The present work was submitted to the Faculty of Engineering

# Centrifugal slurry pump vibration analyze

## Bachelor Thesis

by


## Zolboo Batsaikhan


| | |
|---|---|
| Supervisor 1 / Examiner 1 | Professor Ph.D. Ariunbolor Purvee |
| Supervisor 2 / Examiner 2 | Ph.D. Odbileg Norovrenchin |
| Advisor | Mr. Gureragchaa |

Ulaanbatar/Nalaikh, May 7, 2019

# Abstract

This bachelor work is a part of the “Slaked lime system” problem developing project and it is aimed to discover and modify a slurry pump overheat problem occurred at Oyu Tolgoi mine. And it is searched for ways to reduce overheating so that the mining operation could have benefit in numerous ways.

The main objective of this work is to analyze vibration of the pumps, as it is experiencing overheating problem in the bearing area. Problem causing roots would be detected and analyzed for optimal solutions. Design modification would be done as one of the result of this research work.

# Acknowledgement

I would like to thank GMIT Engineering Faculty and Oyu Tolgoi LLC for giving me the great opportunity to apply my knowledge in a real life problem, and to learn from world leading organization. The completion of this undertaking would not be possible without participation and assistance of supervisors, professors and engineers from the company. Their contributions are sincerely appreciated and acknowledged.

I would like to express my deep gratitude to my supervisors Professor Ph.D. Ariunbolor and Ph.D. Odbileg for their guidance, support and patience in helping complete this thesis. Their valuable and constructive suggestions during the study and development of this research. It was a pleasure to be assisted and to learn from them. Their willingness to give their time so generously has been very much appreciated.

I wish acknowledge the help provided by company advisor superintendent Mr. Gurragchaa, manager Mr. Ankhbayar and graduate engineer Mr. Galdan. These gentlemen helped to advance my ideas and were providing useful materials and information. Moreover, the company’s human resources specialist Mrs. Tsolmon is wholeheartedly acknowledged due to her great assistance in organization and navigation.

Finally, I would like to thank my family and friends for all the understanding and support rendered during the course of this bachelor thesis.

# Table of Contents

# Chapter 1

# Introduction

## 1.1 Overview

This chapter will outline the intent of the company, project and the reason why this topic was chosen as a bachelor thesis subject. Moreover, overview of the lime system of the mine will be provided.

Oyu Tolgoi (OT) LLC is Mongolian government and Turquoise Hill Resources LLC co-owned company that has high impact on Mongolian economy. OT became one of the world's largest copper-gold-silver producing mine in the last few years. OT mining operation consists of three main sectors; underground mine, open pit mine, and concentrator plant. (1)

A task has been occurred in the concentrator plant production line where slaked lime system plays an important role that adds reagents to the grinding and flotation process in order to control pH of the concentration process.

Identical dual lime slaking systems that consist of equipment to receive and store dry quicklime and prepare lime slurry ready for process use. As the two lime slaking systems are completely independent of each other, each lime slaking system may operate individually, in which case the redundant lime slaking system is in standby, or both systems may operate at the same time. Each lime slaking system is designed to provide bulk storage and equipment necessary to convey dry quicklime at a specified feed rate of 11 tons per hour that with the addition of water is transformed into lime slurry via a controlled chemical reaction. Each lime silo has a 1000 tons live storage capacity (1132 m3 working volume). Each lime slaking system is designed to produce 26% solids by weight lime slurry which in turn is diluted down to 15% solids by weight with controlled water addition.

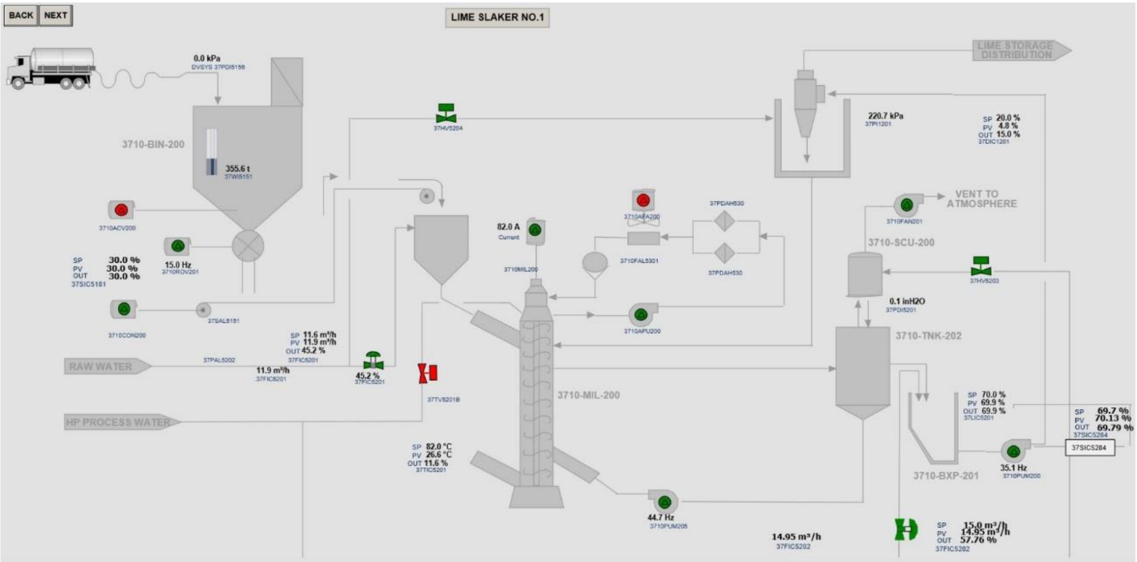


*Figure 1.1 Lime slaker system*

Dry quicklime from bulk chemical truck is pneumatically discharged into the lime silo, whereby the motive air supplied by the air discharge blower is supplied.

Dry quicklime from the lime silo is released through the lime silo activator and the lime silo rotary valve. The lime silo rotary valve doses the dry lime into the lime mill screw where the dry product is transported to the lime slaking plant.

The dry feed and process water enters the lime mill via the lime mixer. The calcium oxide (CaO) in the feed reacts with the process water to form calcium hydroxide (Ca (OH) 2). Heat is generated by the chemical reaction.

The slaked lime slurry exits the lime mill through the product outlet, which empties into the lime slaker separation chamber. The lime slaker separating chamber has a baffle plate that divides the tank into two. A properly cleared product exits the product port as the baffle plate draws the heavier oversize material into the lime liquor mill recycle pump to pump it back into the lime liquor mill for regrinding.

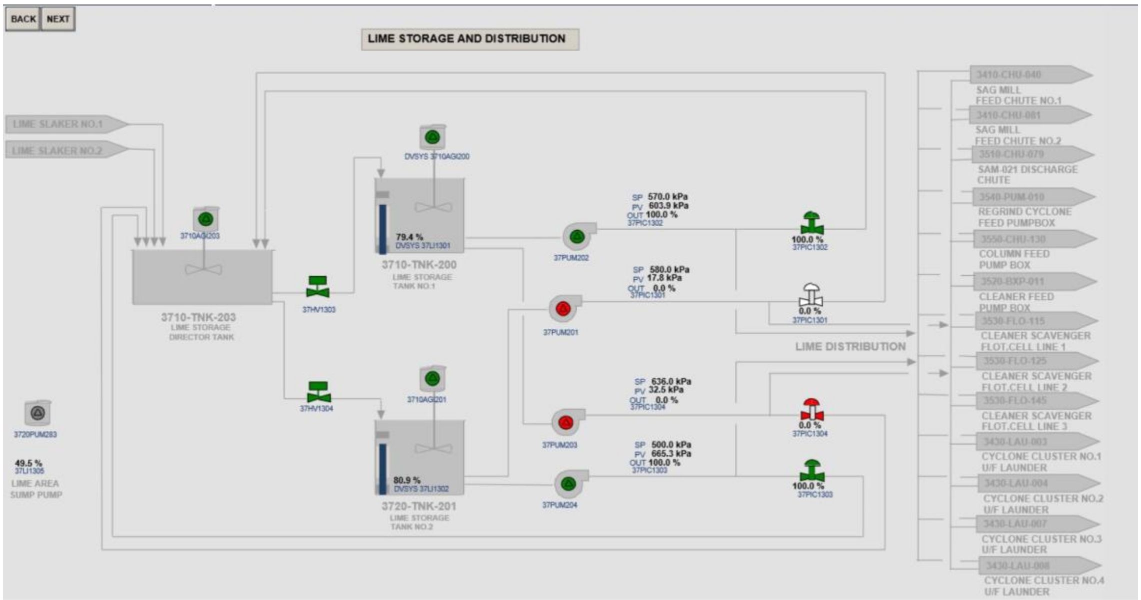


*Figure 1.2 Lime distribution*

Lime slurry exiting the lime slaker separating chamber is collected in the slaked lime pump box. Dilution water is added via the dilution water flow control valve to set the desired final slurry concentration.

Lime slurry is delivered to lime degritting cyclone by the lime transfer pump. At the lime degritting cyclone, the specified sized particles in the lime slurry overflows to the lime storage distributor while the heavier oversize product underflow is gravity fed back into lime slaking mill for further regrinding. The lime transfer pump speed is adjusted with a variable frequency drive to maintain a constant level in the slaked lime pump box No. 1 as determined by the slaked lime pump box level transmitter.

## 1.2 Problem statement and motivation

The lime system is currently experiencing overheating problem in the lime transfer pumps. These pumps make the whole grinding and flotation system stop to do planned maintenance or unplanned maintenance. These downtimes do not only seriously affect the maintenance team performance but the more money and time could be saved.

This research is purposed to analyze and decrease the vibration of pumps (3710-PUM-201/202/203/204). (Refer to Figure 1.2)


*Figure 1.3 Pump-203*

## 1.3 Contribution

In this thesis, the main objective is to discover overheating problem by using vibration analyze of centrifugal pumps with Fast Fourier Transform (FFT) spectrum.

## 1.4 Outline

Chapter 1 outlines the intent of this project and the main goal that has to be achieved. Additionally, this chapter provides brief overview of the OT lime system.

Chapter 2 provides a theoretical background of vibration concepts and the pump overview with main focus on vibration based failure.

Chapter 3 Experiment methods and data considerations would be presented.

Chapter 4 will present analysis on the data and would recommend possible solution decrease vibration on the pumps.

Chapter 5 will conclude the research work and introduce important future study concerns.

# Chapter 2

# Background Research

This chapter will provide a brief knowledge about slurry pump with a specific focus on common issues that may cause pump overheat and how it can be solved. The use of this work will be used to obtain optimal solution for the overheating problem.

## 2.1 Introduction

A centrifugal slurry pump is a kind of rotating machinery commonly used in many industries such as mining, dredging, steel and general industry. It is often on the critical path of the production line, where operations may fail during operation that may interfere with the production process. The early detection of such failures not only ensures the continuity of the production processes, but also immediately avoids major damage to the machines. A reliable maintenance system therefore plays a crucial role in keeping such industrial machinery in good working condition.(2)

The need to maintain a high level of operational reliability, to ensure the reliability of production equipment, to improve product quality and to increase productivity, is leading industries to improve their existing maintenance system(3). In addition, the maintenance system also ensures that modern industries pollute the environment at low risk while achieving maximum productivity.

The analysis of the pump is important for the continuity of the production process. The following section presents the methods of the centrifugal pump and the vibration analysis.(2)

# 2.2 Literature Review

A literature review has been done to collect a knowledge, and to further develop the idea towards a research aims. The purpose of the review was to gather relevant information about:

- Centrifugal pump and its components
- Vibration in centrifugal pumps
- Source of vibration in centrifugal pumps
- Fast Fourier Transformation

## 2.2.1 Centrifugal pump

A centrifugal pump is a mechanical device which operates a rotating impeller to accelerate fluid by converting electrical energy into kinetic energy of the fluid. The centrifugal pump as shown in Figure 2.1 is the most common centrifugal pump type which is widely used in industries. The stationary volute converts the kinetic energy of the fluid into fluid pressure. The suction of nozzle delivers the fluid into the pump's impeller view due to low-pressure area at the suction view. The low-pressure area is created because the rotation of the impeller pushes the fluid sitting between vanes outward into the volute. This outward movement creates a vacuum at the impellers view that continuously draws fluid into the pump.

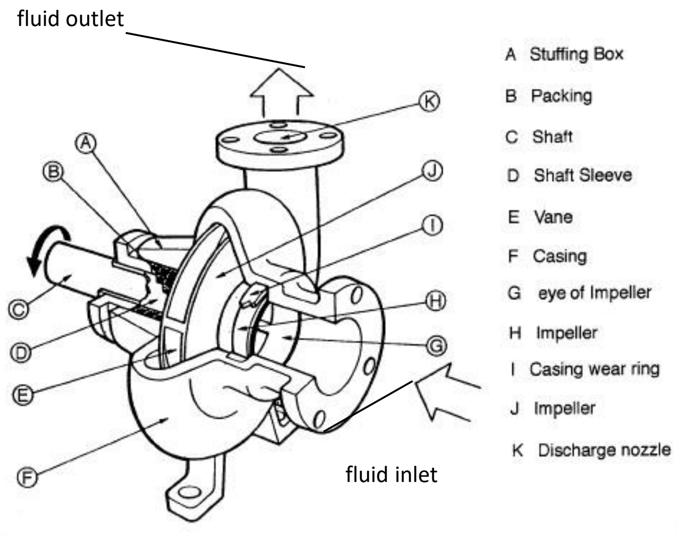


Figure 2.1 Major parts of centrifugal pump (2)

### 2.2.2 Slurry pump

The pumping slurries use many different types of pumps. The positive displacement centrifugal pump is the most common type of sludge pump. The centrifugal slurry pump uses the centrifugal force generated by a rotating impeller to convert energy into the slurry in the same manner as the clear liquid type centrifugal pumps.

The difference between centrifugal sludge and ordinary pumps is the size and construction of the impellers, the ease of maintenance, the type of shaft seal to be used and the choice of optimal materials.

To protect the inside of the pump from abrasive, erosive and corrosive materials. The centrifugal slurry pump is designed so that large abrasive particles can pass. Therefore, much wider and heavier impellers are required to accommodate the passage of large particles.(4)

### 2.2.2 Warman slurry pump

WARMAN slurry pumps are built in variety of designs and materials and for many different slurry services. Heavy duty WARMAN AH type pump is designed to perform continuous pumping of highly abrasive/dense slurries in process. (4)


Figure 2.2 Warman (AH) slurry pump (4)

### 2.2.2.1 Impeller

The impeller is the main rotating part which normally has a vanes to transfer the centrifugal force to the liquid. Mostly, slurry pump impellers use plain or Francis type vane (see Figure 2.2)

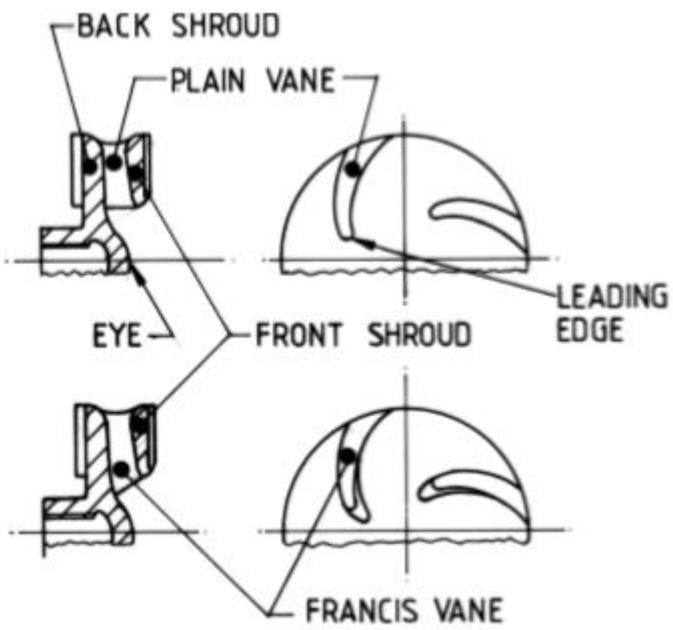


Figure 2.3 Francis and Plain vane (2)

The Francis blade has a leading edge projecting into the impeller eye, while the simple blade has a leading edge square to the rear shroud.

The Francis vane has the following advantages: The profiles are the higher efficiency, the improved suction performance and a slightly better lifetime for certain slurry types, as the angle of incidence to the liquid is more effective. The plain vane provides better wear life for very coarse slurry applications.

Depending on the size of the particle in the slurry, the number of impellers varies between three and six. Closed impellers are commonly used for higher efficiencies and are less prone to wear in the front liner area. However, open wheels are more common with smaller pumps or where particulate blockage can be the problem.(4)

### 2.2.2.2 Shaft and bearing

A shaft is a one of the important component in a centrifugal pump which delivers torque from the motor to the impeller located on the shaft. The pump shafts are commonly made of carbon steel and stainless steel. It is subjected to several stresses such as torsional, shear, flexural, tensile, etc. Among these stresses, torsional stress is generally most dominant and is used as a basic factor to determine the shaft diameter. Another important consideration in determining the pump's shaft diameter is the operating speed. If the operating speed is at its critical speed, it can result in excessive and destructive rotor vibration.

In small and medium sized centrifugal pumps, ball bearing are the most commonly used because of their high speed capability and low friction. Ball bearings are considered to have a relatively low load rating because the small contact area results in high contact stress for a given load (5).

### 2.2.2.3 Casing

Most of the slurry pump casing are slower than their water pump groups, primarily to reduce wear though lower internal velocities.

Semi – volute or annual geometry with large clearance at the cutwater is mostly applied in the casing shape. Difference between casing shapes illustrated in figure 2.4.

Efficiencies of the more open casing are less than of the volute type, however, they appear to offer the best compromise in terms of wear life. (4)

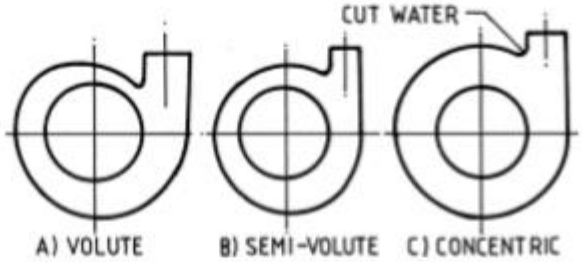


Figure 2.4 Pump casing shapes (4)

### 2.2.3.1 Vibration

Vibration is the movement of a mass back and forth from its stationary position. It ought to be always known that a force will be root of vibration, and that vibration can be characterized in terms of velocity, displacement and acceleration. The force must overcome the mass of structure, damping properties and stiffness. These properties are base of the structure and will depend on the design and materials of the machine. There are three types of vibration:

• Free vibration (also called resonance)

• Forced vibration

• Self-generated vibration

Free vibration happen when a structure is vibrating freely after input force applied. One of the example is the bell ringing. The initial beat of the gong contribute the input force, but bell vibrates continuously and even after the input force has been removed, it rings freely.

Forced vibrations happen when a structure is being constrained, by an input drive, to move and vibrate in a certain way. There are various illustrations of forced vibrations. In turning equipment, the most common form of a forced vibration is due to a characteristic of unbalance within the rotating parts. The remaining unbalance causes vibration as a result of the centrifugal force as the equipment is being rotated by e.g. an electric engine. A combination of forced and free vibrations is experienced when measuring vibrations on mechanical equipment.

Self-generated vibrations are not very frequently experienced in industry. The most common industrial case may be machine instrument chatter. This sort of vibration happens when certain conditions within the equipment will cause a cyclic force. Other cases of this sort of vibration incorporate whistles (e.g. a football official shriek) and the vibration of a violin string when the bow moves across it.

### 2.2.3.2 Vibration spectrum

There are numerous distinctive strategies available for analyzing vibration data. The most fundamental strategy includes displaying the vibration data within the frequency domain, also it is called the vibration spectrum. The frequency of the vibration is the number of vibration cycles per unit time. The vibration spectrum is principal of vibration monitoring since it yields the data that's effectively "hidden" within the vibration waveform. Vibration spectra can be represented in other ways, of which the Fast Fourier Change (FFT) and the Power Spectral Density (PSD) are the most well-known. The concept of the vibration spectrum can be basically clarified by means of an example. Consider the time waveform in Figure 2.5, which contains a frequency of 10 Hz (we are able to count ten complete cycles during a second) and amplitude of 5 mm (the units of the amplitude can be any unit related to vibration, e.g. displacement, speed or acceleration).

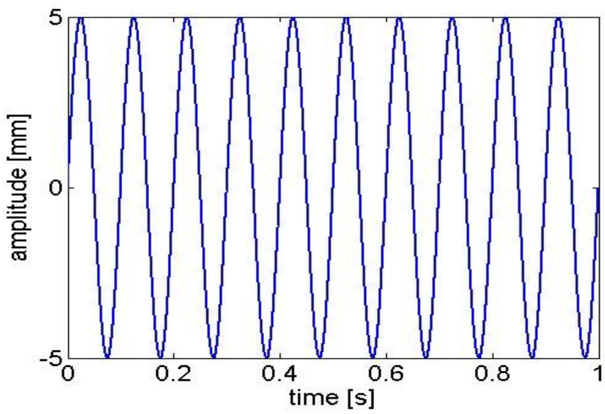


Figure 2.5 Example of time waveform (6)

The time waveform could be a plot of time vs amplitude, and is indicated to as the time domain. The time domain signal can be changed into a frequency domain representation, which is, in fact, the spectrum. The spectrum could be a plot of frequency vs amplitude. The FFT for the time waveform from Figure 2.6 is plotted in Figure 6. Ready to clearly see from this plot that the frequency substance of the signal is 10 Hz, which its amplitude at 10 Hz is 5 mm.

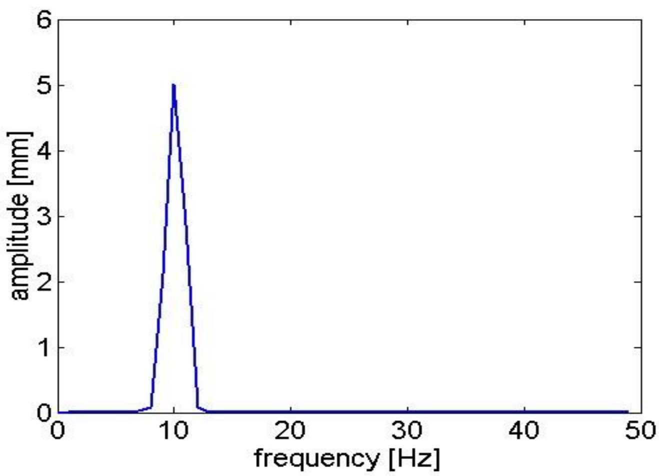


Figure 2.6 FFT Hz time waveform (6)

If the time waveform has more than one frequency is given in Figure [2.7]. Consider the waveforms in Figure 7. In the top graph we have our 10 Hz waveform, called S1. The second waveform is a 25 Hz waveform with amplitude 2 mm, which we can call S2. The third waveform, plotted at the bottom, is S1+S2, which yields a much more complex waveform.

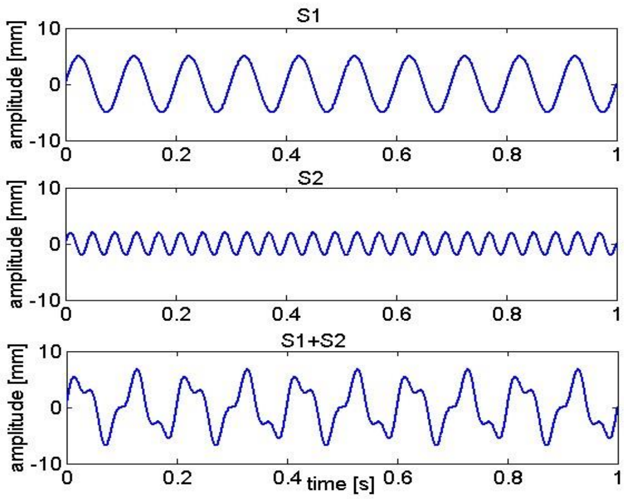


Figure 2.7 A complex waveform consisting of S1+S1 (6)

There are clearly two peaks in the spectrum, namely a 5 mm peak at 10 Hz and a 2 mm peak at 25 Hz. By only looking at the spectrum, it can be characterize our S1 + S2 waveform much better than by examining the waveform from Figure [2.8] The frequency spectrum is therefore easier to interpret with information that often can not be observed by merely looking at the time waveform (6).

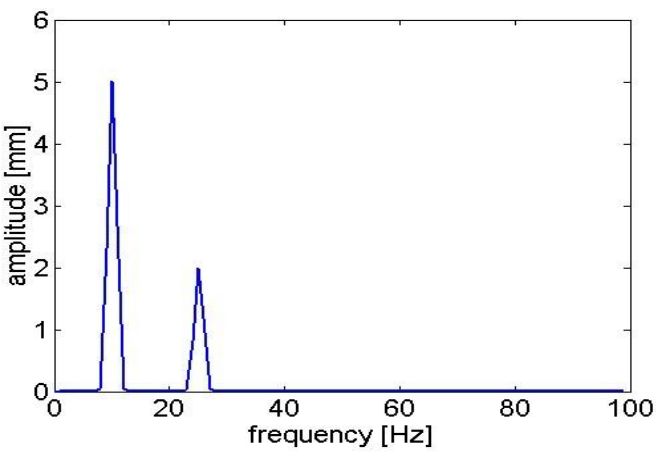


Figure 2.8 FFT for S1+S2 (6)

### 2.2.3.3 Vibration in centrifugal pump

It is important to be interested in vibrations in centrifugal pumps as this has the main effect on the performance. In general, increasing vibration levels indicate premature failure always means that the equipment has begun to destroy itself. It is exaggerated that vibrations are the result of a malfunction of the system. It is expected that all pumps will do this due to response of excitatory forces, such as residual rotor imbalance, turbulent fluid, vibrate Flow, pressure pulsations, cavitation and / or pump wear. The size of the vibration will be amplified as the frequency of oscillation approaches the resonance frequency of a main pump, Foundation and / or piping component. In general, higher vibration levels (amplitudes) indicates errors that develop in mechanical devices.

2.1 Vibration sources in centrifugal pumps

The sources of vibration in centrifugal pumps can be classified into three types of mechanical causes: hydraulic causes and peripheral causes.

2.1.1 Mechanical causes of vibration

The mechanical causes of vibration include:

• Unbalanced rotating components

• Damaged impellers and non-concentric shaft sleeves

• Bent or distorted shaft

• Displacement of pumps and drivers

• Stretching of piping (either by design or due to thermal growth)

• Insufficient of foundations or poorly constructed foundations

• Thermal growth of various components, especially shafts

• Friction parts

• Worn or loose bearings, loose parts

• Loosened locking bolts

• Damaged parts.

2.1.2 Hydraulic causes of vibration

Hydraulic causes of vibration include:

• Operating the pump with other than the best efficiency (BEP)

• Product vaporization

• Impeller blade running too close to the pump cut water

• Internal recirculation

• Air trapped in the system due to turbulence, etc.

• Turbulence in the system System (non-laminar flow)

• Water hammer.

2.1.3 Peripheral causes of vibration

The peripheral causes of vibration include:

• Harmonic vibration from nearby equipment or drivers

• Operation of the pump at a critical speed

• Temporary seizure of the seal faces (this can occur when pumping a non-lubricating liquid, a gas, or a dry solid, a pump outlet return line directed at the seal faces (6).

1. "Оюу толгой" ХХК [Internet]. [cited 2019 May 7]. Available from: http://ot.mn/

2. Kamiel BP. Vibration-Based Multi-Fault Diagnosis for Centrifugal Pumps. 2015;(February).

3. Tran VT, Yang BS. An intelligent condition-based maintenance platform for rotating machinery. Expert Syst Appl. 2012;39(3):2977–88.

4. Centrifugal W. The classic Warman ® AH ® pump continuously evolves — resulting in improvements in performance and never compromising on the quality that you have come to expect.

5. I. J. Karassik, W. C. Krutzsch, W. H. Fraser JPM. Pump handbook [Internet]. Vol. 22, AIChE Journal. 1976. 1156–1156 p. Available from: http://doi.wiley.com/10.1002/aic.690220632

6. Birajdar R, Patil R, Khanzode K. Vibration and noise in centrifugal pump sources and diagnosis methods. 3rd Int Conf Integrity, Reliab Fail. 2009;(July):20–4.

GERMAN - MONGOLIAN INSTITUTE FOR RESOURCES AND TECHNOLOGY

Statutory Declaration

Batsaikhan, Zolboo

Last Name, First Name

Student ID Number

I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

xxx

independently and without undue external help. I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Ulaanbaatar, Mongolia,
May 7, 2019

Place, Date

Signature