UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECTS OF SHAFT MISALIGNMENT AT DIFFERENT SPEED ON VIBRATION AND SOUND EMISSION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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ABSTRACT

Shaft misalignment are responsible for many machine problems; studies have shown that incorrect alignment is the cause for around half of machine breakdowns. Proper alignment is critical to the life of the machine, and coupling wear or failure, bearing failures, bent rotors or crankshafts, and bearing housing damage are all common effects of poor alignment. In rotating machinery, the main aspects in the cause of misalignment is excessive vibration and sound emission. By manipulating the angular misalignment, with the machine rotational speed, the findings on the levels of vibration and sound can be determined. It shows that the relationship of misalignment on the vibration and sound effect very closely. Most of the findings recorded the amplitude increases when RPM increases, and the value increases when compared with λ. Higher λ, amplitude; which indicates how much force or severity the vibration has, also becomes higher. With the findings compareed with ISO 10816; The Vibration Severity Standards, the alignment is considered to be satisfactory when the shaft parameters are within the required limits under all operating conditions of the machine. Other than that, 'strange' sound emitted from machine's operation is the early indication of misalignment in the machine's component itself. Bands of sound emission is plotted on the graph of vibration at any sudden fluctuation for easier detection at certain vibration findings.

ABSTRAK

Aci salah jajaran bertanggungjawab dalam banyak masalah terhadap mesin; kajian telah menunjukkan bahawa penjajaran tidak betul adalah punca kepada separuh daripada kerosakan mesin. Penjajaran yang betul adalah penting untuk jangka hidup mesin, dan membawa kesan kepada kegagalan dalam gandingan, kegagalan galas, rotor bengkok atau aci engkol, dan kerosakan perumahan galas. Dalam jentera berputar, aspek-aspek utama yang menyebabkan punca salah jajaran adalah getaran yang berlebihan dan pelepasan bunyi. Dengan memanipulasi ketidakjajaran sudut, λ dengan kelajuan mesin putaran, penemuan pada tahap getaran dan bunyi boleh ditentukan. Ia menunjukkan bahawa hubungan salah jajaran terhadap kesan getaran dan bunyi adalah sangat rapat. Kebanyakan penemuan mencatatkan peningkatan amplitud apabila kenaikan RPM, dan kenaikan nilai berbanding dengan λ. λ tinggi, amplitud; yang menunjukkan berapa banyak daya atau keterukan getaran itu, juga menjadi lebih tinggi. Dengan penemuan yang dibandingkan dengan ISO 10816; Piawaian Keterukan dalam Getaran, penjajaran itu dianggap sebagai memuaskan apabila parameter aci adalah dalam had yang dikehendaki apabila mesin beroperasi dalam keadaan normal. Selain itu, pelepasan bunyi yang ‘aneh’ yang dihasilkan daripada operasi mesin adalah petunjuk awal bahawa terdapat salah jajaran di dalam komponen mesin tersebut. Takat pelepasan bunyi pada graf getaran yang menaik yang melepasi corak kenaikan biasa turut disediakan untuk memudahkan pengesanan bunyi tersebut terhadap getaran.

DEDICATION

This thesis work is dedicated to my beloved parents who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve,

Mr. Mazda @ Mazdarudin bin Md. Isa & Mdm. Zoraida binti Muhamad,

my amazing siblings,

Mohamad Syazwi, Nursyaza Firzana and Muhammad Syazani,

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

$^{\circ}$	Degree
˚C	Degree of Celcius
∆L	Change in length (m)
∆T	Change in temperature (˚C)
∆t	Change in time
$\propto$	Acceleration
dB	Decibel
F_{cen}	Centrifugal force
Hz	Hertz
ISO	International Organisation of Standardization
kg	Kilogram
m	Mass
m	Meter
mils	A thusandth of an inch
mm	Millimeter
mm/s	Millimeter per second
mm/s^2	Millimeter per second square
r	Radius

RPM	Revolutions per minute
s	Displacement
v	Velocity
λ	Angular misalignment
$\mathcal{T}$	Coefficient of thermal expansion

This particular chapter will describe about shaft alignment in rotary machinery and the need to study its effects. It covers the background of study, problem statement, objectives, scope of study and chapter overviews.

- **Background of Study**

Men's daily life is surrounded by rotating dynamic machinery. In machinery industry, rotating shafts and motors are widely used to produce steel, glass, for transportation and many more. Poorly aligned machine contributes 30% of the machine's downtime (Hariharan & Srinivasan, 2010). Misalignment is the name described when the centerlines of two shafts do not positioned in the same axis. It is the leading source of vibration on machines (Wowk, 2002). Keeping machinery aligned can save a factory 20% to 30% in costs due to machine down time, replacement parts, inventory, and energy consumption (Ganeriwala et al., 2005).

Poorly aligned shafts are responsible for many machine problems; studies have shown that incorrect alignment is the cause for around half of machine breakdowns. Proper alignment is critical to the life of the machine, and coupling wear or failure, bearing failures, bent rotors or crankshafts, and bearing housing damage are all common effects of poor alignment. The alignment is considered to be satisfactory when it is possible to ensure the shaft parameters within the required limits under all operating conditions of the machine. Shaft misalignment is a standout amongst the most well-known problem of wind turbine drive train when the rotary shaft do a contact with inflexible couplings (Ahmed et al., 2010). Perfect alignment of the shaft is hard to achieve and the couplings joined to the rotary shaft may exhibit precise or parallel misalignment characterized additionally as axially misalignment (Mankowski & Wang, 2013).

1.2 Problem Statement

Misalignment is the common problem in the machinery industry. Over the years, there have been a lot of research in understanding of rotor dynamics, yet no sufficing analysis explains the range of the discovered scenario. Research on shafting alignment of ship hull deformations are conducted as it is a significant influence on the propulsion of shafting alignment. Besides, analysis on the misalignment of ship construction is growing more rapid in order to increase the long use of the ship, leaving misalignment in machinery industry falls a step behind. Other than that, the angular misalignment effect on the running torques has not been thoroughly investigated. Study of regular rotating machinery that leads to misalignment is yet leave with no satisfactory explanation. Therefore, research is conducted to address these matters.

1.3 Research Objectives

The objectives of the research are:

- To determine the effects of shaft angular misalignment on vibration and noise emitted in rotating machinery.
- To identify the vibration severity of misalignment at different RPM.
- To establish noise data set at various misalignment condition.

1.4 Scope of Study

The project is using the shaft misalignment rig machine as the primary tool to collect numerical data. This is an experimental activity that is conducted in the university's manufacturing engineering faculty itself, more specifically in the Block B's laboratory. The limitation of this project is focused on the investigation of speed and angular misalignment of the rig. It is performed up till the limitation of the machine's speed as well as the angular misalignment. Vibration is detected using the vibration meter (DIGI VIBRO (Model-1363)) and commercial mobile applications such as Sound Analyser and Frequency Sound Generator is used for sound detection. Other than that, ISO 10816, Vibration Severity Standards is referred for vibration severity of misalignment at different RPM.

1.5 Chapter Overviews

The final project covers five chapters that contain the introduction, literaturw review, methodology, results and discussion and lastly conclusion. Chapter 1: Introduction; introduces the need to study misalignment that is divided into the introduction of study, problem statement, objectives, scope as well as the significant of study.

For chapter 2: Literature review; covers the gathered findings of numerous information form various sources such as books, journals, articles and websites. Topics that related to the study of misalignment is included here. Chapter Methodology will be discussing about the experimental apparatus, methods and procedures for data analysis. Chapter 4 is about the findings of chapter 3 which is about result and discussion. Here, justification will be given with respect to the results obtained primarily related to the objectives. Finally, the chapter of conclusion will summarise the report and suggestions for future work are also included in this chapter.

This chapter will explain about the literature review. The issues that will be discussed are about shaft misalignment, causes and effects of misalignment, methods of alignment, methods of misalignment and the components involved in shaft alignment.

2.1 Introduction

The main focus of this study is to investigate the effect of angular misalignment on the vibration and noise emission of the rotating speed machinery. This chapter reviews and explains about the past studies that have been done. Literature review examines respectively to the source and describes to justify the statement with proof of research or study in related field.

2.2 Shaft Misalignment

2.2.1 Shaft

A shaft is normally designed to equip a special task in a machine. In general, shaft is defined as a rotating member used for the transmission of power. Shafts place members like pulleys or gears in their specific positions. As shafts connects the members together, shafts transmit torque along the members (White, 2010).

2.2.2 Alignment

Alignment is described as shaft-to-shaft alignment of coupled machine. This consists of a driver machine and a driven machine. The driver machine gives the driven machine rotating mechanical power via a coupling. The driver machine is usually the electric motor, turbine or a reciprocating engine. The driven machine, on the other hand, is the result of driver machine, usually generating powers or moving fluids and could be a generator, a fan or a pump (Wowk, 2002). Power is transmit from driver into driven machine by mean of coupling which connected between both shafts. These centerlines of two shafts, when they are coupled together and rotating at their normal operating conditions, must stay in one single straight line (Gairola, 2004).

Therefore, shaft misalignment is the deviation of a relative shaft position from a collinear axis of rotation measured at the points of power transmission during running at normal operating condition (Baer et al., 2013). The required alignment is done by correctly adjusting the machine by moving its feet (Gairola, 2004). The main reason for alignment is to obtain the centerlines coaxial during rotating. It is presumed to create the lowest amount of distortion in the coupling and also unwanted bending in the shafts. This would be fair assumption if the mechanical components all had perfect geometry, i.e., the shaft were straight and round, the coupling were mounted perpendicular to the shafts, the bearing maintained a constant rotating center, and thermal strain were constant. However, the world of the industry is not so perfect; aligning at the exact centerlines coaxial seems to be not in favour (Technol, 2011). Figure 2.1 shows the typical misalignment condition.

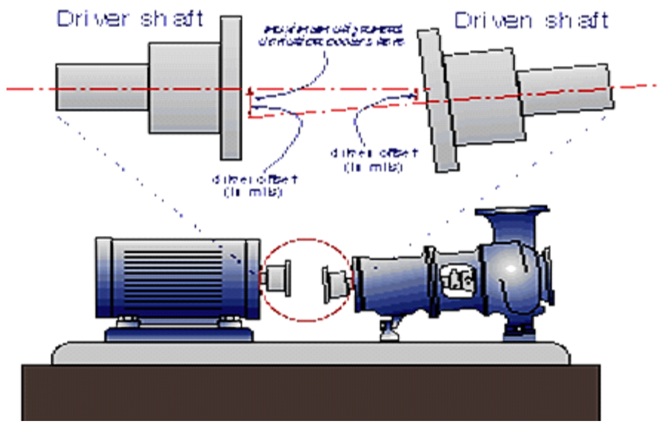

Figure 2.1: Typical misalignment condition (Redmond et al., 2002)

Dodd (1975) defined misalignment such that “It exists when there is a sliding or bending motion between floating members of a coupling”. This indicates that there is relative motion of the coupling halves when they rotate. One-half is relative to the other. Therefore, perfect alignment is at condition where there is no relative motion takes place, that is, no bending motion or sliding within a coupling.

Furthermore, the Society of German Engineers explains alignment as “the geometrically perfect arrangement of all rotating shafts and wheels” (Campbell, 1991). This is a more universal definition where it excludes everything that is not a shaft or wheel and it also does not define how to measure alignment.

2.3 Types of Alignment

There are four types of misalignment that in machinery shaft have to hold. They are the perfect alignment, offset or parallel misalignment, angular or face misalignment and lastly combination of both angular and offset misalignment (Girish, 2007).