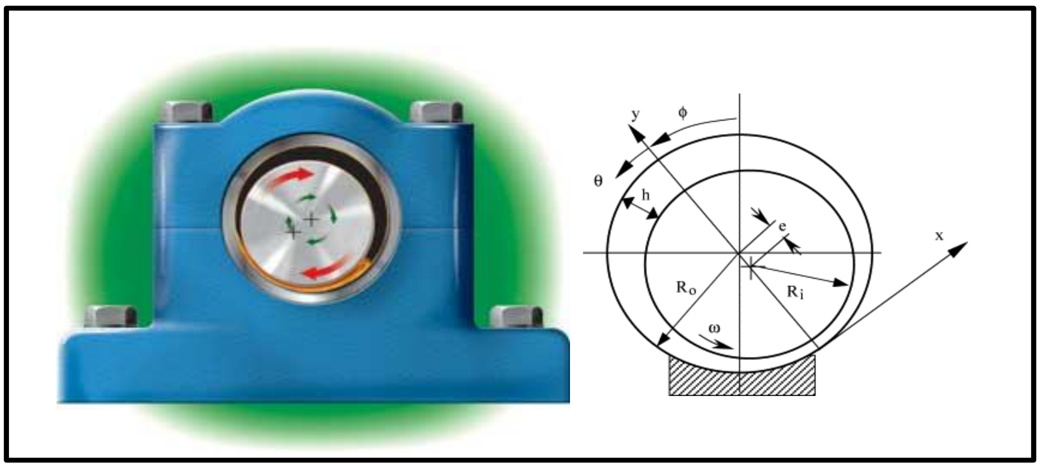


Figure 1.1: Abnormal behaviour of hydrodynamic journal bearing. Oil whirl and whip instabilities.

Literature also observed that at the onset of self-excited instability, rotor behavior is unlike critical speed resonance where the amplitude of motion builds up as the rotor reaches its critical speeds and then decreases as it passes critical speed (Khonsari and Booser, 2013). At the inception of non-synchronous whirl, the amplitude of rotor motor motion often passes through a maximum critical speed and never dies down. If this amplitude of whirling vibration is excessive then the catastrophic failure occurs.

Since the discovery of this phenomenon by Newkirk in 1925, many studies have been conducted to have better understanding and prediction on the onset of this non-synchronous whirling. Several numerical approximations have been successfully developed to analyse the dynamic behavior of rotating machinery. There are several approaches in solving and modeling complicated rotating machinery systems. Sunar and Shurafa (2011) suggest that the diagnostic of oil whirl and whip can be summarized as the following:

- High amplitude, reaching machine safety limit
- Sub-synchronous frequency as observed in the frequency spectrum
- Circular or nearly circular orbits.
- Forward precession, observed in full spectrum plots.

The virtue of modern technology such as computer technology enables the solving and fault diagnosis of complicated rotating machinery is less complicated. This view is supported by Zhang, Zhou, Guo and Yan (2013), that shaft orbit of the rotor often shows some fault information. The shape and feature of shaft orbit can be extracted by the measurement and analysis of the shaft orbit through available computer software. Zhang et al. (2013) suggested that the system of data acquisition and analysis based on LabVIEW software and hardware which is available at Universiti Teknologi PETRONAS own laboratory could be used to diagnose the rotating machinery.

The main purpose of this paper is to analyze whirl speed for rotor bearing systems supported on fluid film bearings. In this study, the analysis and fault diagnosis is based on experimental and simulation of the test rig based on LabVIEW software and hardware. In the light of the purpose above, the work of

Kalita and Kakoty (2003), Sunar and Shurafa (2011) and particularly the work of Zhang, Zhou, Guo and Yan (2013) will be used as the main source of references.

1.1 Problem Statement

Rotor mounted on thin fluid film bearings can experience fluid induced instabilities that manifest as severe whirls speed effects on rotors. Uncontrolled whirl in this type of equipment are of substantial concern to the engineers due to its limited safety limit and inefficient equipment operation. This phenomenon also, if left untreated may lead to other consequences such as equipment damage and loss of lives. When machine fault occurs, the shaft orbit of a rotor often contains some faults phenomena to a certain extent. Understanding various factors and their effects to the stability of rotor mounted on thin fluid film bearing are therefore, to be beneficial to both the design and analysis aspects of the instability problems.

1.2 Objective

i. To describe the dynamics of the rotor mounted on thin fluid film bearings.

ii. To model the rotor fault simulation test bench based on LabVIEW software and hardware system based on the work of Zhang, Zhou, Gou and Yan (2013).

iii. To analyze the results of simulation and compared with the previous works done by other researchers.

1.3 Scope of Study

This study was conducted to determine the analysis of whirl speeds for rotor bearing systems supported on fluid film bearings based on the machine fault simulation test bench set up at the block 18's laboratory at the Universiti Teknologi PETRONAS. The test bench set up was designed to simulate a number of machinery malfunctions. The machinery malfunctions simulations were limited to altering of disks locations and shaft lengths. The simulations of the shaft orbits and rotor faults, data acquisition, fault diagnosis and pattern recognition were based on the work of Zhang et al. (2013) and LabVIEW software and hardware manufacturer's modules.

CHAPTER 2

LITERATURE REVIEW AND THEORIES

2.0 Introduction of rotor dynamics

The subject of rotor dynamics as suggested by various literatures is a specialized branch of applied mechanic concerned with the behavior and diagnosis of rotating structures (Tiwari, 2008). The rotating structures are ranging from jet engines and steam engines to cars' engines and computer disk storage. The most basic level of rotor dynamic is related to one or more mechanical structures (rotors) supported by bearings and influenced by internal phenomena that rotates around single axis. If the speed of rotation is not operating at the correct speed ranges, the amplitude of vibration will occur. This amplitude which is commonly excited by unbalance of the rotating structure may result in catastrophic failure if the amplitude of vibration is excessive.

For better understanding of basic phenomena of dynamic system, literatures classified their behaviour into four types (Tiwari, 2008).

- Single DOF Rotor Model
- Rankine Rotor Model
- Jeffcott Rotor Model
- Rigid Rotor Supported on Flexible Bearings
-

However, for the purpose of this paper, only single DOF Rotor Model will be elaborated.

2.1 Single DOF Rotor Model

According to Tiwari (2008) this is the simplest of the rotor system that can be classified in the following table:

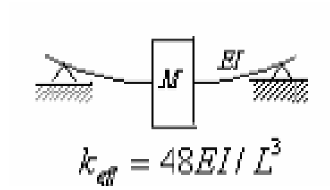
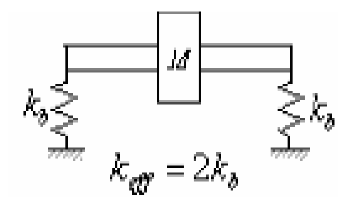
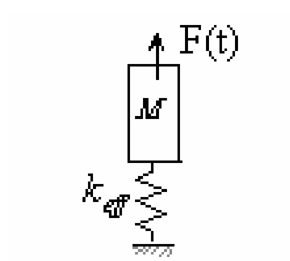
1) The bearing is assumed to be rigid (simply supported) and the shaft is flexible. A flexible rotor mounted on rigid bearings	
2) The bearing is flexible and the rotor is rigid. A rigid motor mounted on flexible bearings	
3) The combination of the above cases. An equivalent of single degree of freedom spring mass system	

Table 2.0 Single DOF Rotor Model. Adapted from Tiwari (2008)

Tiwari (2008) suggested that analysis and calculation of single DOF Rotor Model that can be applied to the transverse, torsional and axial vibrations of rotors. As discussed earlier, the unbalance response of rotor can be reduced by the following method:

1) Correction at the source. According to Tiwari (2008), there are two types of unbalance, static and and dynamic unbalance. In static unbalance, the principal axis of the polar mass moment of inertia of the rotor is parallel to the centerline of the shaft as shown in Figure 2.0b. The rotor can be balanced by a single plane balancing. In Figure 2.0c & d, the dynamic unbalance is when the principal axis of the polar mass moment of inertia of the rotor is inclined to the centerline of the shaft. In this case, the rotor can be balanced by a minimum of two planes. The classification of unbalances for a short rigid rotor is provided in the following figure:

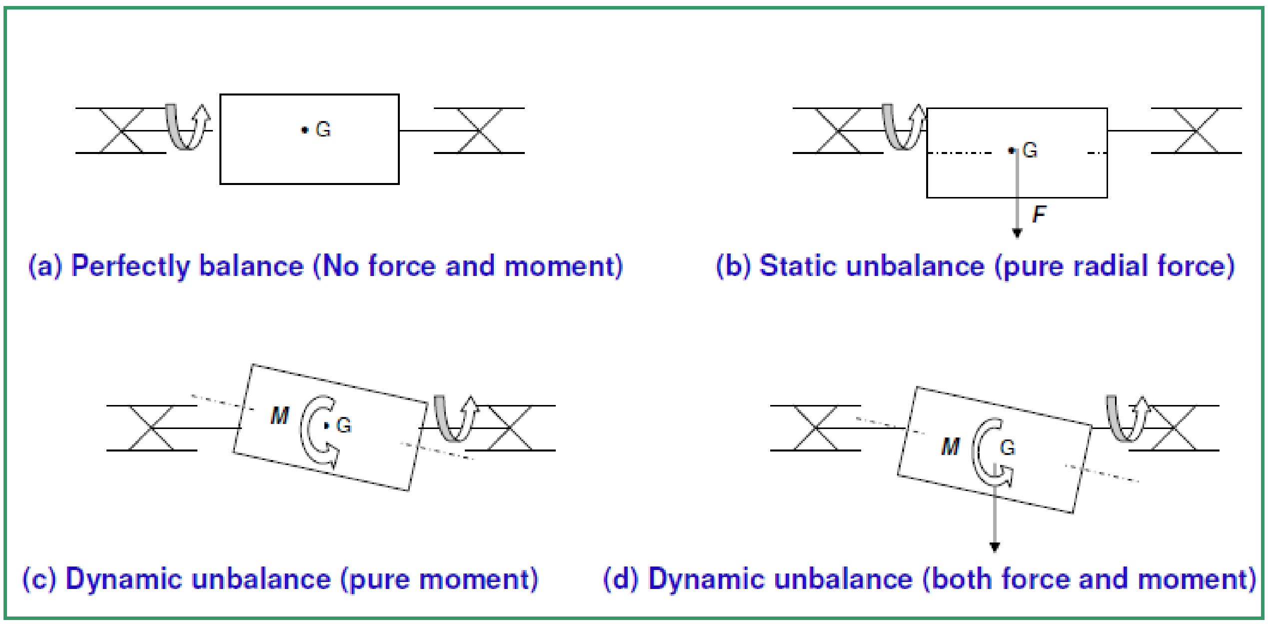


Figure 2.0. Classification of unbalances for a short rigid rotor. Adapted from Tiwari (2008).

2) Operate rotor away from critical speed. Tiwari (2008) suggested that by moving the rotor operating speed farther away from critical speed, the unbalance response of rotor can be reduced. The critical speed can be altered either during operation or at the design stage. In order to alter the critical speed, the rotor mass or its distribution and dimensions of the rotor and its support lengths can be changed at the design stage.

3) Add damping to the system or active control of the rotor. The most effective way to reduce the amplitude of the synchronous whirl is to add damping if machine operation near a critical speed can not be avoided.

2.2 Bearing system

According to Kalita et al. (2004), bearings are "Designed to transfer pure radial loads, or a combination of the two between two objects one rotating relative to the other." Although there are numerous type of bearings, for the purpose of this paper, we will only discuss one particular type of bearing, that is journal bearing. Journal bearings system are made up of a circular section of shaft, the journal that are rotating inside a bearing bush (Figure 2.1). As there is 0.1-0.2% of space between the two surfaces is partially filled by the lubricating fluid (Courtney et al. (2009).

The journal was rested at the bottom of the bush when the journal is at rest. However, when it rotates, the lubricant is drawn up around the journal due to the effect of what is called elestrohydrodynamic lubrication. Kalita et al. (2004) further illustrate that as "as viscosity is exponentially related to pressure, a large increase in viscosity occurs between the journal and bush creating a thin film preventing contact."

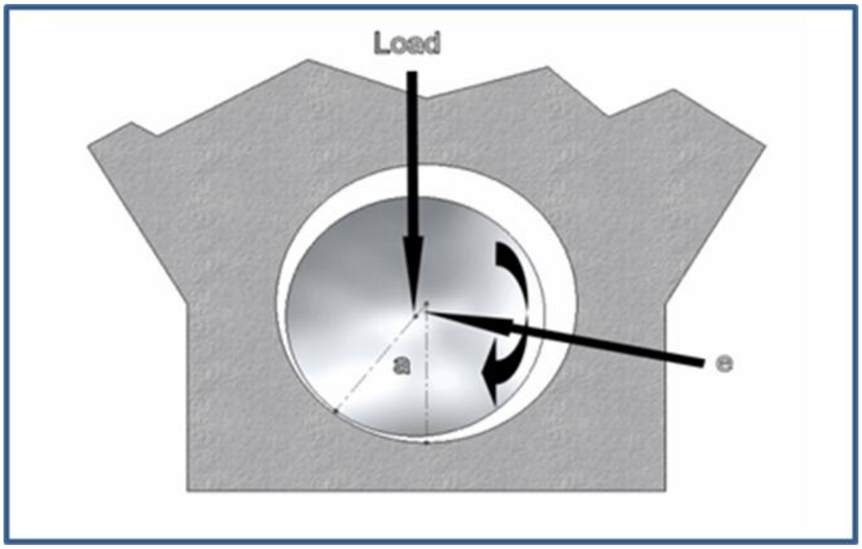


Figure 2.1: Hydrodynamic bearing

As the thin oil film acts as a complicated set of dampers or springs in the journal bearing systems, the dynamic characteristics of the machines may have been altered and thus provides a major factor in the vibration of turbo machinery. The instability due to oil film in journal bearings is called oil whip or non-synchronous whirl which is the purpose of this paper discussion.

2.3 Instability in Rotating Machinery

Literature mentioned that all objects including rotating machinery exhibit natural frequency depend on the structure of the object. Tiwari (2008) defined that the critical speed of a rotating machine occurs when the rotational speed is equal to its natural frequency. As the speed of rotation increases and approaches the critical speed, the motor begins to resonate and hence increases system vibration. With the present trends towards high speed and loading conditions (Tiwari, 2008), the occurrence of various mechanisms that can cause instability in rotor bearing systems is of particular concern to the engineers.

As the operating requirements of speed and power are more demanding in modern turbo machinery, conditions are encountered in which the turbines or motors are running more than their first critical speed. When this condition occurs, the system might be susceptible to whirl of many forms (Gunter, 1970). To illustrate the different oil film characteristics bearing is used, Figure 2.2 shown that the steady running of the oil film may hold for a pressure bearing film with the journal in vibration.

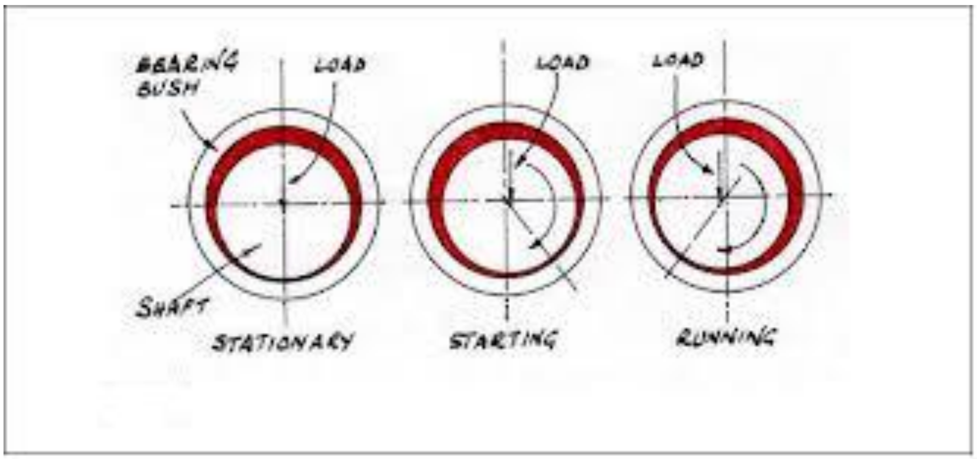


Figure 2.2: The dynamic analysis of rotor bearing system supported on fluid film journal bearing.

According to Khonsari and Booser (2013), there are many factors often attributed to rotor whirling in turbo machinery. Some of mechanisms that can induce motor whirling particularly pertinent to fluid-film journal bearings are as follows:

Lack of balance in the rotating mass supported by the bearings.	These problems may be alleviated or eliminated by carefully balancing the rotor
Half frequency oil whirl	These problems are caused by a wedge of oil film traveling around the bearing circumference at an average velocity of half the shaft surface speed. Amplitude of this rotor whirl often approaches 50 to 100% of the total clearance and threatens machine performance
Oil whip	This problem may create a potentially catastrophic vibration. Occurs when whirl frequency coincides with the natural frequency of the shaft at rotational speeds two or more times tha rotor natural frequency.

Table 2.1: Mechanisms that can induce motor whirling. Adapted from Khonsari and Booser (2013).

2.4 History and Theory

Due to severity of the consequences of rotating machinery failures, the accurate prediction of dynamic characteristics, therefore, is very important in the design of any type of rotating machinery. There are various literatures and studies relating to the field of rotor dynamics during the past years. According to Kalita et al. (2004), there are numerous approximations and theories have been successfully developed to analyze the dynamic behavior of rotor systems. However, Kalita et al. mentioned that the most prevalent approach for analyzing large scale and complicated rotor systems is by using Finite Element method.

According to Kalita et al. (2004), the persons who first utilize this finite element method were Ruhl and Booker. Although in their analyses, only elastic bending energy and translational kinetic energy were included. Many effects such as rotary inertia, gyroscopic moments, shear deformation, internal and external dampings were largely ignored. Another person such as Thorkildsen, includes rotary inertia and gyroscopic moments in his finite element model. The work of Zorzi and Nelson (Kalita et al, 2004) generalized the work of Nelson and McVaugh by including both internal viscous and hysteretic damping in the finite element model.

Modern technology especially with the advance of computer technology further improves the quality of prediction. The virtue of technology in finding fault especially in fault diagnosis of the rotating machinery has become hot research topic. Zhang et al. (2013) stated that one of the most advance software and hardware used to diagnose the rotating machinery is LabVIEW software and hardware. LabVIEW is graphical programming software developed by National Instrument (NI). It is considered as advance developing instruments due to its powerful capability of data acquisition and signal analysis. Furthermore, LabVIEW can be utilized on online diagnosis of the fault information of any rotating machinery independently (Figure 2.4).

2.5 LabVIEW software and hardware

Zhang et al. (2013) stated that in order to attain the vibration signal from the rotating equipment, a flexible machine fault simulator is built (Figure 2.3). As machine fault simulator is readily available at test bench at University Technology Petronas' laboratory, the test and simulation is based on the available equipment. Zhang et al. (2013) further suggested that online fault diagnosis must be based on LabVIEW hardware and software block diagram modules (Figure 3.2). The initial step of diagnosis which is the measurement of shaft orbit represents only the first step of fault diagnosis. The other steps in the modules include data storage management, data acquisition, shaft orbit synthesis, shaft orbit simulation, rotor fault simulation, invariant moment calculation and pattern recognition.

Figure 2.3: Machine Fault Simulator. Universiti Teknologi PETRONAS' laboratory

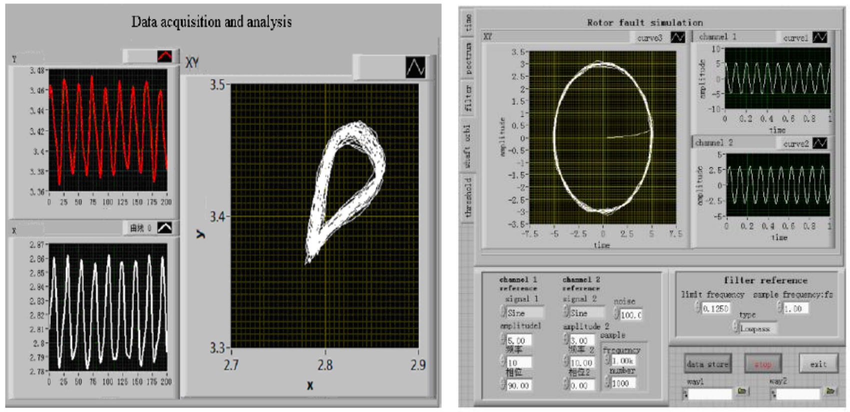


Figure 2.4: Control panel of LabVIEW data acquisition and analysis (left) and rotor fault simulation (right)

In order to verify the fault diagnosis results, Zhang et al. (2013) suggested a spectrum analysis module is used. Figure (2.5) shows the control panel of spectrum analysis. The left ellipse curve is the synthetical shaft orbit. The fault diagnosis in the spectrum analysis shows that the fault result is rotor imbalance.

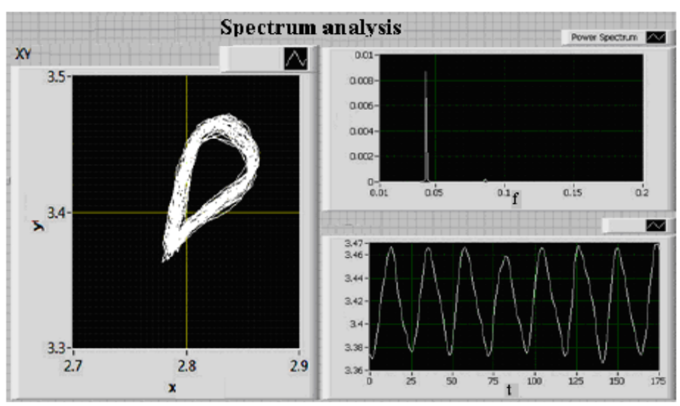


Figure 2.5: Control panel of spectrum analysis

CHAPTER 3

METHODOLOGY

3.0 Introduction of the methodology

As previously stated, the primary purpose of this study is to analyze whirl speeds for rotor bearing system supported on fluid film bearings. There are several numerical approximation for vibration analysis of rotor bearing system as stated by Kalita et al. (2004), but the most established approach is the Finite Element Method (FEM). However, in this study the fault finding and analysis will be based on rotor simulation. The available fault finding simulation software and hardware at the Universiti Teknologi PETRONAS' laboratory is LabView software (Signal Express version). LabView Software is a kind of graphical programming software developed by United States NI (National Instrument) company.

Zhang et al. (2013) stated that LabVIEW is graphical programming software that has been used as developing tools of virtual instruments due to its powerful capability of data acquisition and signal analysis. Therefore, this study is about rotor whirl analysis and simulation based on LabVIEW modules. A test bench which includes a flexible rotor test bench (Figure 3.0) and a data acquisition system are set up. The simulation of the shaft orbits and rotor faults, data acquisition, fault diagnosis and pattern recognition are developed based LabVIEW software and hardware modules.

3.1 Development of Instrumentation

Based on the work of Zhang et al. (2013), a flexible rotor test bench is set up (Figure 3.0 and Figure 3.1). The test bench consists of an adjustable speed AC motor, couplings, a flexible rotor, an eccentric discs, base and sensor bracket. This data acquisition system is set up based on LabVIEW software and hardware. LabVIEW's card includes eddy current sensors, pre amplifiers, filters and NI data acquisition card.

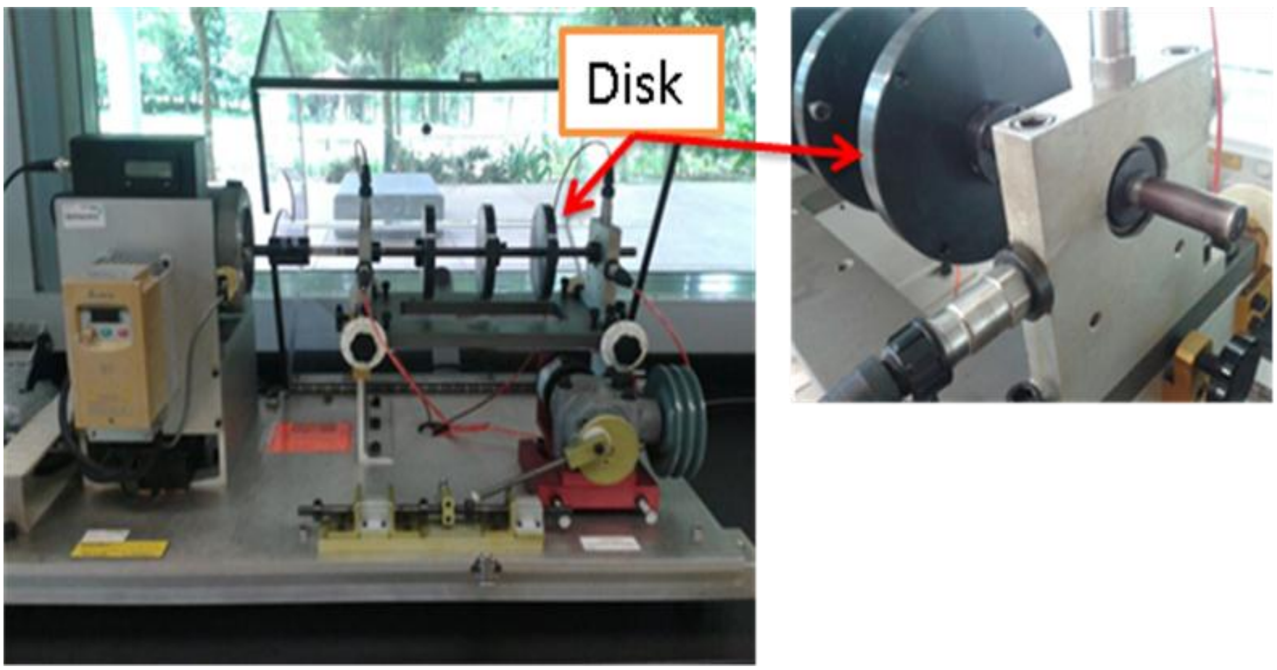


Figure 3.0: Machine Fault Simulator. This Test Bench consists of an adjustable speed AC motor, couplings, a flexible rotor, an eccentric discs, base and sensor bracket.

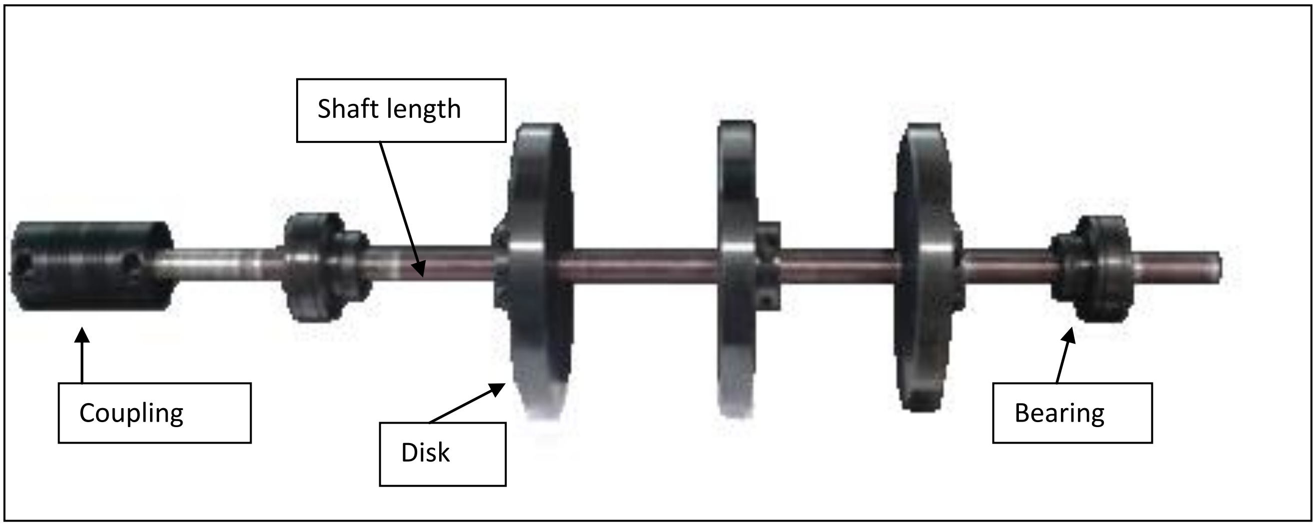


Figure 3.1: Fluid film bearing, coupling and shaft position

3.2 Measurement

To study the effects of rotor whirling supported on fluid bearings, a test bench consists of the above machinery with the capability to simulate a number of machinery malfunction is used. The set up consists of an adjustable AC Motor, a shaft, a flexible rotor, an eccentric disc, base and sensor bracket. The shaft and rotor are supported by sleeve and fluid film bearings and contain moveable disk to control balancing (Figure 3.0 and 3.1). The fluid film bearing (Figure 3.1) is a full bearing set up so that the sleeve bearing can be moved axially to modify shaft length. The disk location (Figure 3.0) is set up to be moveable between two bearings. The shaft and disk specifications are shown in shown in Figure 4.0 and Figure 4.4

The LabVIEW software and hardware instrumentation are used to collect the raw mechanical vibration signals performed certain mathematical calculation through direct vibration reading. The raw data was calculated through LabVIEW software for further processing, analyzing and storing. The data instrumentation components employed during the study was:

- Eddy current. Measuring radial relatives shaft vibration with respect to the bearing housing (Figure 3.2). Both sensors were mounted in the Y and X axis direction.
- Key phasor. Measuring the rotor speed
- Proximator. Converts the electrical signal to an engineering unit (from mV to mils)
- Data acquisition interface unit (DAIU)
- Speed Control Unit

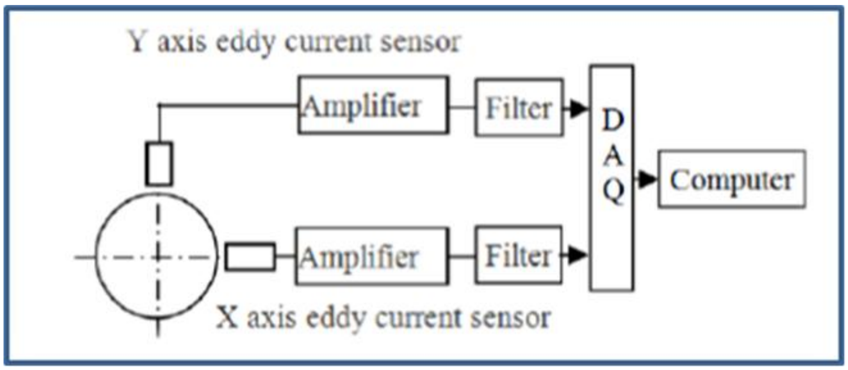


Figure 3.2: Block Diagram of shaft Orbits measurement system. Adapted from Zhang et al. (2013).

3.3 Data Collection Method

Data collection method is based on the work of Zhang et al. (2013). Block Diagram of LabVIEW modules are shown below (Figure 3.3). As shown in Figure 3.2 above, two way signals (X and Y) are of real time displayed on the graphic window. The noise and interference were eliminated by using analog low pass filter and digital filter. Zhang et al. (2013) stated that the single channel signal is almost similar to a sine wave. The synthesized shaft orbit shape is therefore close to an ellipse shape.

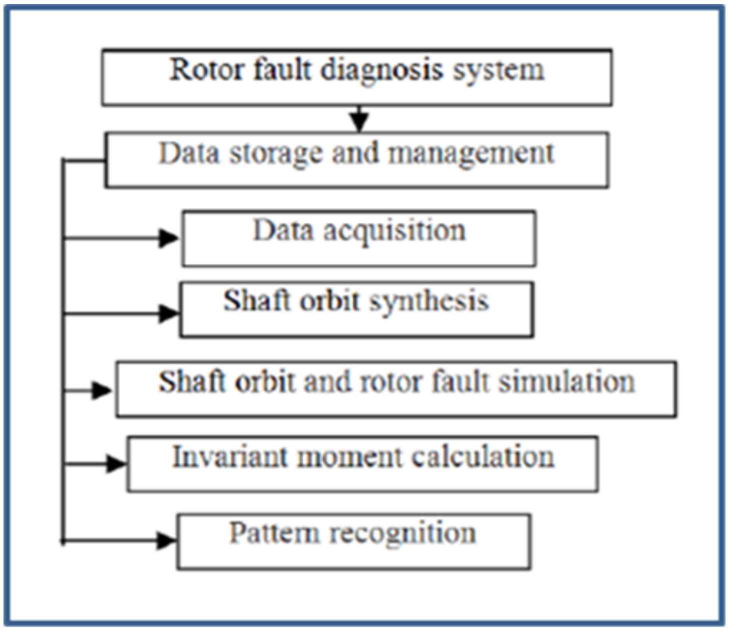


Figure 3.3: Block Diagram of LabVIEW Modules. Adapted from Zhang et al. (2013)

The above block diagram of LabVIEW modules (Figure 3.3) consists of several modules to achieve best measurement, shaft orbit and rotor fault simulation, invariant moment calculation and analysis through pattern recognition.

3.4 Shaft Orbit and Rotor Fault Simulation

Zhang et al. (2013) stated that the shape of shaft orbits simulation based on LabVIEW may contains some information regarding the fault information of the machine. The information such as rotor imbalance, misalignment, static and dynamic friction, oil whirl and oil whip can be established by simulating shaft orbits to facilitate the fault information identification and fault diagnosis.

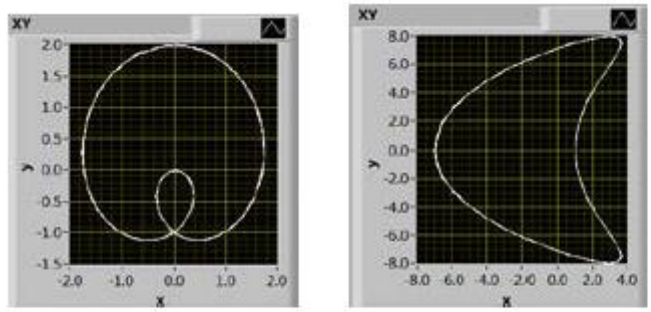


Figure 3.4: Shaft Orbits Simulation based on LabVIEW, Oil Whirl (left) and Rotor Misalignment (right)

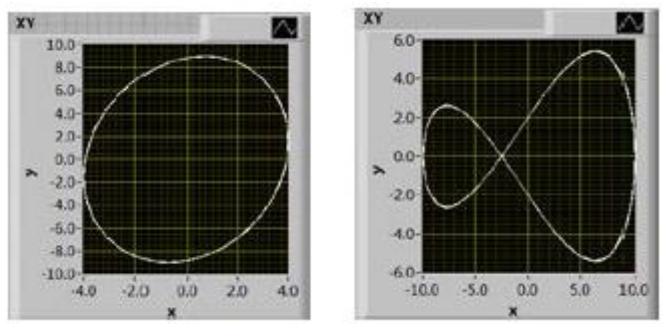


Figure 3.5: Shaft Orbits Simulation based on LabVIEW, Rotor Imbalance (left) and Rotor Rubbing (right)

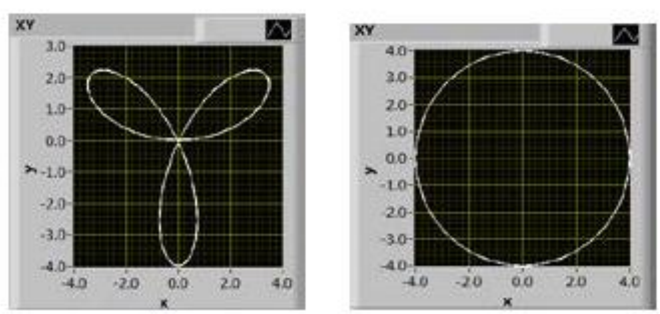


Figure 3.6: Shaft Orbits Simulation based on LabVIEW, Oil Whip (left) and the ideal State (right)

3.5 Validity

Zhang et al. (2013) suggested that in order to verify the result, the spectrum analysis included in the LabVIEW module need to be utilized. The result in control panel of spectrum analysis is shown in Figure 3.7. The spectrum analysis shows that the fault result is rotor imbalance,

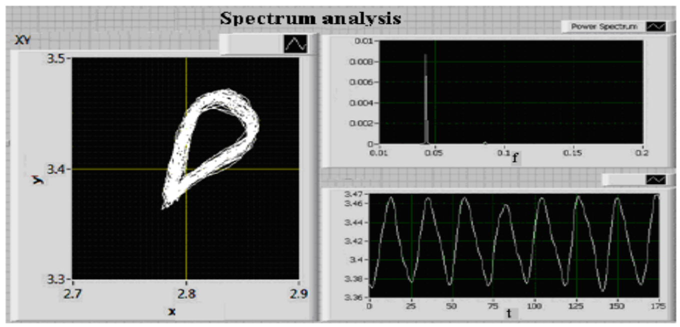


Figure 3.7: Control panel of spectrum analysis

CHAPTER 4

DATA ANALYSIS AND FINDINGS

The analysis of whirl speeds for rotor bearing systems supported on fluid film bearings was researched. As indicated earlier, the analysis on the measurement and identification method of shaft orbits and rotor fault simulation was based on the LabVIEW software and hardware. Based on the availability of test bench set up at the University Technology of Petronas' laboratory, the rotor shaft orbit was measured in real time by the data acquisition hardware system. Series of runs were conducted to observe the changes in the instability response of the fluid bearing due to changes in disk location and shaft length. From the simulation, four types of orbits were identified containing typical fault characteristics.

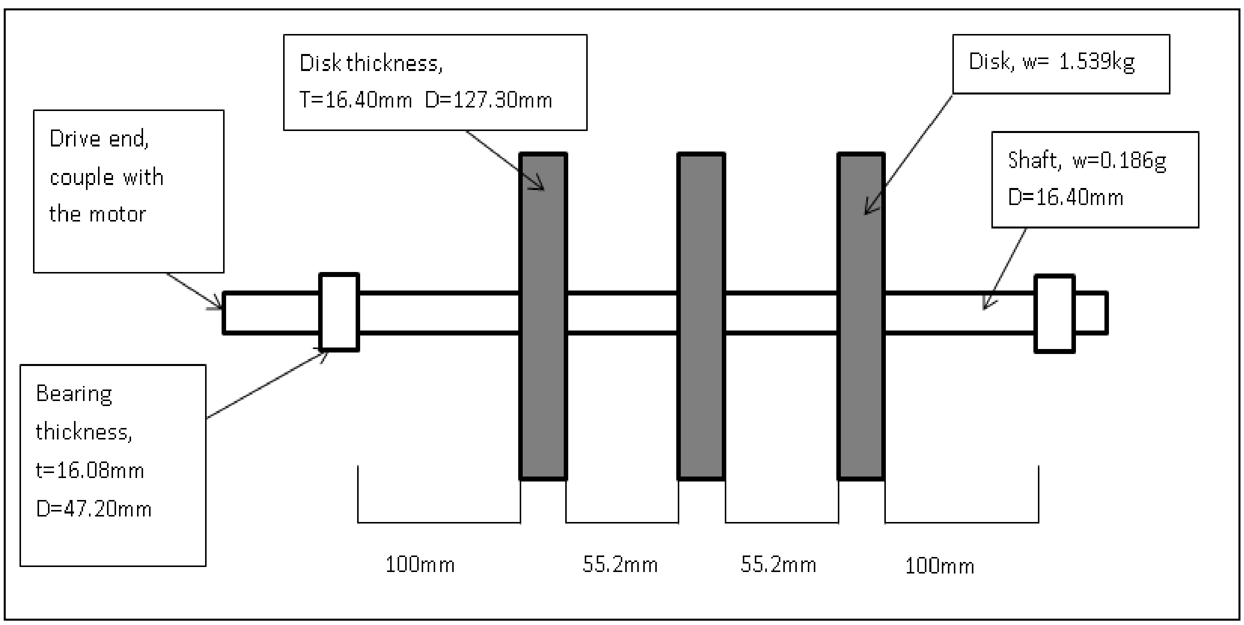


Figure 4.0: The initial disks location and shaft length

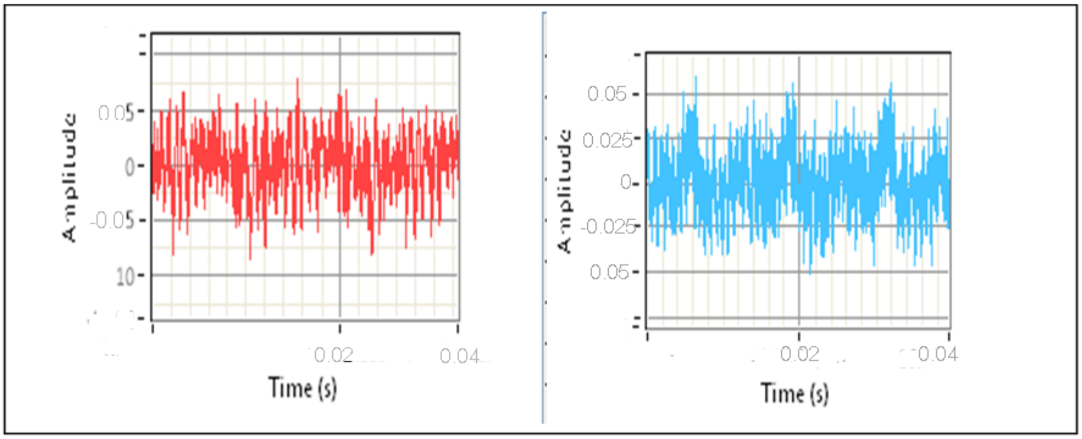


Figure 4.1: Waveform before instability (using initial disk location and shaft length set up)

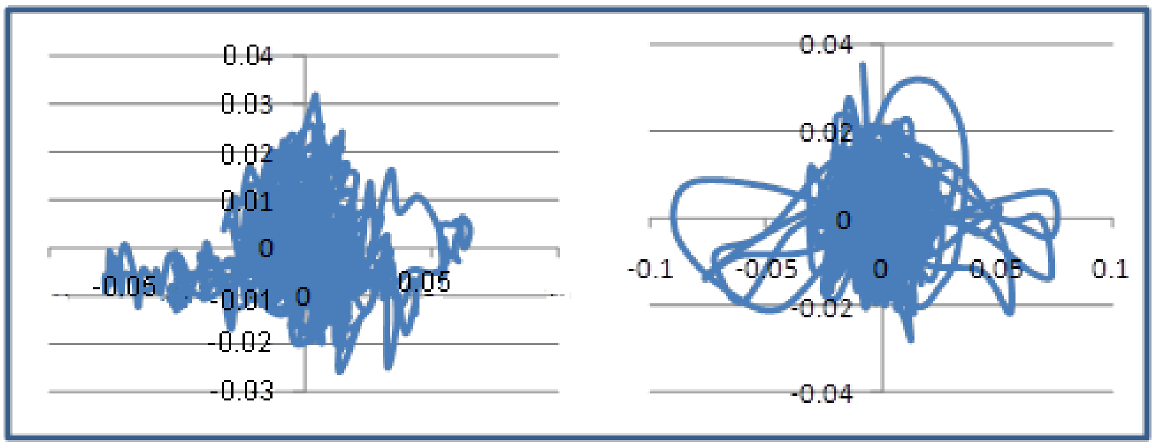


Figure 4.2: Orbit Plot

Figure 4.0 shows that the initial set up of the disk location and shaft length of the rotor. Series of runs were conducted to observe the changes in the instability response of the fluid bearing system due to changes in disk location and shaft length. From the first and second simulation, the types of orbits identified were as in Figure 4.2. As the span between the fluid film bearing and sleeve bearing was maintain at the initial length, Figure 4.1 shows the waveform of the vibration signals which indicates that the vibration amplitudes were small. The circular forward precession can be seen in orbit plots as indicated by Figure 4.2. The orbit shape is maintained centrally even as vibration increased. Upon comparing these results with the results obtained from the work of Zhang et al. (2013), the outcomes show that the main diagnosis of the rotor experimented that rotors were at the ideal state (Figure 3.6 right).

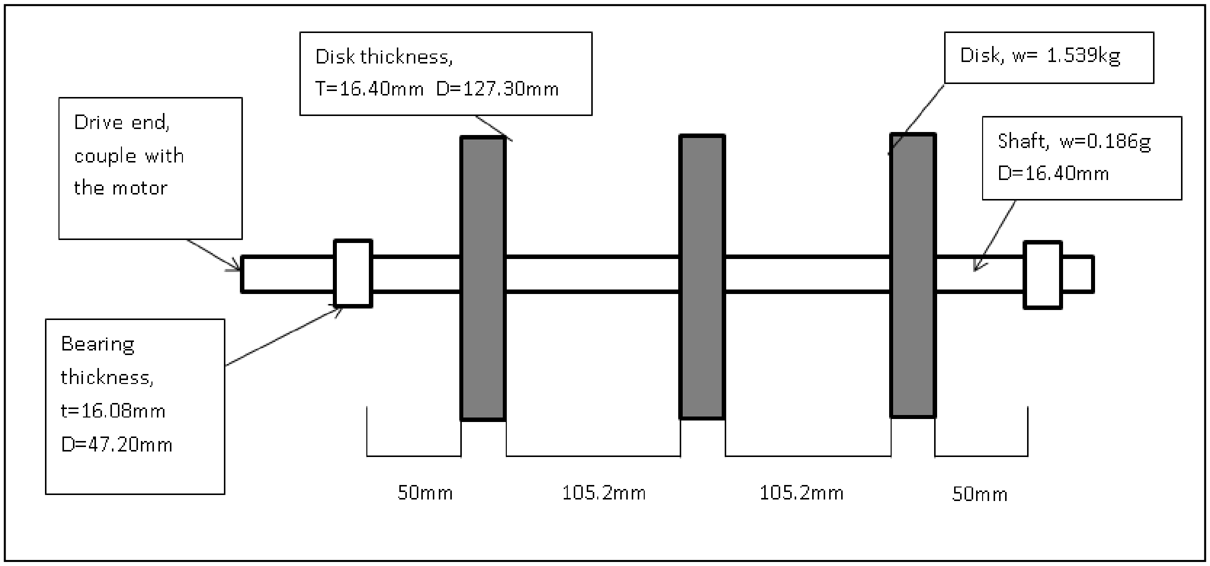


Figure 4.3: Different disk location and shaft length

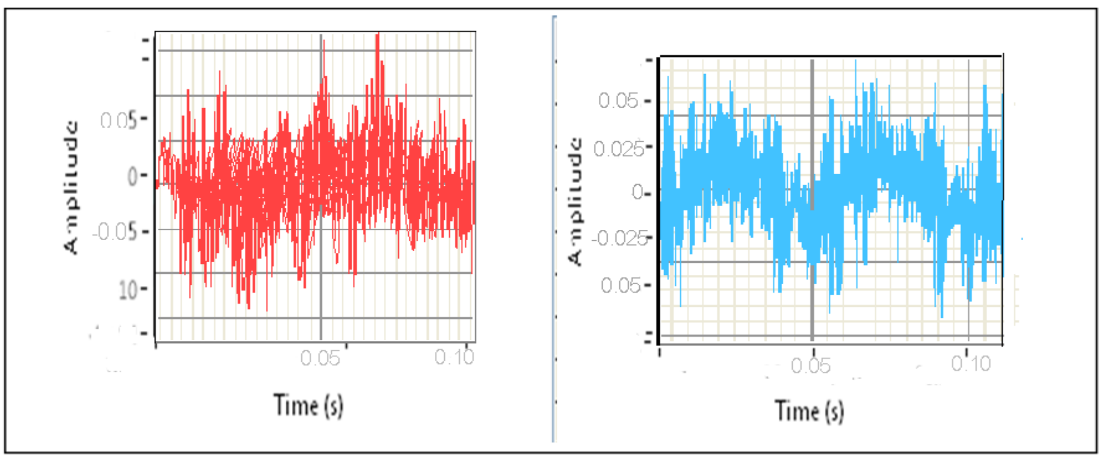


Figure 4.4: Waveform after the instability (After the changes of disks location and shaft length)

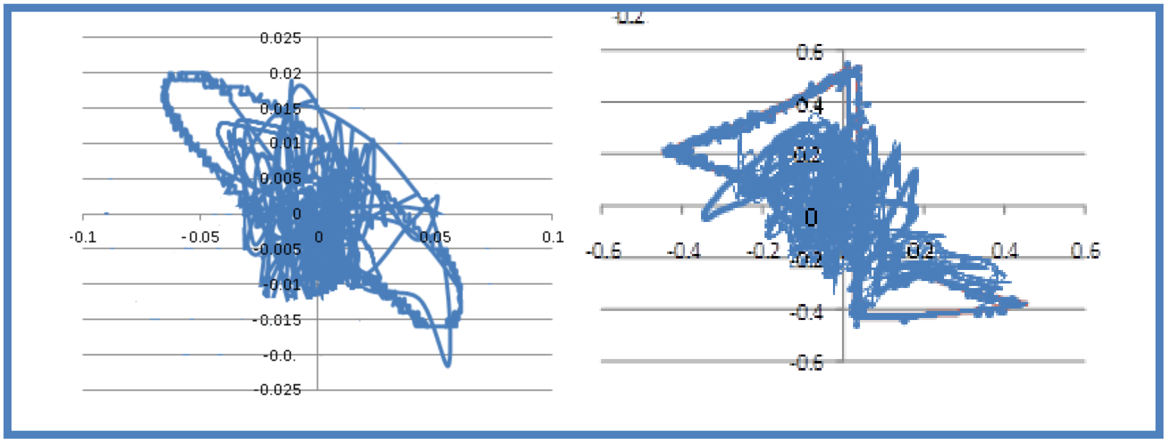


Figure 4.5: Orbit plot after instability

From the third and fourth simulation, the types of orbits identified were as in Figure 4.5. As the span between the fluid film bearing and sleeve bearing was altered by changing disks location, Figure 4.4 shows that the waveform of the vibration signals which indicates that the vibration amplitudes were significantly larger. The circular forward precession can be seen in orbit plots as indicated by Figure 4.5. The orbit shape was enlarged as vibration increased. The disk location was found to have a significant impact on the rotor stability. Upon comparing these results with the results obtained from the work of Zhang et al. (2013), the outcomes showed that the main diagnosis of the rotor experimented were rotor imbalance (Figure 3.4 left) and misalignment (Figure 3.4 right).

These findings were supported by Sunar and Al Shurafa (2009), which indicate that the shaft length, disk axial separation distance from the fluid film bearings and disk imbalanced may have influence on rotor mounted on fluid film bearings. According to Sunar et al. (2009), the smaller the shaft length, the higher the instability the threshold and frequency. The analysis of whirl speeds for rotor bearing system supported on fluid film bearings based on LabVIEW hardware and software was proven to be effective.

CHAPTER 5

CONCLUSIONS

The purpose of this study was to provide analysis of whirl speeds for rotor bearing systems supported on fluid bearings. Most of high speed rotating machinery such as turbines and rotary compressors used both journal bearing and thrust bearing configuration. Only fluid bearing such as journal bearing plays a significant factor in rotor whirling and vibration. Rotor mounted on thin fluid film bearings can experience fluid induced instabilities that manifest as severe whirl effects on rotors. Uncontrolled whirl in this type of equipment was of substantial concern to engineers due to its limited safety limit and inefficient equipment operation. When bearing fails or show sign of distress, the shaft orbit of rotor often contains some fault phenomena to a certain extent. Therefore, it was a particularly important for the engineer to recognize and make corrective adjustment before catastrophic failure of the entire machinery occurred.

The analysis tested in this study indicated significant differences in shaft orbit of various test bench simulations based on LabVIEW software and hardware system diagnosis. By developing data acquisition, signal analysis, pattern recognition and fault diagnosis, this system automatically detected the shaft orbit of rotor and immediately provide fault results. The experimental results showed that disk locations and shaft length provide significant differences in the stability of the rotor supported on thin fluid bearings. This study was also helpful in providing online system diagnosis in finding rotor fault based on LabVIEW software and hardware.

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APPENDICES


Figure A-1 Experiment set-up

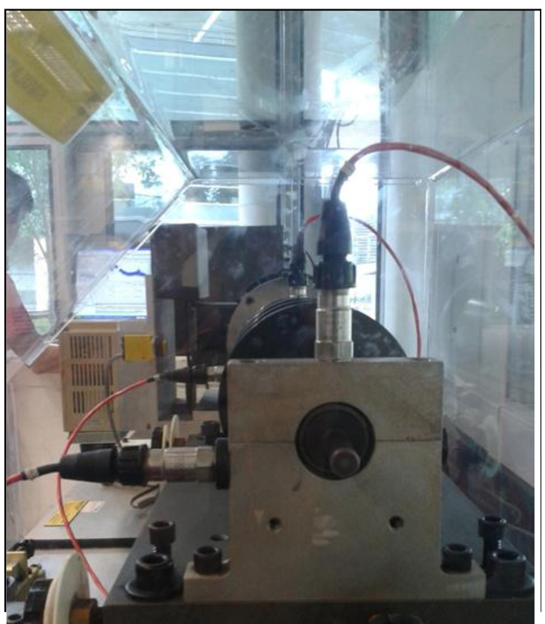
Figure A-2 Side view of the machine fault simulator (sensor probe of y and x axis)

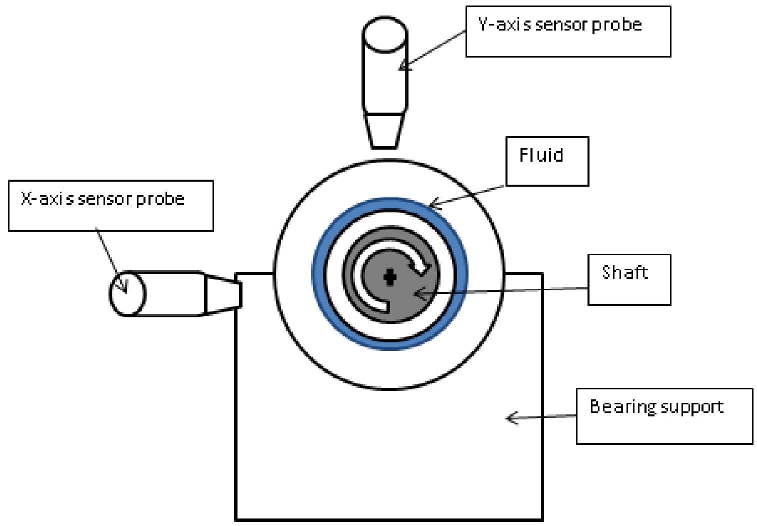

Figure A-3 Graphic 2D side view of the machine fault simulator (sensor probe of y and x axis)

Figure A-4. Speed or frequency controller

Figure A-5. Overall view of the system (machine fault simulator and the computer that run the LabVIEW software