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VIBRATION ANALYSIS OF VERTICAL CENTRIFUGAL PUMP

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Dissertation submitted in partial fulfilment of

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(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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(MECHANICAL ENGINEERING)

Approved by,

____

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

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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ARVINDREN KUMAR A/L SATHASIVAN

ABSTRACT

Pumping sets play an important role in industrial plant and need continuous monitoring to minimize the loss of production. Pump defects can cause major problems if it is not repaired in the early stages, as it might cause process downtime and high cost of repair. Thus, it is important to detect the early signs of wear in the pump so precautions can be taken and process shut down can be planned in advance so that it does not affect the production or process. Vibration analysis is one the proven reliable method in determing the early signs of problems in pumps by interpreting the vibration data from the rotary components. Abnormal vibration data are studied thoroughly by experts to determine the source of the problem and the intensity of the problem.

In this case study, the vibration of the vertical centrifugal pump are studied. The vibration data of vertical centrifugal pump is studied using MATLAB solution to determine the vibration of the pump at different parameters. The results obtain are compared with LUDECA Machinery Fault Diagnosis Guidelines to determine the type of problem and the severity of the problem, where the amplitude of the graph obtained shows the severity of the problem and the frequency of the graph shows the type of fault.

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ABBREVIATION AND NOMENCLATURES

FFT	-	Fast Fourier Transform
Hz	-	Hertz
MATLAB	-	Matrix Laboratory Software
RPM	-	Reolution per minute

CHAPTER 1

INTRODUCTION

1.1 Background Of The Project

Vibration analysis is a process of monitoring the condition of an equipment by studying the vibration of the dynamic parts. All rotating equipments vibrate to some degrees, but as the components get older, they tend to vibrate more dramatically and in distinct ways. Sensors such as accelerometers and tachometers can be connected to the equipments to continuously monitor the vibration of the machine, which can be used to identify the signs of wear and damage well before the damage becomes a major and expensive issue.

Centrifugal pumps are used to transport fluids by converting kinetic energy of the impeller to hydrodynamic energy of the fluid flow. The main difference between vertical centrifugal pumps and horizontal centrifugal pumps is vertical centrifugal pump has its shaft positioned in a vertical orientation while horizontal centrifugal pumps has horizontal shaft. Vertical centrifugal pumps has a smaller footprint and more suitable for installation where the ground surface area is limited.

Vertical centrifugal pumps are used widely in industries for pumping fluids to a certain point. The cost of a centrifugal pump can be very high up to few million ringgit in big industries such as oil and gas. The complete failure of the pumps could be a big liability to any company and it is important the pumps are monitored and maintained properly to avoid any major failures. One of the best way to monitor the condition of the pumps are by using vibration analysis, which helps the detects early signs of damages or wear in the pumps, where in most cases can be repaired with relatively lower cost.

1.2 Problem Statement

The health or condition of the vertical centrifugal pump cannot be predicted easily due to its complex design. Therefore, a proper method is required to determine the condition of the pump at any specified time so it will easy for the industries to repair or carry out maintenance in case if there are any faults or signs of wear in the pump. The health monitoring method of the pump also should be able to determine the sign of wear in the pump well before it becomes a major problem, so the maintenance cost can be kept as low as possible and to provide enough time for the users to plan shutdown of the process.

1.3 Objective

The objective of this project is to analyse the vibration of the vertical centrifugal pump to detect sign of wears and problems in the pump. The vibration data obtained from the simulation software will be studied thoroughly to find any abnormalities in the vertical centrifugal pump for a specific period of time. Besides, the vibration analysis also will be used to ensure maintenance or repair work has been done properly and the pump is in a optimum condition for the processes.

1.4 Scope Of Study

This project involves in the study of vibration system and simulation software. The types of vibration and calculation involved in vibration system are very important in the vibration analysis of the vertical centrifugal pump. Besides, software such as Matlab will be used to simulate the vertical centrifugal pump and to analyse the vibration of the pump. Using the finite element method, the software breaks down the model of the design into small elements which can efficiently be used to solve the problems.

1.5 Relevancy and Feasibility of the Project

This project is important as it deals with current issue in industries for machine monitoring process. The study of this project can benefits many industries as it helps to monitor the condition of the pump at any period of time which helps to detect early signs of damages or wear in the pumps, where in most cases can be repaired with relatively lower cost.

Besides, the timeframe for this project is feasible and can be completed within the allocated time. It is also a good project for final year students as it gives exposure on the problems in real world environment and helps to strengthen the understanding of concept of vibration.

CHAPTER 2

LITERATURE REVIEW

2.1 Vibration Analysis

Vibration analysis is a commonly used machine condition monitoring technique for fixed-plant rotating machinery, due to relatively fast data collection and interpretation when compared to other available off-line techniques (Ebersbach & Peng, 2008). The data is collected digitally, which enables further interpretation of the data using computers. Besides, the development of transform, such as Fourier transform (FFT) (Peng & Chu, 2004), have made the conversion of the time domain data into frequency spectra easier. According to Sek (2009), the Fourier series is a periodic function that can be represented as a sum of infinite number of (co-)sinusoidal components at equally spaced frequencies with the interval of 1/T, where T is the period of the function. The number of FFT elements is equal to the size of the time sample. The second half of these complex numbers corresponds to negative frequencies and contains complex conjugates of the first half for the positive frequencies, and does not carry any new information.

In vibration analysis, the FFT is used to see the spectrum which is the graphical display of the frequencies of the machine components that is vibrating together with the amplitude of the components at these frequencies, referring to Commtest Inc. (2006). In addition, the cause of vibration and the condition of the machine can be inferred by studying the individual frequency at which the component vibrates, as well as the amplitudes corresponding to those frequencies.

Vibration of a pump is usually its lowest when operating at best efficiency point (BEP), and can double in amplitude as flow is reduced to 25% or so of BEP. This is a important consideration when taking routine measurement as a range of vibration levels may occur although the pump internal condition is unchanged (Beebe, 2004). If operation at BEP is not possible at certain time, then a standard flow may need to be chosen for routine measurement of the pump vibration.

The most commonly used transducers to detect the vibration in the components of the pump are velocity transducer, accelerometer and displacement transducer. Velocity transducer and accelerometer are usually held on the bearing or on the shaft-rider and also called as contact transducers. While, displacement transducers are usually called non-contact transducers. Mounting of vibration transducers are very important, because the firmer they are attached to the components, more accurate and reliable data are obtained. Some of the main type of mounting used are magnet mounting, which are quite reliable on a flat surface, studs, glued and screwed in. Besides, it is also highly recommended calibration checking of the transducers to be carried out regularly, within specific period of time, to ensure accurate data are obtained.

Dunton (1999) says that the vibration analysis time waveform data was viewed on oscilloscopes and frequency components in the early days. The following is the relationship between frequency and time.

$$f = \frac{1}{\omega} \quad \text{.............................. Equation 1.0}$$

Where f is the frequency (Hz) and p is the period of time (s).

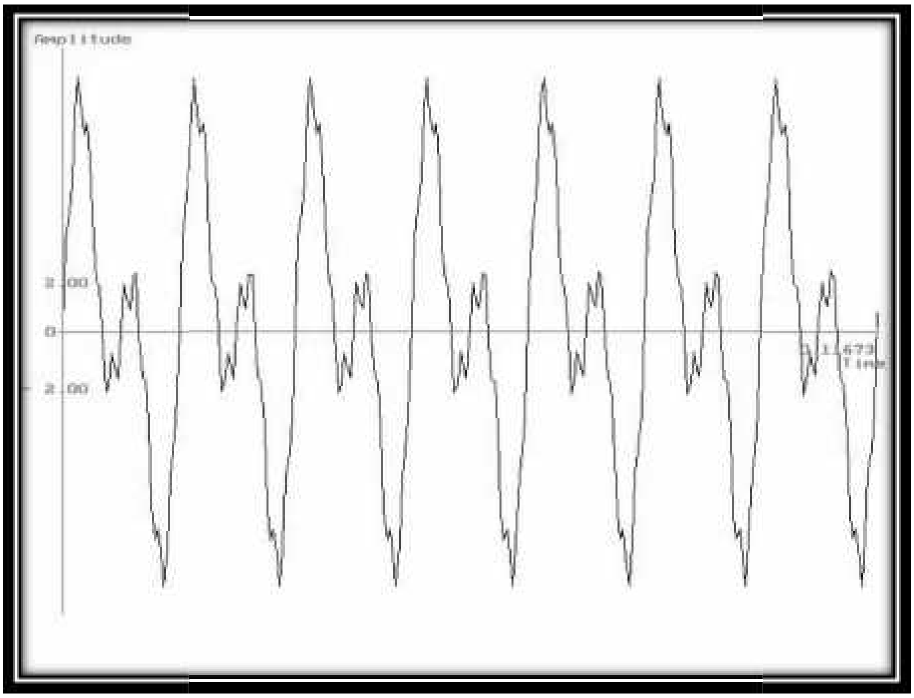

Figure 1 : Example of a time waveform.

The time waveform is effective to be used in the applications of gears, sleeve bearing machine, looseness, rubs and beats. From the patterns of the waveform, the faults of machine can be determined. Each cause can be diagnosed by detecting the trends such as unbalance, eccentricity, bent shaft and misalignment. The amplitude severity also gives an information on how severe the condition of the machine.

Time waveform is the basic method to display the raw vibration data but the spectra can be presented in various ways but the most popular ones are Fast Fourier Transform (FFT) and Power Spectral Density (PSD) for vibration analysis purposes.

2.2 Vertical Centrifugal Pump

Centrifugal pumps are used to transport fluids by converting kinetic energy to hydrodynamic energy of the fluid flow. Electric motors are used in the system to produce the rotational energy. The shaft is positioned in vertical orientation for the vertical centrifugal pump and the footprint are relatively smaller compared to horizontal vertical centrifugal pump. The fluid enters the suction nozzle and into the centre of an impeller. When the impeller rotates, it spins the liquid sitting in the cavities between the vanes outward and provides centrifugal acceleration. As the liquid leaves the centre of the impeller, a low-pressure area is created causing more liquid to flow towards the inlet. Because the impeller blades are curved, the fluid is pushed in a tangential and radial direction by the centrifugal pumps producing the pressure needed to pump the liquid. The amount of energy given to the liquid is proportional to the velocity at the edge of the impeller. The bigger the impeller or the faster the impeller rotates, the higher the velocity of the liquid at the vane tip, thus the greater the energy produced to pump the liquid. The velocity is converted to pressure according to Bernoulli's principle.

The centrifugal pumps consist of two main components which are stationary components comprised of casing, bearings and mechanical seal and rotating components consists of mainly an impeller and shaft. The casing of the centrifugal pump is an air tight passage surrounding the impeller and is designed such as way that the kinetic energy of the water discharged at the outlet of the impeller and is converted into pressure energy before the water leaves the casing and enters the delivery pipe. The commonly used casings are volute casing, vortex casing and casing with guide blades. The pump bearings support the hydraulic loads imposed on the impeller, the mass of impeller and shaft. Pump bearings keep the shaft axial end movement and lateral deflection within acceptable limits for the impeller and shaft seal. The mechanical seal is composed of two finely machined surfaces, which prevent water from passing. Impeller is the main rotating pat of the centrifugal pump consists of series of backward curved vanes. The impeller is mounted on the shaft, which is connected to the shaft of the electric motor.

Figure 2 : Image of vertical centrifugal pump

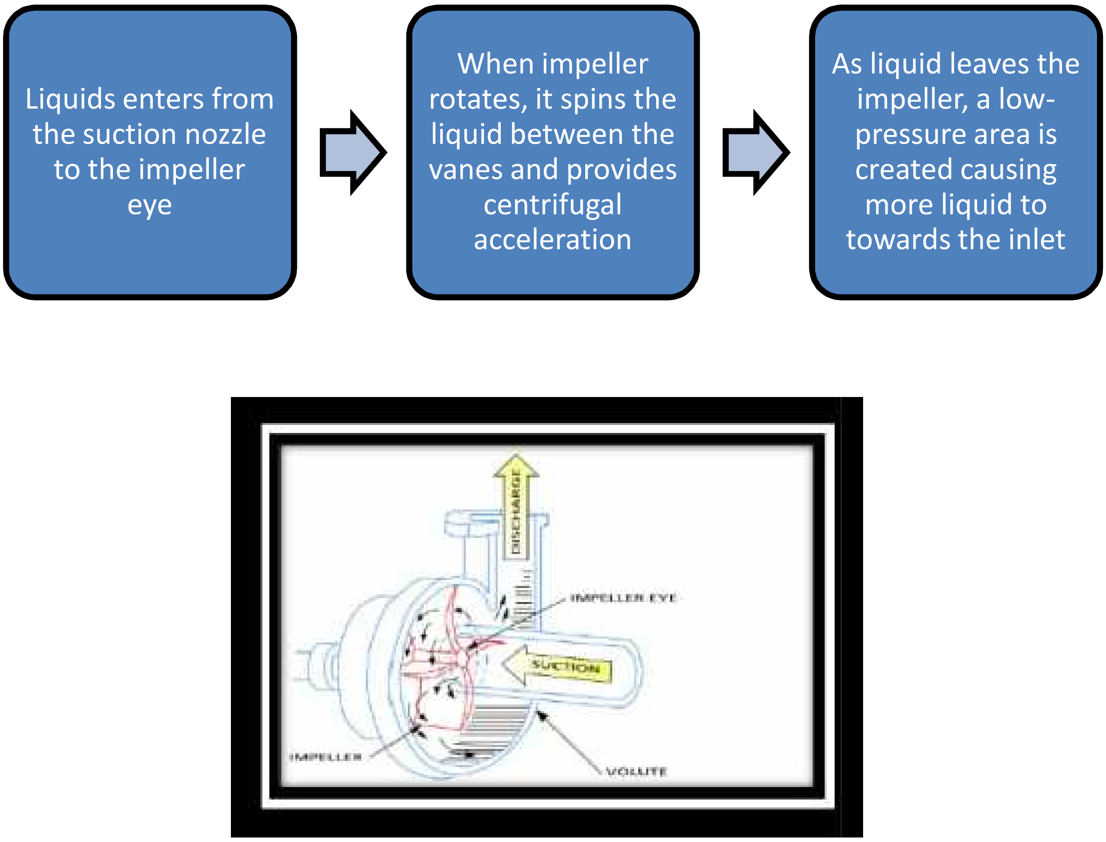

Figure 3 : Simplified Working Principle of the Centrifugal Pump

2.3 Vibration Analysis of Vertical Centrifugal Pump

The most revealing information on the condition of rotating machinery is a vibration signature, according to some sources. According to Ravindra Birajdar et al (2009), the vibration in centrifugal pump has a significant effect on the machine's performance. This is due to the possibility of the machine to undergo a premature failure as the vibration level is increasing over time and loads, mainly because of the equipment has started to destroy itself. He adds there are several sources of vibration in centrifugal pumps and they can be classified in to three categories, which are mechanical causes, hydraulic causes as was as the peripheral causes.

Vibration of a pump consists of amplitude, frequency and direction which helps to monitor and diagnose the condition of the pump. (Brian.P.G, 2011). Centrifugal pump generate pumping frequencies due to flow, recirculation number of vanes multiplied by rpm and mechanical problems such as imbalance, misalignment, looseness, worn bearings, pipe strain and resonance. Vibration measurements are taken on each bearing location in three planes, which are vertical, horizontal and axial. The diagnostic information from vibration analysis will be determined by:

i. Severity – Amplitude
ii. Frequency – Cycles per Minute CPM or Hz - Cause of the Problem

Vibration measurement has three amplitudes as follows:

i. Displacement
   - Good for determining the movement of the machine.
   - Turning speed vibration levels.
   - Normally used to measure large sleeve bearing machines.
   - Severity requires the need to know the frequency.
ii. Velocity
   - Used for broad frequency ranges.
   - The most common measurement of centrifugal pump vibration analysis.
   - Velocity severity is independent of frequency.
iii. Acceleration
   - Good for determining high-frequency vibration problems due to worn rolling element bearings or gears.

The direction of the vibration measurement or plane of measurement will also determine the machine vibratory problem. When analyzing vibration data, an FFT vibration spectrum may be broken down into several frequency ranges to help determine the machine problem. Horizontal centrifugal pumps and vertical centrifugal pumps have different vibration measurement locations. Overall vibration severity is used for determining the condition of a machine.

2.4 The Basic Causes of Centrifugal Pump Vibration

According to Eastman, there are three types of vibration in a vertical centrifugal pump, which are:

i. Mechanically Induced Vibrations
ii. System Induced Vibrations
iii. Operation Induced Vibrations

Mechanically Induced Vibrations	• Bearings Defect • Bent Shaft, Shaft Crack • Unbalanced Rotor • Misalignment, Looseness • Check Valve installed Backwards
System Induced Vibrations	• Partially/Plugged Strainer • Clogged Impeller or Suction Line • Installation defect
Operationally Induced Vibrations	• Cavitation • Flow • Speed • Insufficient Immersion of Suction Pipe or Bell

Table 1 : Basic Causes of Centrifugal Pump Vibrations

Figure 4 : Crack in Centrifugal Pumps

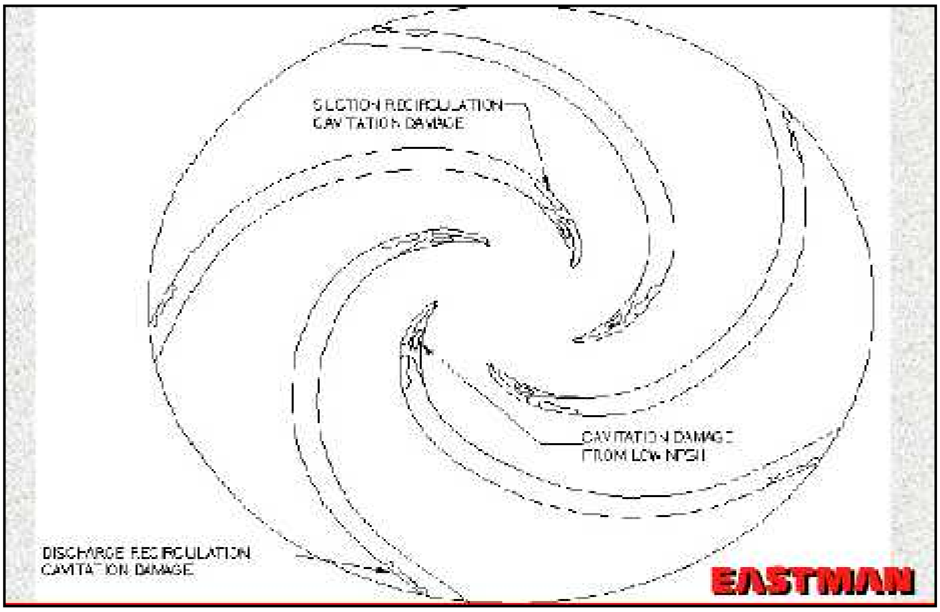

Figure 5 : Cavitation in impeller

According to Choi.L.Y, the most common centrifugal failure in chemical and process industry is due to cavitations. Cavitations is the formation of vapour cavities in the liquid due to the rapid changes of pressure that cause the formation of cavities where the pressure is relatively low. Cavitations within pump can cause undesirable effects on impeller such as:

- Pitting
- Erosion
- Drop in head capacity and efficiency curves

Today, advantages of vibration analysis are accepted in many industries and it has become an essential tool, because of its efficiency in fault detection during early stages and thus reducing unscheduled down time. It increases productivity, improves quality and provides the feeling of safety and reliability to staff

(Deshpande, 2014). Vibration analysis is a powerful tool that when integrated into the vertical centrifugal pump, will help save the maintenance cost by (Rogan, 2009):

i) reducing the risk of unexpected downtime

ii) extremely effective safeguard against total loss

iii) timely ordering of replacement parts to reduce expediting costs

iv) advance planning shortens repairs and inspection time

2.5 Mathematical Modelling of a Centrifugal Pump

The mathematical model of the centrifugal pump can be developed by analysing the dynamics of the system and its based on the basic laws of physics and fluid mechanics. According to the research done by Janevska.G on a system consists of centrifugal pump powered by asynchronous three-phase electric motor and constant level water tank, a mathematical model can be developed which can be simulated in MATLAB to analyse the vibration.

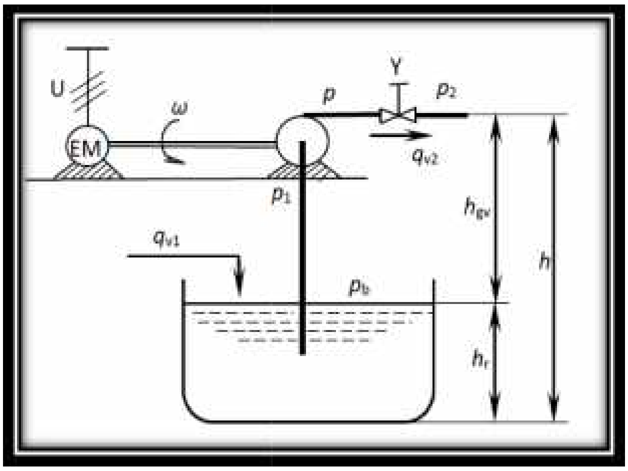

Figure 6 : Functional Scheme of the Pump System

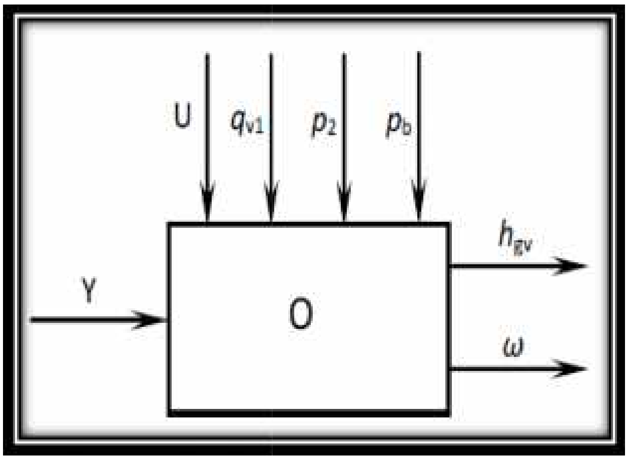

Figure 7 : Block diagram of the Pump System

Using Newton law of force, which stated that the angular acceleration is proportional to the torque on the axis. Hence, the equation of motion can be derived as:

$$J\frac{d\omega}{dt} = M_a - M_P \qquad \text{Equation 1.1}$$

$$= M_{MT} - (M_P - M_\zeta) \qquad \text{Equation 1.2}$$

Where J is the moment of inertia and it is constant in this case. Thus, the torque from the motor is equal to the sum of the torque of the motor and the torque produced by the fluid due to viscosity. M_{MT} is the active torque from the asynchronous motor, M_P is the passive torque of the pump and $M_\zeta$is the viscous torque. Assuming the number of stator's poll pairs is one and the network frequency is, f, the motor torque equation can be derived as follow:

$$M_{MT} = k_{MT}U^2(2\pi f - \omega) \qquad \text{Equation 1.3}$$

Viscous torque M_ζ and passive torque M_P are given respectively:

$$M_\zeta = k_\zeta \omega \qquad \text{Equation 1.4}$$

$$M_P = \rho g q_{v2} H / \eta_P \omega \qquad \text{Equation 1.5}$$

Where,

ρ = density of fluid (m^3/kg)

g = gravitational acceleration (m^2/s)

q_{v2} = outlet fluid velocity (m/s)

H = head (m)

η_P = efficiency of the pump

ω = angular velocity (rad/s)

k = constant

U = motor speed (m/s)

f = frequency (Hz)

Pump suppliers set the pump characteristics for a nominal speed, n. Due to the complexity of centrifugal pump dynamics, the assumption that q_v- H curve with sufficient accuracy describe the behaviour of the pump in transitional regimes is accepted into analysis of the work. According to Janevska.G, the characteristics of a centrifugal pump can be described by the equation:

$$H = A\omega^2 + B\omega q_v + C{q_v}^2 \qquad \text{Equation 1.6}$$

where, A,B and C are characteristics constants for each pump.

2.6 Machinery Fault Diagnosis Guidelines

The LUDECA Machinery Fault Diagnosis Guidelines is basic guide to understand vibration analysis for machinery diagnosis. Some of the fault that can be determined using LUDECA Machinery Fault Diagnosis Guidelines are unbalance, misalignment, shaft bending, looseness and bearing overload.

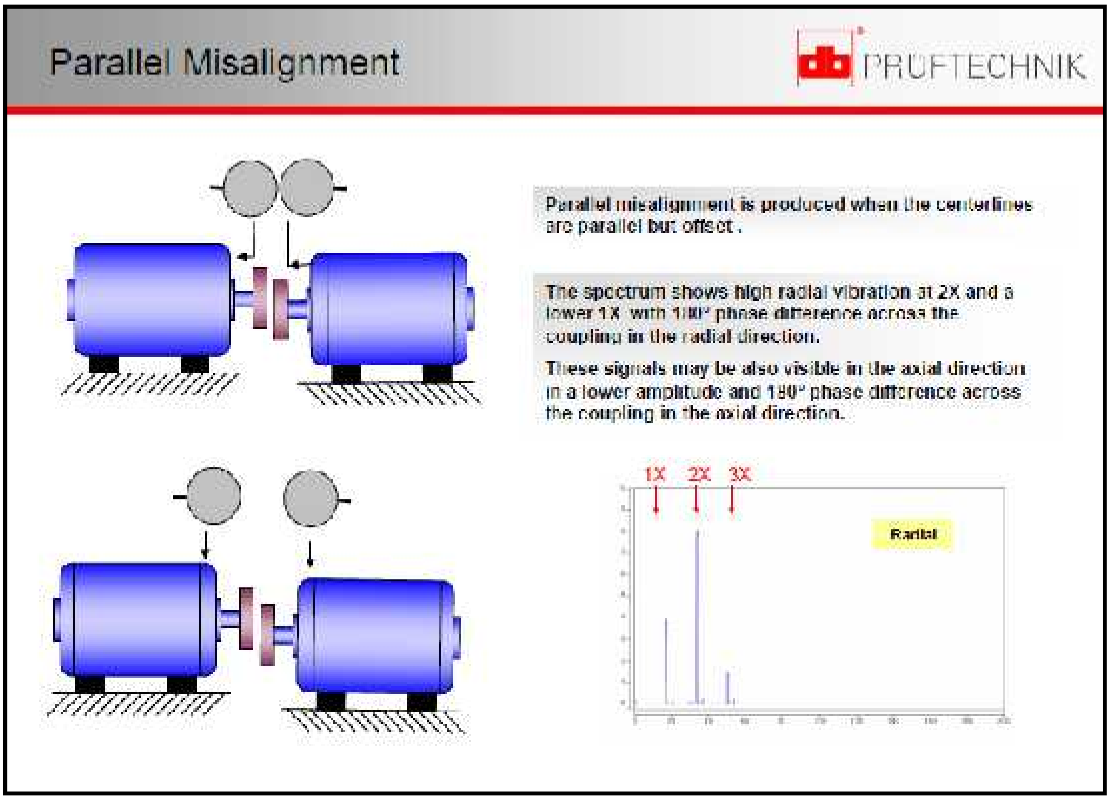

Figure 8 : Parallel Misalignment Guidelines

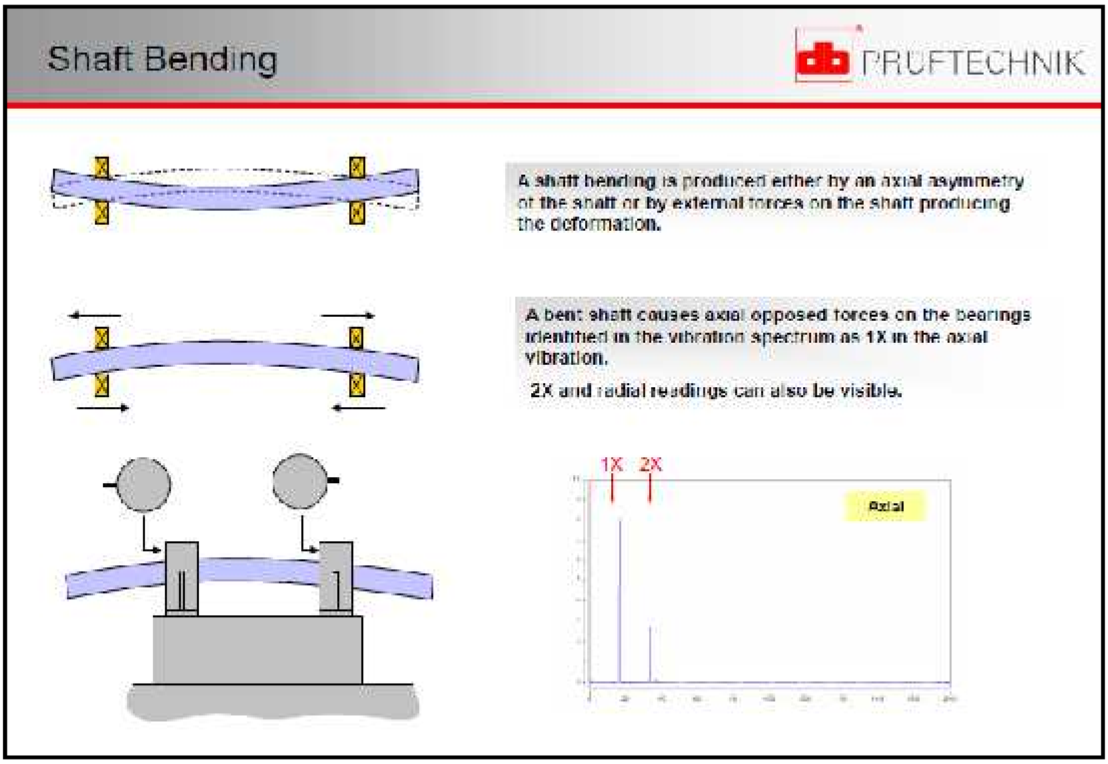

Figure 9 : Shaft Bending Guidelines

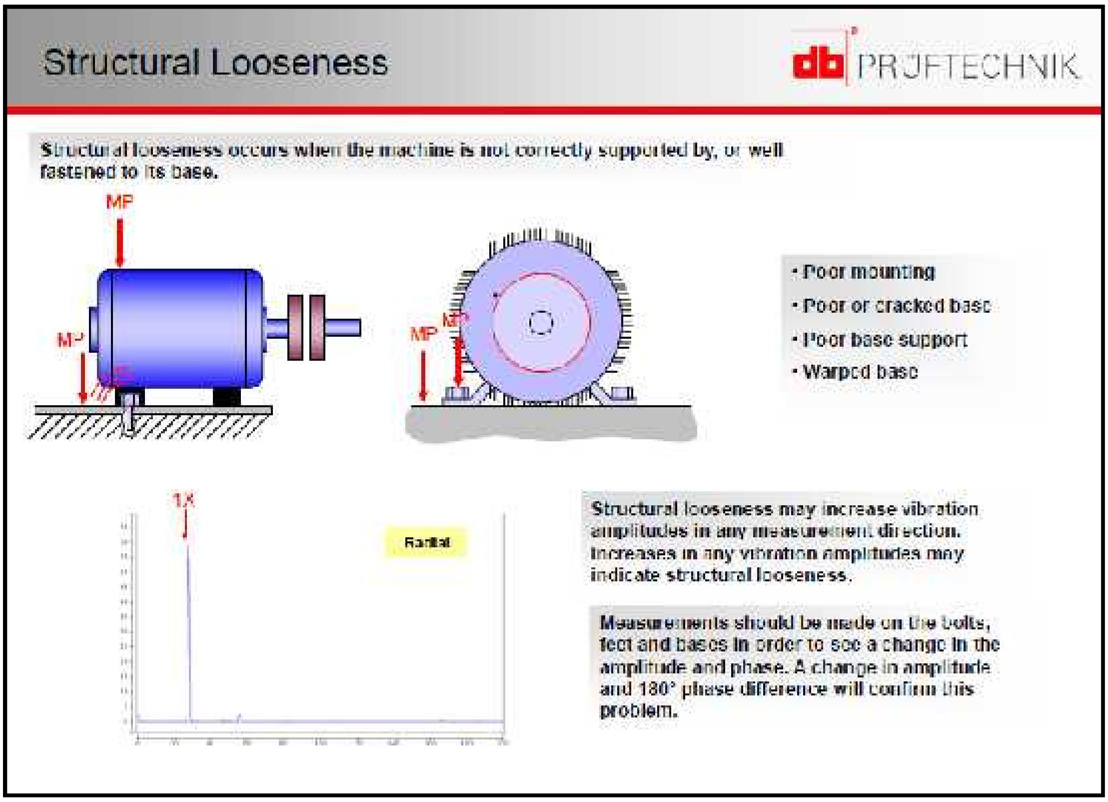

Figure 10 : Structural Looseness Guidelines

CHAPTER 3

METHODOLOGY

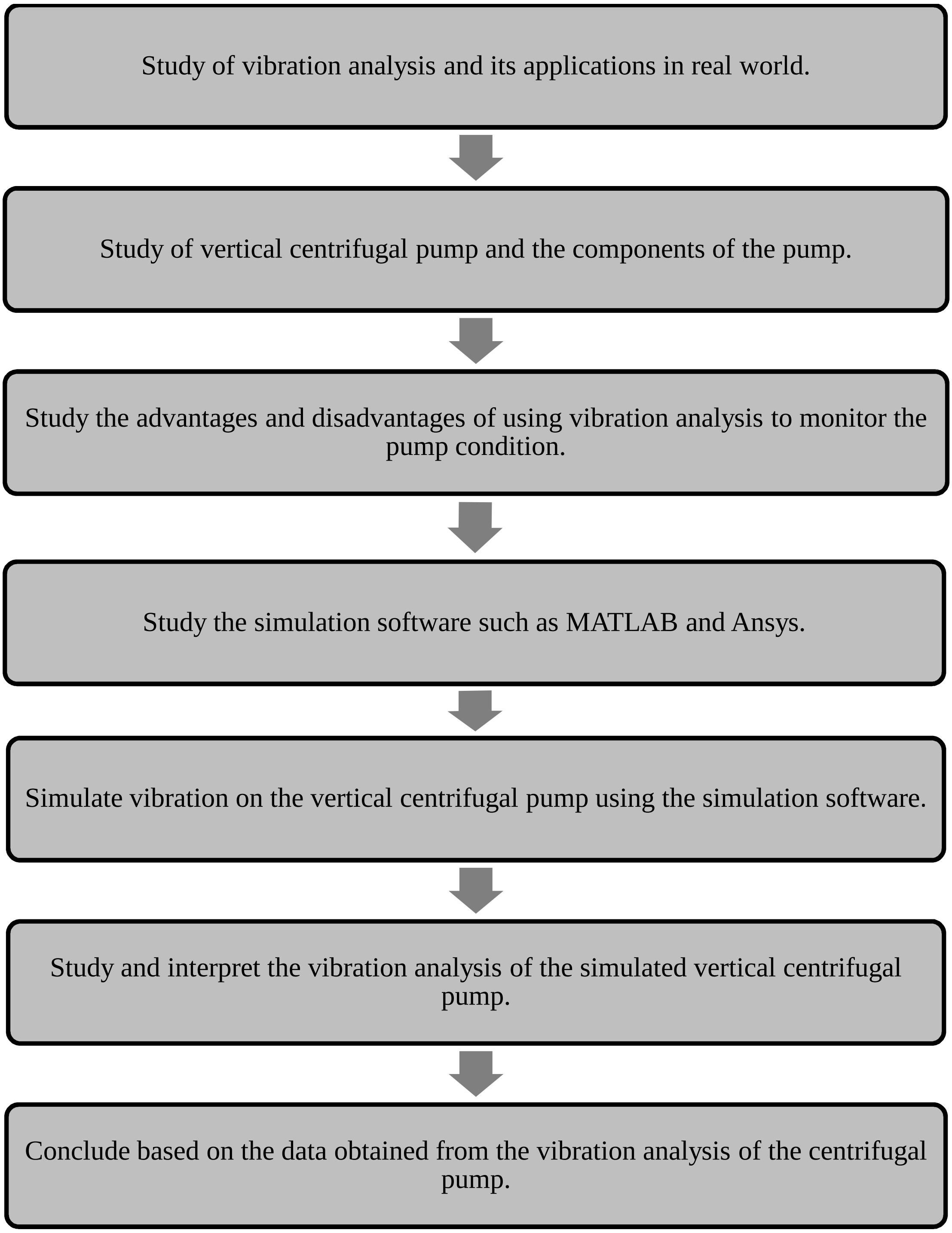

Figure 11 : Methodology of the Project

The methodology of this project mainly consists of two stages, where the early stage basically focused on the research about the vibration analysis and vertical centrifugal pumps. The methods involved in the vibration analysis and the application of vibration analysis in real life are thoroughly studied to further improve the understanding on this topic. Besides, research is also done on the static components and rotary components of the vertical centrifugal pumps and the type of maintenance carried out generally in heavy industries for this pump.

The later stage focuses more on the vibration simulation of the pump using the simulation software. Finite element method will be used to break down the model of the design into small elements. The vibration data obtained from the simulation will be analysed and interpreted to determine the condition of the pump. Based on the analysis, any components that are malfunctioning or showing sign of wear can be identified. Below are the planned activities to be carried out for this project and the timeline for each activity.

The simulation is done using different parameters, to see the differences of the pump vibration, which was converted into an FFT spectrum to be compared with the LUCEDA Machinery Fault Guidelines to determine the type of problem in the pump. Besides, a mathematical model was taken from a previous literature done by Janevska.G, was run using Simulink using manufacturer's parameter for vertical centrifugal pump to determine the angular velocity of the pump, which can be compared with the angular velocity given by the manufacturer to determine if there are any faultiness. All the results are recorded and labelled accordingly and the results are analyzed and interpreted.

3.1 Project Activity (MATLAB)

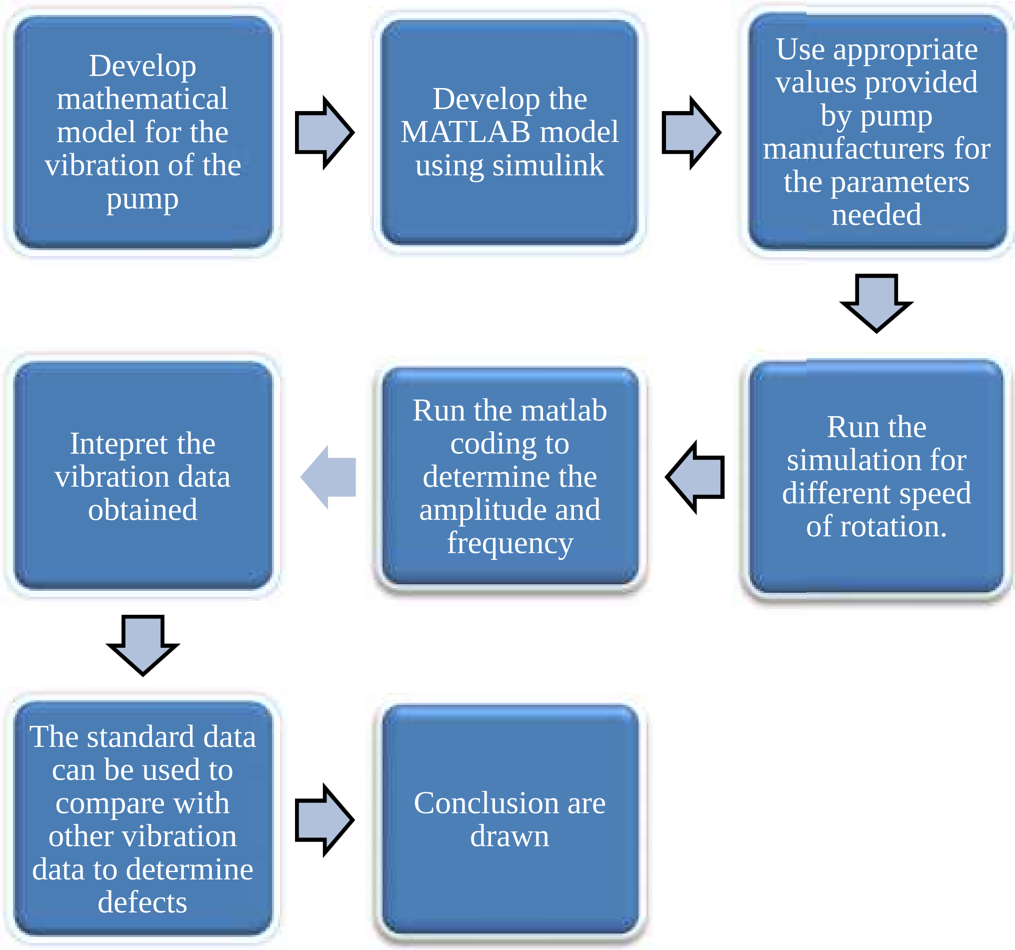

Figure 12 : Project Activity for MATLAB Simulation

The project activities are mainly the simulation of the vertical centrifugal pump vibration and interpretation of the data. For MATLAB, the mathematical model has to be developed to study the vibration of the pump. The matlab code on the other hand will show the frequency and amplitude of the pump at certain situation. The standard data obtained using the rotational speed from the manufacturer can be used as a standard to compare with other data to determine any unusual vibration which could be a sign of defect in the pump. The frequency and amplitude obtained can be compared with the machinery guideline to determine the type of problem.

3.2 Gantt Chart

Table 2: Gantt Chart for FYP II

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature Review														
2	Simulation of vertical centrifugal pump using MATLAB														
3	Simulation of vertical centrifugal pump using ANSYS														
4	Interpretation of vibration data obtained												★	★	
5	Submission of Progress Report														
6	Pre-Sedex Poster Presentation										★				
7	Submission of Technical Paper														
8	Submission of Dissertation														★
9	Viva														★

★ **= Key Milestone**

The Final Year Project 2 mainly consists of simulation of the vertical centrifugal pump to obtain data on the vibration analysis. MATLAB software is used to obtain the vibration data. The key milestone for this project is the interpretation of the vibration data obtained and also the pre-sedex presentation and Viva of the project. The simulation has been finished by week 11. The dissertation was submitted on week 14.

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 Results (MATLAB)

The mathematical model of the vertical centrifugal pump is developed using the following torque formulas :

$M_{MT} = k_{MT}U^2(2\pi f - \omega)$................Equation 4.1

$M_{\zeta} = k_{\zeta}\omega$...Equation 4.2

$M_P = \rho g q_{v2} H / \eta_P \omega$.......................Equation 4.3

C.R.I.'s vertical multistage centrifugal pumps are non self priming axial suction and delivery type available with DIN standard for connection. All components like impeller, diffuser & shaft of these pumps are made of corrosion resistant AISI Stainless Steel and designed to deliver the best possible hydraulic efficiency. Using the specifications of this pump, the block diagram of the centrifugal pump angular velocity was developed. The following are the specifications given by the pump manufacturer:

F, frequency = 50 Hz

H, Head = 10 - 330 m

q_{v2}, discharge velocity = 1- 110 m^3/h

η_P, efficiency = 0.9

k_{MT}, motor constant = 0.1

k_{ζ}, leakage constant = 0.05

ρ, density = 1000 kg/m^3 (assuming water is used)

r, impeller radius = 0.15 m

U = motor speed = 2πrf

= 2 x π x 0.15m x 50 rps

= 47.12 m/s

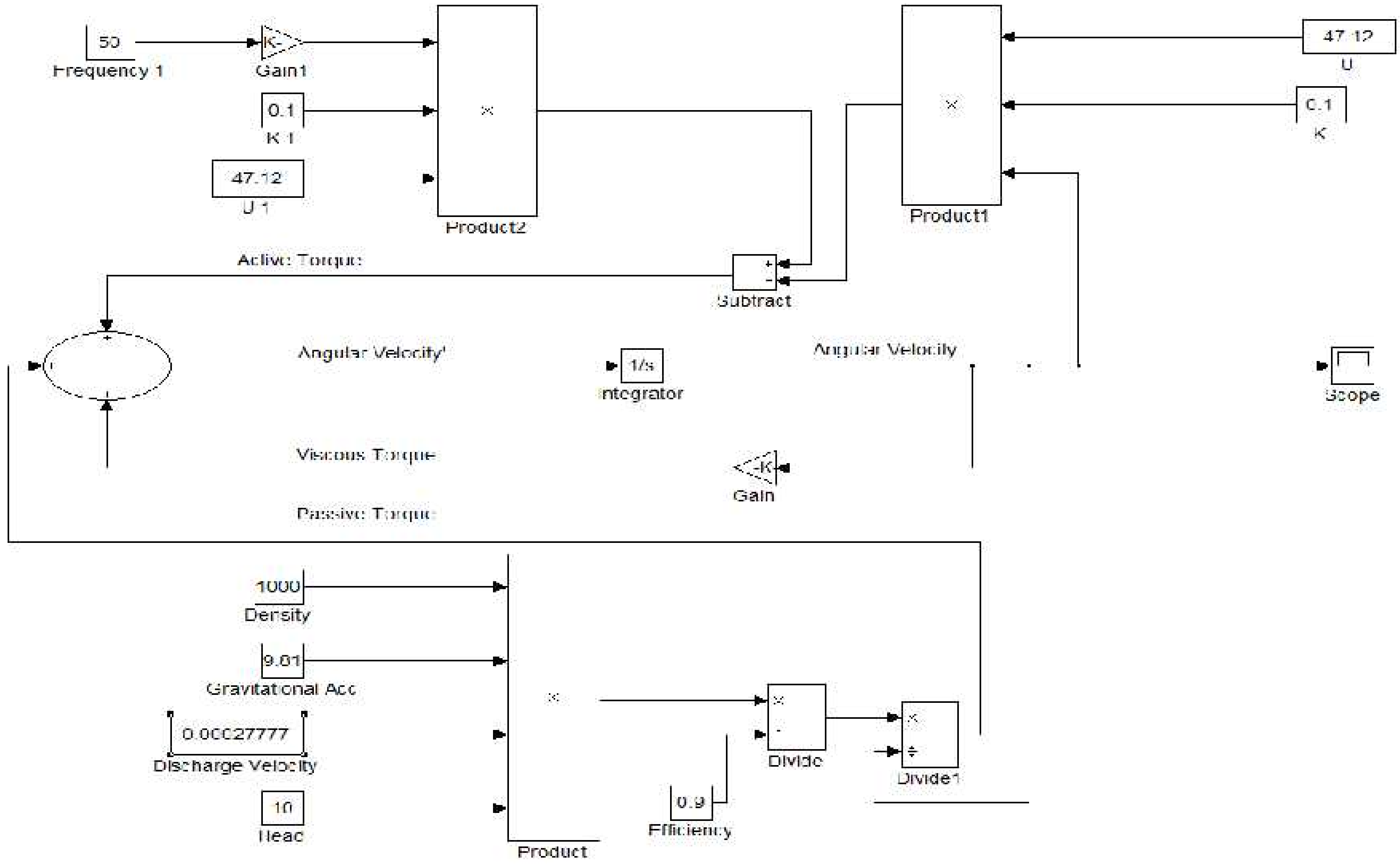

Figure 13 : Block Diagram for Simulink

The value of the frequency and discharge velocity was kept constant to study the effect on the angular velocity, which directly shows the amount of vibration in the vertical centrifugal pump.

Frequency = 10-50 Hz, discharge velocity kept constant at 1 m^3/h (0.000277 m^3/s)

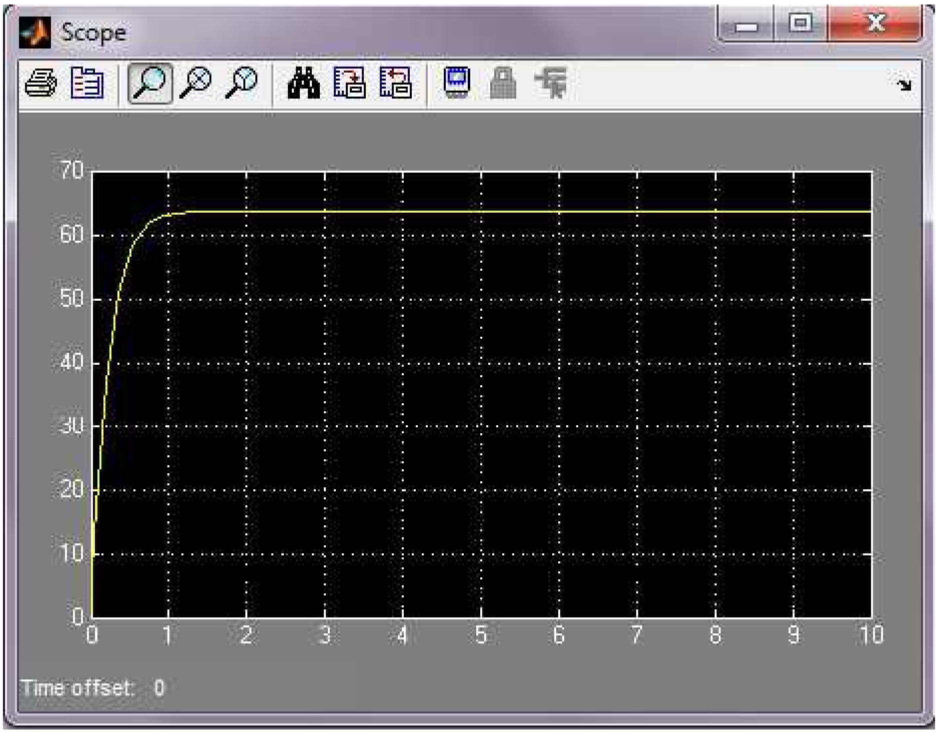

Figure 14 : Angular Velocity graph for frequency 10 Hz

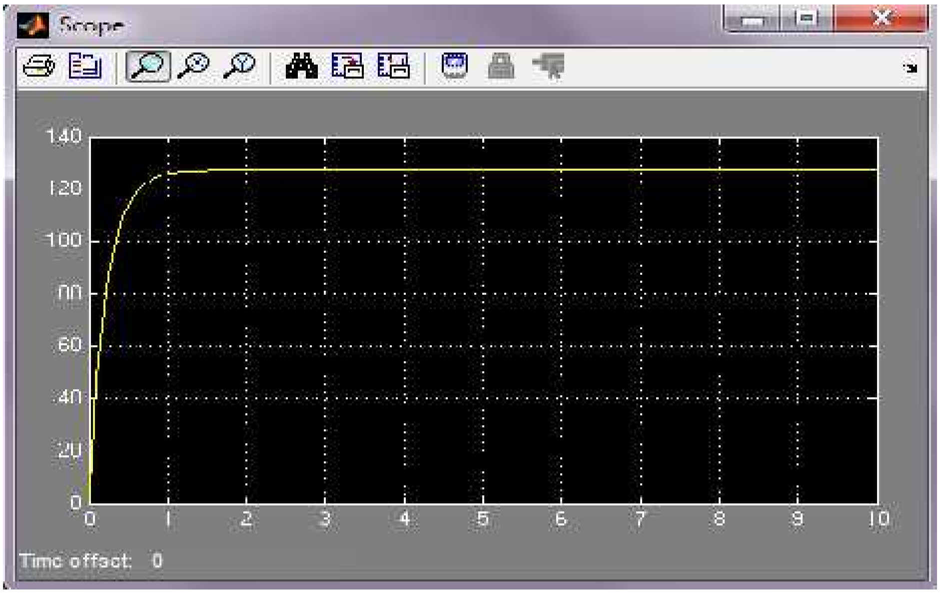

Figure 15 : Angular Velocity graph for frequency 20 Hz

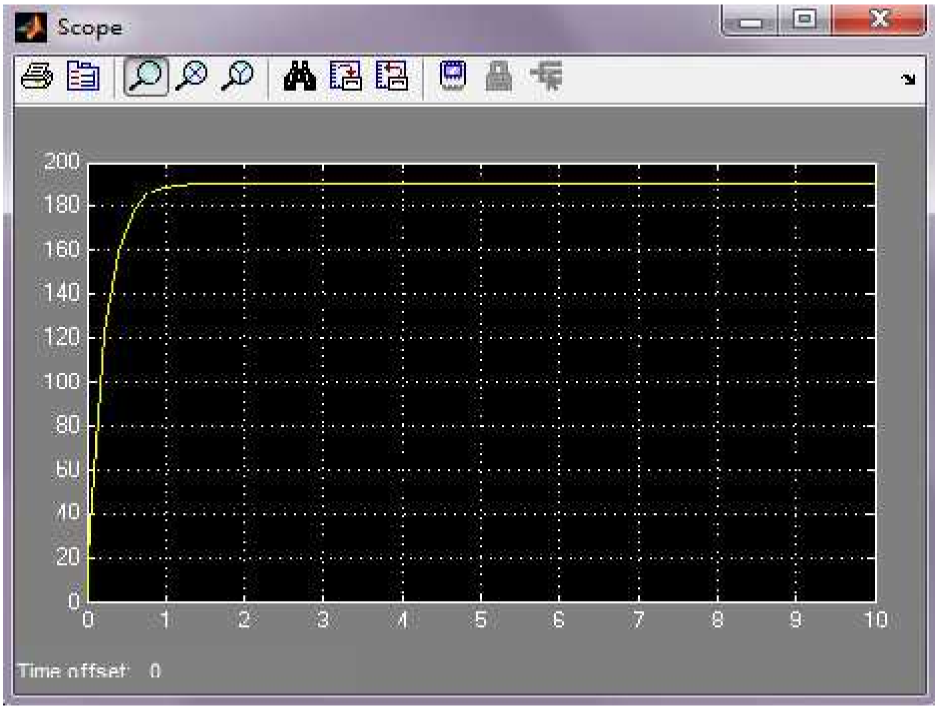

Figure 16 : Angular Velocity graph for frequency 30 Hz

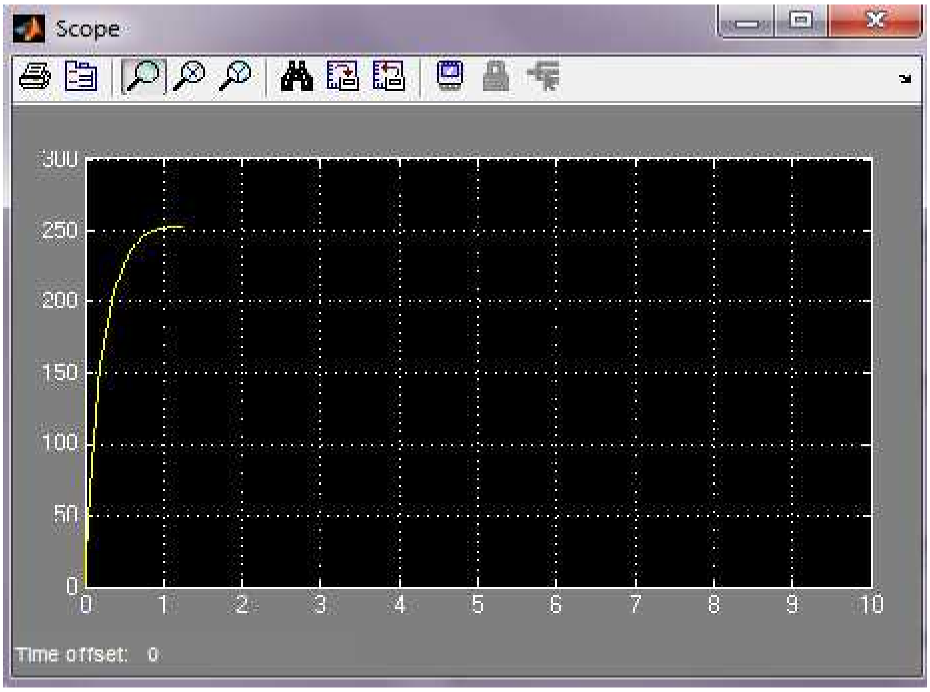

Figure 17 : Angular Velocity graph for frequency 40 Hz

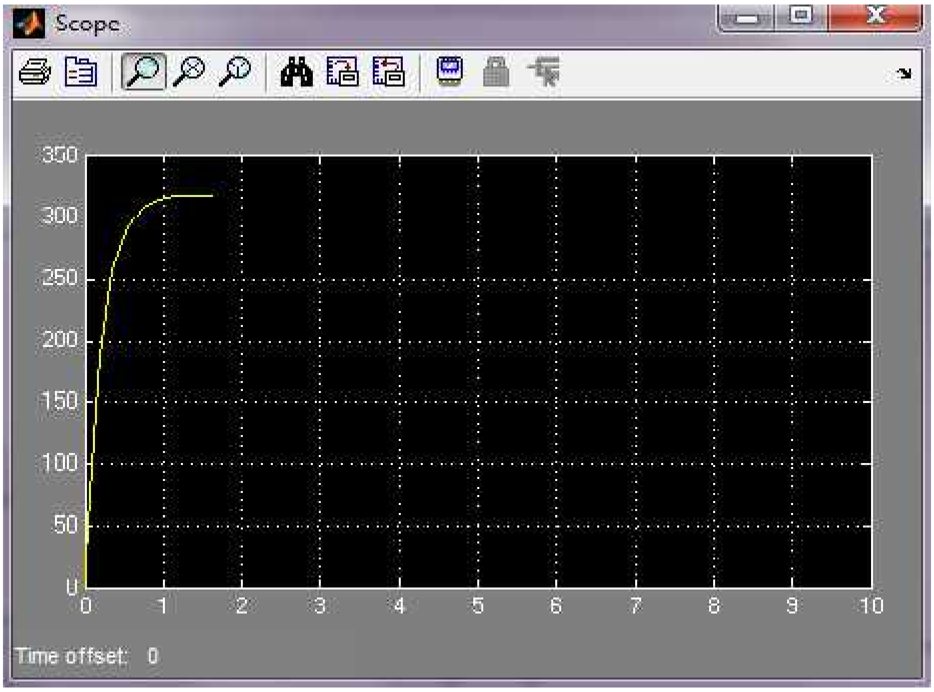

Figure 18 : Angular Velocity graph for frequency 50 Hz

Table 3 : Frequency and Max Angular Velocity

Frequency (Hz)	Max Angular Velocity (rad/s)
10	62
20	130
30	190
40	250
50	320

Discharge velocity = 10 -110 m^3/h, while frequency kept constant at 50 Hz

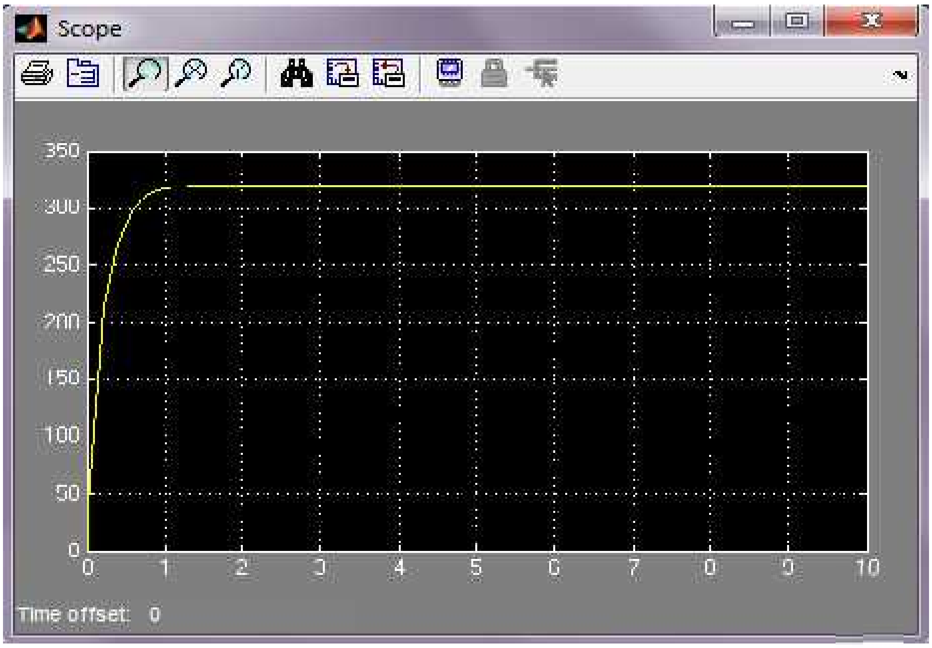

Figure 20 : Angular Velocity graph for discharge velocity at 10 m^3/h

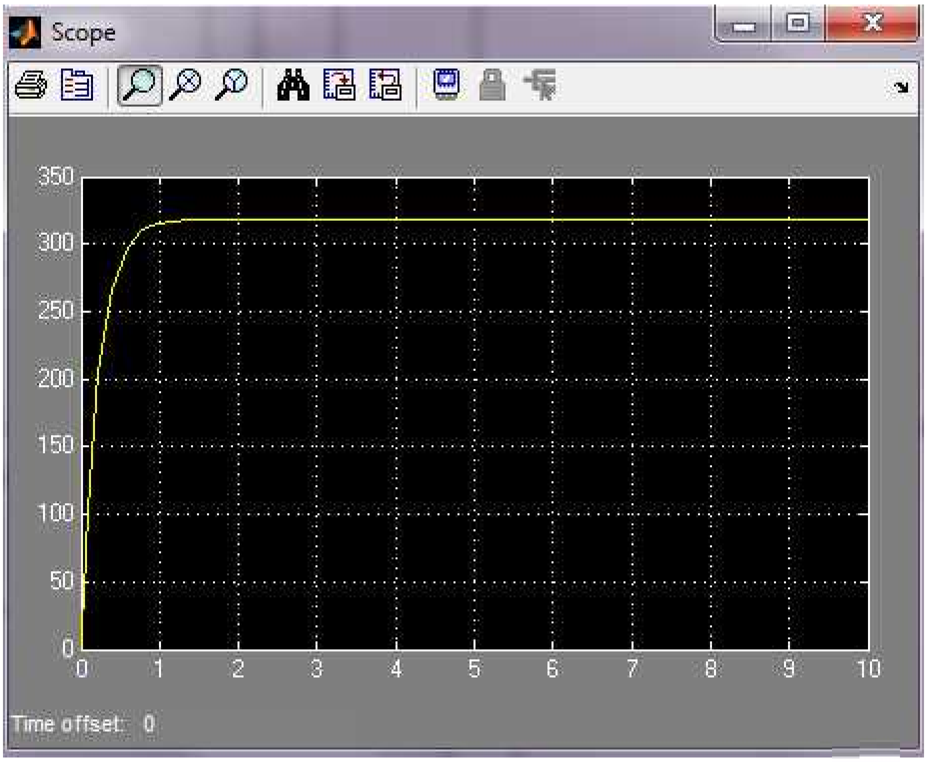

Figure 21 : Angular Velocity graph for discharge velocity at 30 m^3/h

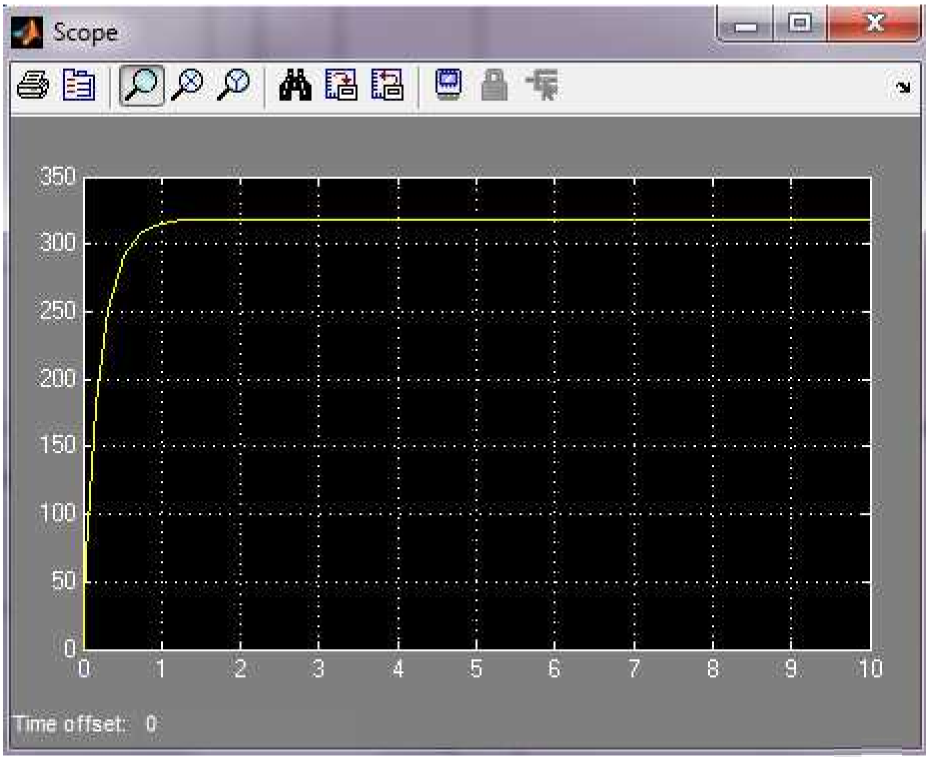

Figure 22 : Angular Velocity graph for discharge velocity at 50 m^3/h

Table 4: Discharge Velocity and Max Angular Velocity

Discharge Velocity (m^3/h)	**Max Angular Velocity (rad/s)**
10	320
30	320
50	320
70	320
90	320
110	320

4.2 Discussions (MATLAB)

For the first simulation, where the frequency was varied from 10 Hz to 50 Hz, the maximum angular velocity changes from 62 rad/s to 320 rad/s. The angular velocity increases gradually from zero to the maximum value and stays constant at the peak. The vibrations are mainly caused by the rotation of the impeller and shaft and it increases gradually once the pump is started and remain constant throughout the pumping process until it is closed. According to the pump manufacturer, the maximum motor frequency for the pump is 50 Hz, thus the maximum angular velocity about 320 rad/s. Angular velocity higher than 320 rad/s shows that there are some defects in the pump, which could cause malfunction of the whole pump.

For the second simulation, where the discharge velocity was varied from 10 m^3/h to 110 m^3/h, where the maximum angular velocity were constant at 320 rad/s. The change in discharge velocity was negligible and does not affect the vibration of the pump. Therefore, it can be concluded that changing the frequency will affect the overall vibration of the pump. The vibration data obtained using the manufacturer's parameters can be kept as a standard to compare for specific rotational speed. Using this method, problems in the pump can be identified if there are any excessive angular velocity relative to the manufacturer's standard. However, this method does not show the type of problem and can be used for small vertical centrifugal pump, where it is cheaper, simpler and does not involve vibration specialist to interpret the data the determine the type of fault in the pump. A more advanced vibration analysis will involve FFT spectrum where the severity of the problem and type of problem can be determined using the vibration data obtained.

4.3 Results and Discussions (MATLAB - FFT)

The vibration graph is usually obtained from real time data using sensors connected to the vertical centrifugal pump. However, in this case study the vibration graphs are obtained using vibration formulas to imitate the similar results to those from real time data. The measurements used were based manufacturer specification on C.R.I.'s vertical multistage centrifugal pumps. The rotational speed of the pump is 3000rpm. The graph obtained is as following:

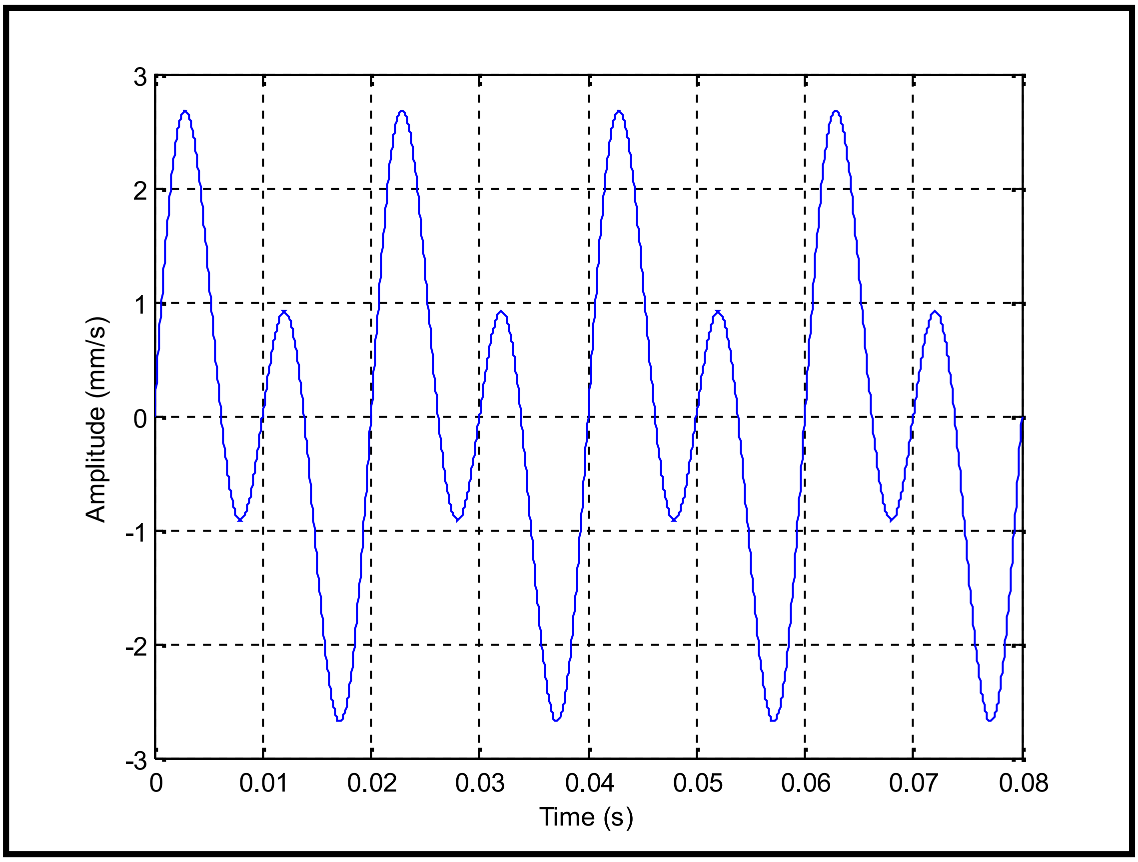

Figure 23 : Vibration graph of the pump at 3000 rpm with no load

Based on the graph, it can be observed that the curve peak has amplitude of 2.5mm/s, 0.9mm/s and -2.5mm/s. The time taken for each cycle is 0.01s. This is at no load, where the pump is functioning at an optimum level. However, when there are any fault in the pump, it will cause an extra load acting on the pump. For an example, the pitting in the impeller will exert extra force on the pump during the rotation of the impeller, which will affect the vibration of the entire pump. Therefore, a small load of 0.5N, 1.0N, 1.5N and 2.0N are introduced to the equation to observe the change in the vibration results.

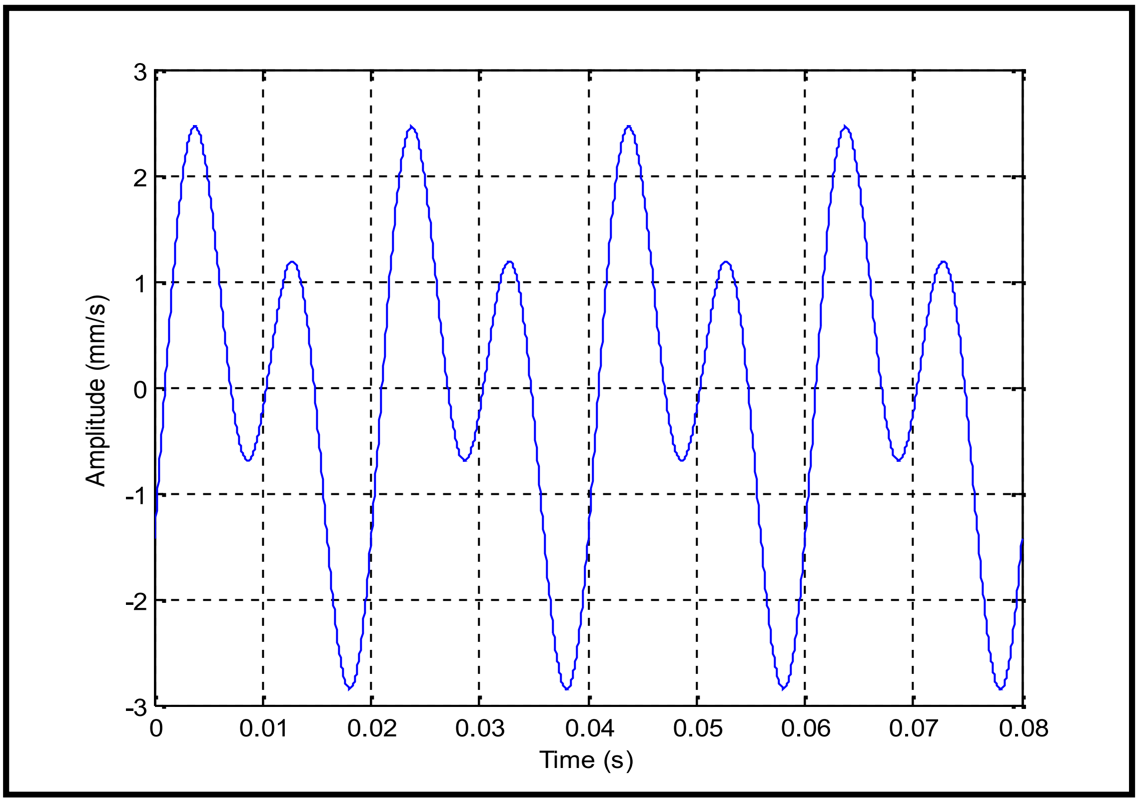

Figure 24 : Vibration graph of the pump at 3000 rpm with 0.5N load

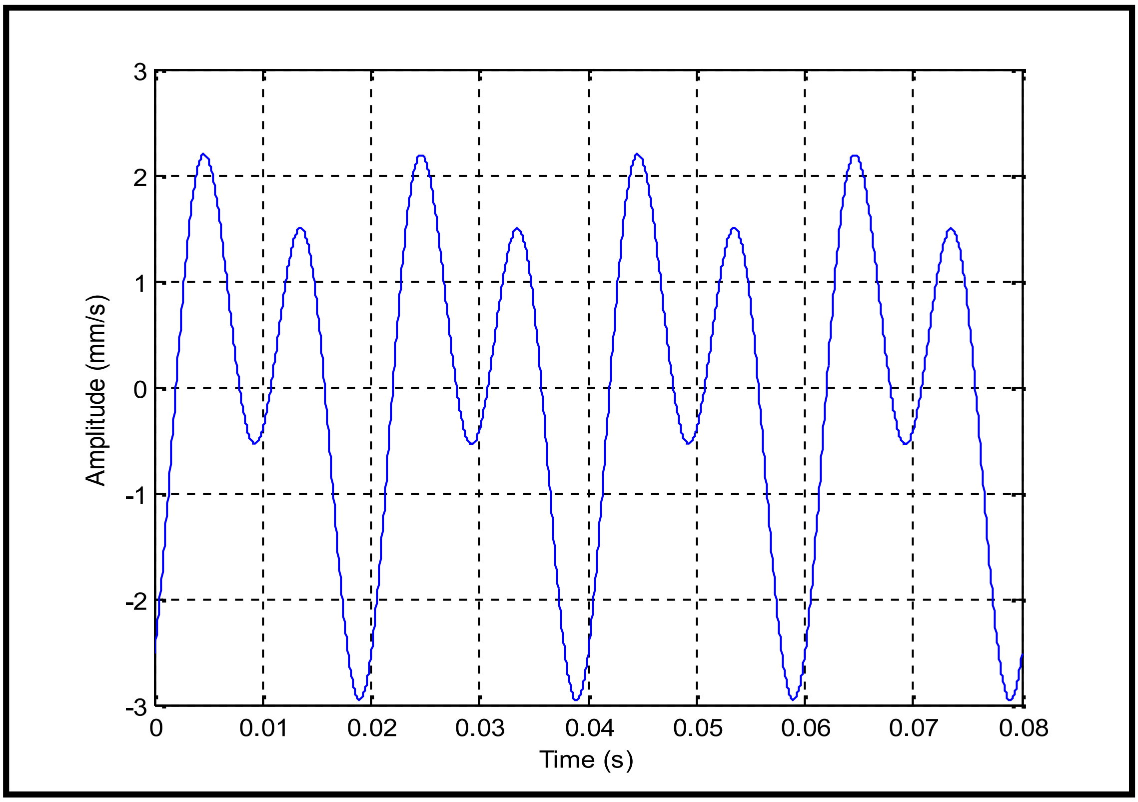

Figure 25: Vibration graph of the pump at 3000 rpm with 1.0N load

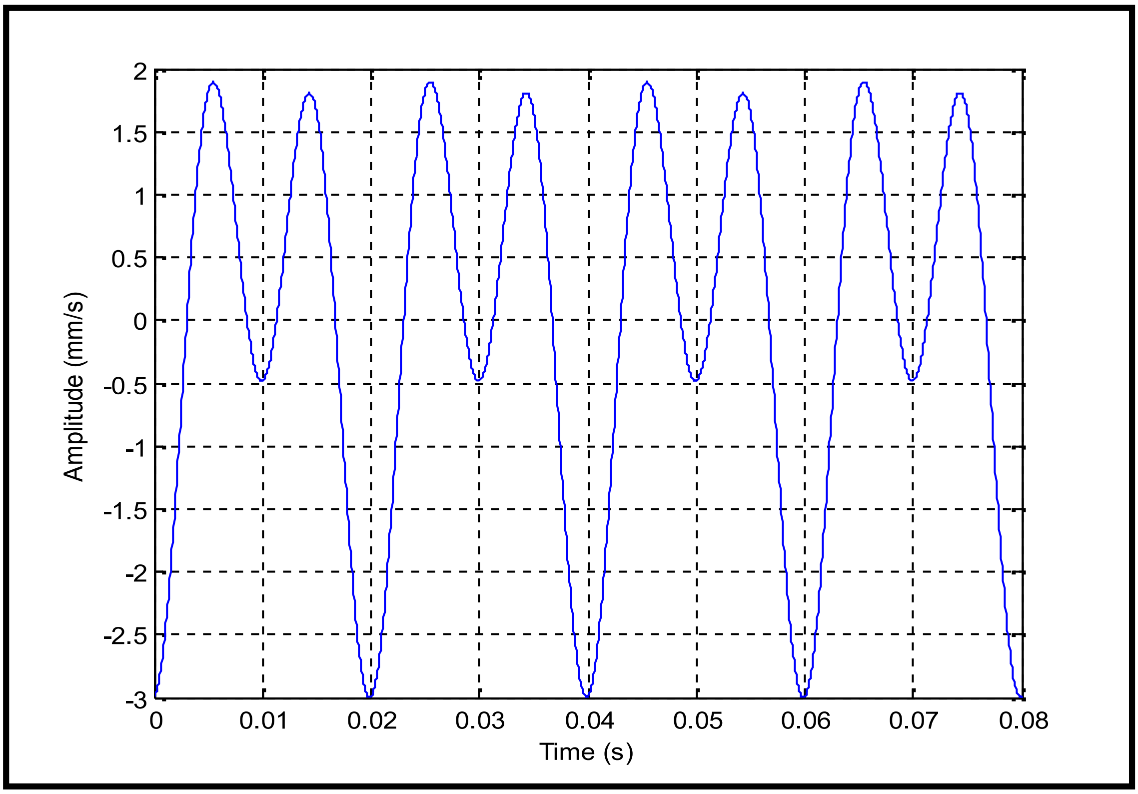

Figure 26 : Vibration graph of the pump at 3000 rpm with 1.5N load

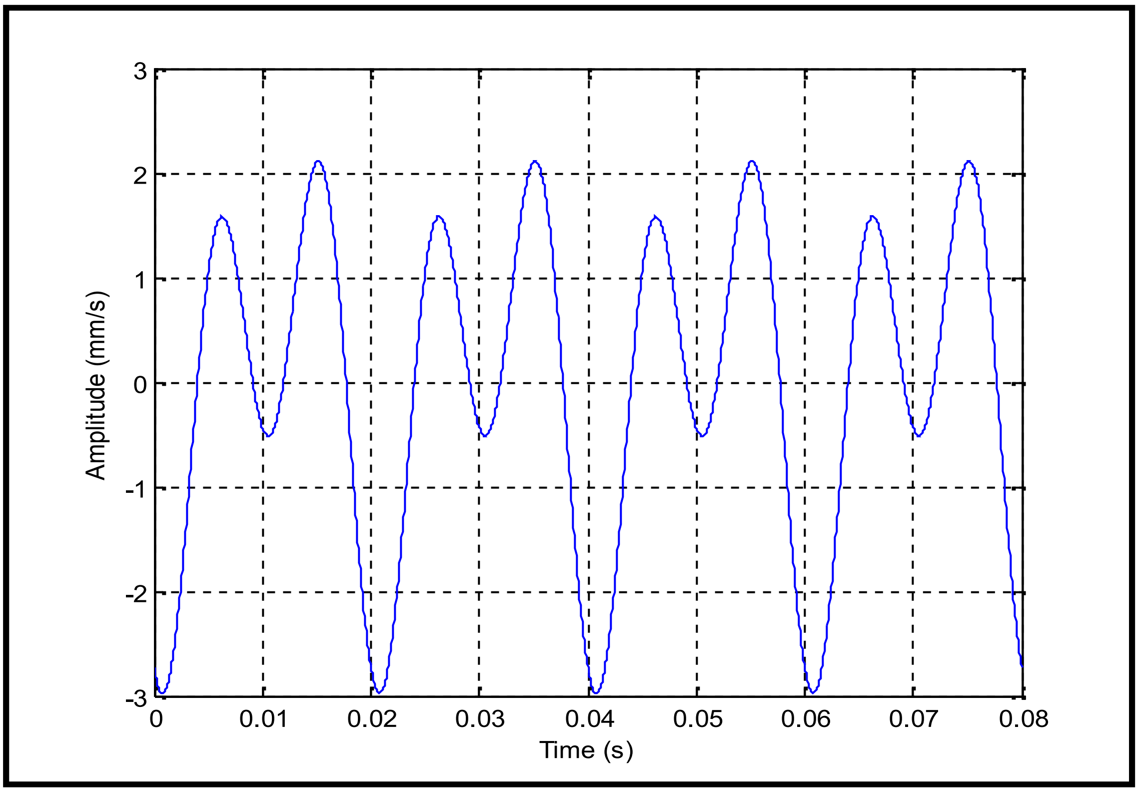

Figure 27 : Vibration graph of the pump at 3000 rpm with 2.0N load

Table 5: Table of Amplitude and Time Taken per cycle

Load	No Load	0.5 N Load	1.0 N Load	1.5 N Load	2.0 N Load
Amplitude at peak (mm/s)	2.5, 0.9, -2.5	2.3, 1.1, -2.9	2.1, 1.3, -3.0	1.9, 1.9, -3.0	1.5, 2.1, -3.0
Time taken per cycle (s)	0.01	0.009, 0.011	0.009, 0.011	0.009, 0.011	0.009, 0.011

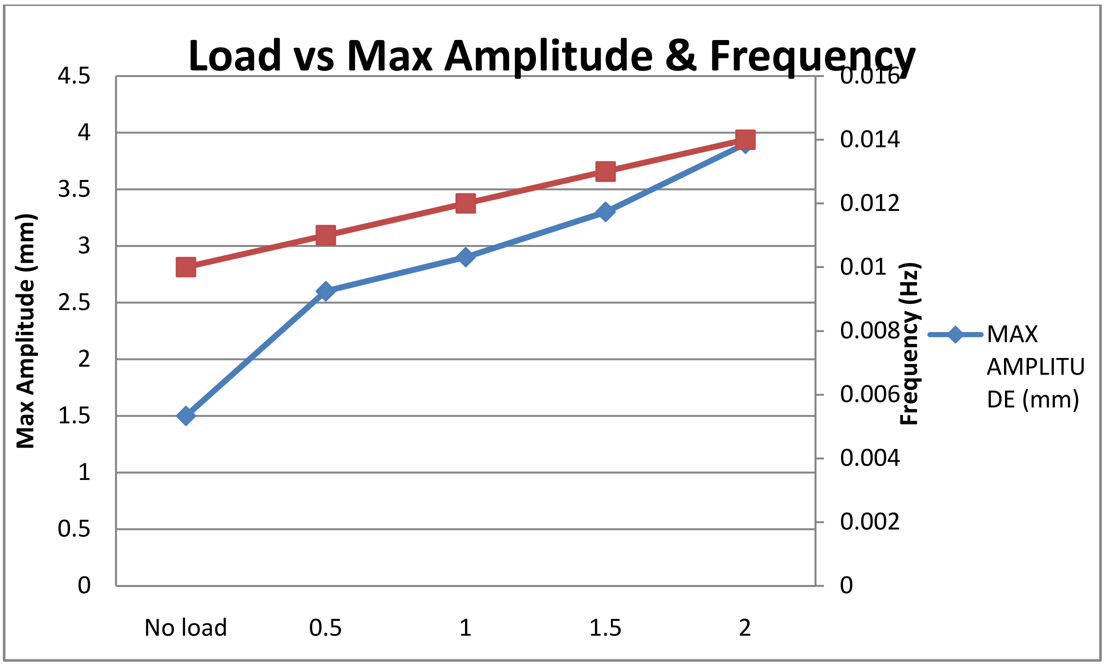

Figure 19 : Graph shows Load vs Max amplitude & Frequency

Based on the graph for 0.5N load, it can be observed that the amplitude for two of the peak curves has increased to 1.2mm/s and -2.9 mm/s from 0.9mm/s and -2.5mm/s respectively. Besides the frequency for the first cycle drop from 0.01 s to 0.009s, while the frequency for the second cycle increases from 0.01 s to 0.011s. The amplitude for the 1.0N, 1.5N and 2.0N is observed to increase further as the load increases. However, the frequency for all loads are the same. This shows that as the problem gets worse, the amplitude increases, where the amplitude shows the severity of the problem. Whereas, the frequency remains same because frequency shows the type of the problem and it is the same for all the data since the same pump is used. To determine the type of the problem of the pump, the data has to be changed into frequency spectrum to be compared with the machinery fault guidelines. The frequency spectrum for the pump with the load is:

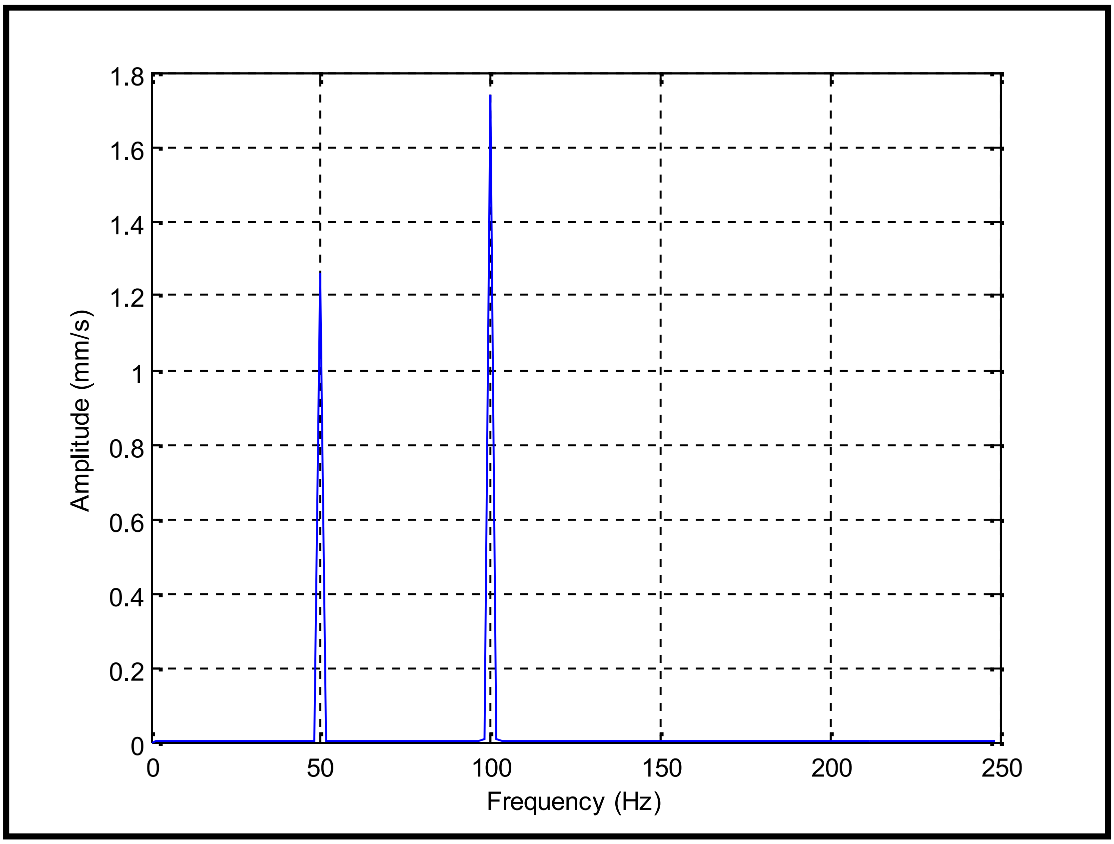

Figure 28 : Frequency Spectrum of the pump at 3000 rpm with load

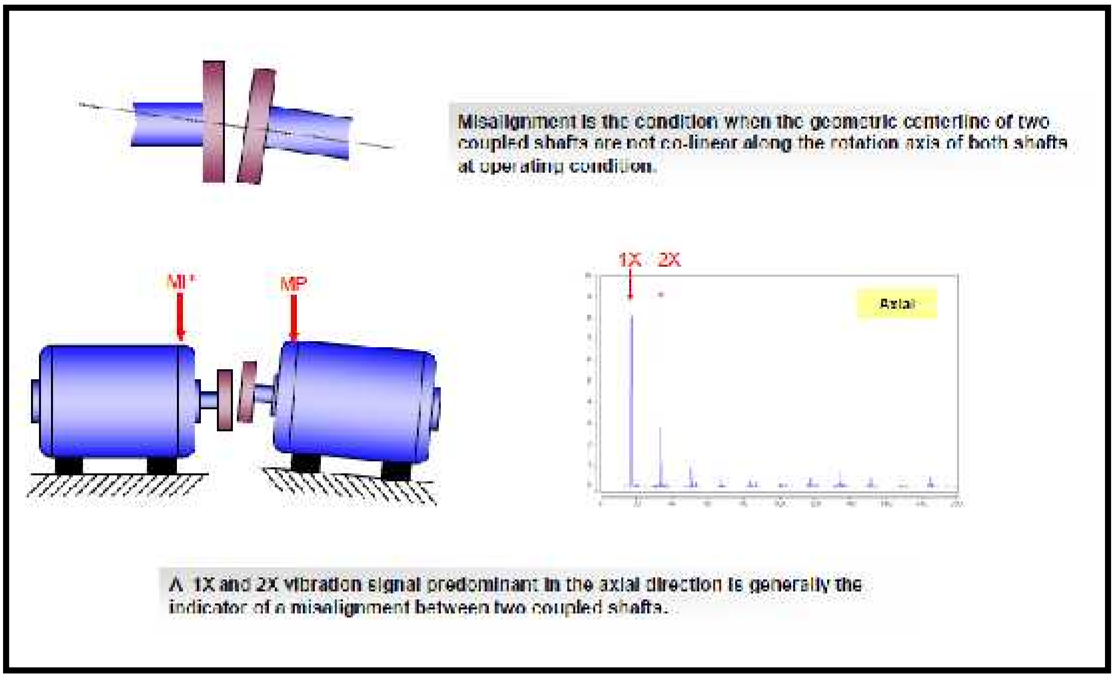

Figure 29 : LUDECA Machinery Fault Diagnosis Guidelines on Misalignment

Based on the frequency spectrum, it can be compared with the LUDECA Machinery Fault Diagnosis Guidelines on Misalignment to determine the type of problem associated with the pump. The graph pattern of the frequency spectrum can be related to misalignment as it shows two significant vibration signal, similar to figure 29. Misalignment is the most obvious fault that can be observed in this situation. However, there could be some other developing fault that can occur at the same time. The vibration data obtained from the real time data, using proper equipment, will show a better vibration data that can be studied to determine the developing problems.

CHAPTER 5

CONCLUSION

5.1 Conclusion

As a conclusion, this project is very important as it helps to detect early sign of maintenance issues in the vertical centrifugal pump before the situation gets worse and expensive. In the industry, many of the pumps do not have a proper pressure indicator or flow instrumentation that can detect abnormal hydraulic operating conditions after a period of time of operations. Hence, vibration measurement is a robust method even though conventional for the detection of vibration faults of the pumps such as cavitations. It also represents the most viable tool to the plant personnel. Many heavy industries are spending millions of ringgit to replace the whole pump or major components of the pump due to failure to detect the wears or problems in the pump early. There are also some other methods but vibration analysis are one of the most reliable method and it also covers a wide variety of issues such as misalignment, bearing damage, cracking, mechanical looseness or rubbing, balance, gear failure and cause of noises. Besides, vibration analysis also can be used to ensure repairs and maintenance are done properly and the machine is in the optimum condition.

A dissertation for the research work has been prepared. The simulation for the vertical centrifugal pump has been carried out and the results are interpreted. The amplitude of vibration graph can be used to determine the severity of the problem in the pump while the frequency can be used to determine the type of problem associated with the problem. As a conclusion, the objective of the project is achieved, where the vibration of the vertical centrifugal pump has been analysed to detect sign of wears and problems in the pump

5.2 Recommendation

The project has been carried to successfully. However, there are some improvements can be made in the future to further improve the obtained data and to study the vibration analysis in further detail. Some of the recommendations for the project are:

- Use different software such as ANSYS, SOLIDWORK and CATIA to simulate the vibration using the manufacturer's CAD drawing of the pump.
- A real time data using pump and proper equipment should be used such as sensors, and vibration interpreter machines to obtain a more accurate vibration data.
- The results obtained should b compared some other standards, which are provided by the specific manufacturer of the pump.

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APPENDICES

1. SPECIFICATIONS OF THE VERTICAL CENTRIFUGAL PUMP

50 Hz — Multistage Centrifugal Pumps - VERTICAL CENTRIFUGAL PUMP - MV SERIES

Description | **Specifications** | Features | MOC | Applications

Power Range(KW)	0.37 KW - 45 KW
Speed	2900 rpm
Versions	AC, 1Ph, 230V, PSC, [Incorporated with TOP] AC, 3Ph, 380/415V
Duty	S1 (Continuous)
Degree of Protection	IP 55 (Optional IP44, IP54)
Class of Insulation	'F' / 'B' (Optional)
Flange Type	Round / PJE
Discharge Range	1 - 110 m³/h
Head Range	10 - 330 m
Max.Suction Lift	7 m
Sealing Type	Mechanical Seal (Cartridge Type)
Max.Liquid Temperature	-15°C to +120°C
Max.Ambient Temperature	40°C
Max.Opearting Pressure	3MPa (30 bar)
Flanch Standard	DIN
Pipe Connections	DN 25,32,40,50,65,80 & 100