



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**EXPERIMENTAL INVESTIGATION OF REAR SPROCKET  
FAILURE OF A FIXED BICYCLE USING ACOUSTIC  
EMISSION AND VIBRATION ANALYSIS**

This report is submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

by

**MUHAMMAD HAZIQ BIN ISMAIL**

**B071310363**

**910909-14-6611**

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Date : .....

## **APPROVAL**

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

.....  
(Project Supervisor)

## ABSTRAK

*Getaran adalah kesan yang tidak diinginkan. Getaran yang terlalu tinggi akan menyebabkan penunggang basikal tidak selesa di samping komponen basikal terdedah dengan kerosakan. Dalam usaha untuk memenuhi keselesaan pengguna dan keselamatan, kajian tentang bunyi bising, getaran dan kekasaran (NVH) adalah sangat penting. Getaran boleh berlaku pada semua bahagian basikal dan salah satu daripadanya adalah gegancu belakang. Disebabkan tekanan kitaran berulang pada tempoh yang lama, gegancu belakang mempunyai potensi untuk gagal atau rosak. Oleh itu, kaedah diagnostik baru untuk mengesan kegagalan gegancu diperlukan. Kertas ini membangunkan penggunaan pancaran akustik dan analisis getaran sebagai alat diagnostik untuk menganalisis kegagalan yang berlaku pada gegancu belakang. Beberapa gegancu belakang dengan saiz yang berbeza dalam keadaan biasa dan kecacatan telah disediakan sebagai sampel pada kelajuan putaran yang sama. Kedua-dua ujian getaran dan pancaran akustik dijalankan serentak dengan menggunakan GUNT PT 500.04 dan SO Analyzer. Ujian getaran mengukur tahap getaran yang terhasil dari putaran sampel manakala ujian pancaran akustik pula mengukur bunyi yang terpancar hasil dari getaran sampel. Berdasarkan siasatan eksperimen, tahap tekanan bunyi pancaran akustik dan amplitud spektrum getaran jelas menunjukkan bahawa sampel cacat lebih tinggi daripada normal sampel. Keputusan ini membuktikan bahawa kombinasi analisis pancaran akustik dan getaran merupakan alat yang berkesan dalam mengesan dan meramal kegagalan gegancu gear pada peringkat awal.*

## **ABSTRACT**

Vibration is unwanted effect. Highly vibration can make bicycle's user not comfort and harms the bicycle component. In order to satisfy the user comforts and safety, research about noise, vibration and harshness (NVH) is very important. Vibration can occur on all part of bicycle and one of it is rear sprocket. Due to repeated cyclic stress at long period of time, rear sprocket has potential to fail or breakdown. Therefore, new diagnostic method to detecting the failure of sprocket is needed. This paper develops the use of acoustic emission (AE) and vibration analysis as a diagnostic tool to analyze the occurrence of failure of rear sprocket. Several rear sprockets with different sizes in normal conditions and defect were provided as samples on the same rotation speed. Both vibration and AE test is conducted simultaneously by using GUNT PT 500.04 and SO Analyzer. Vibration test was measure the level of vibration that produced from the rotation of sample while acoustic emission test measure the sound that emits from vibration of sample. Based on experimental investigation, the sound pressure level (SPL) of AE and the amplitude of vibration spectrum clearly shows that defect sample is higher than normal sample. These results prove that the combination of AE and vibration analysis tools is sufficiently effective in detecting and predicting failure sprocket gear at an early stage.

# **DEDICATION**

To my beloved parents

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## **LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE**

AE	-	Acoustic Emission
AGMA	-	American Gear Manufacturers Association
ASTM	-	American Standard Testing Method
dB	-	Decibel
F	-	Frequency
HAZ	-	Heat Affected Zone
HRV	-	Heart Rate Variability
Hz	-	Hertz
ISO	-	International Organization for Standardization
NDE	-	Non-destructive Examination
NVH	-	Noise, Vibration and Harshness
RMS	-	Root Mean Square
SPL	-	Sound Pressure Level
T	-	Time



# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 Vibration**

In terms of engineering, vibration can be defined as a self-repeated motion or oscillation that occurs on mechanical system from its position of rest under an interval of time (de Silva, 2000). Basically, vibrations are divided with two types which are free vibration and forced vibration. Free vibration is the process that occurs when some system or equipment is setup with initial force and then let it vibrate freely for example the motion of pendulum, plucking a guitar string, blow over the top of bottle and etc. These systems are tending to vibrate at a certain frequency which also known as natural frequency. Forced vibration is occurring when force or motion is applied to object and vibrate at a particular frequency and the example of this type of vibration is vehicle engine, mechanical equipment (turbine, air compressor) and building vibration during earthquake happen (Bradford, 2012)

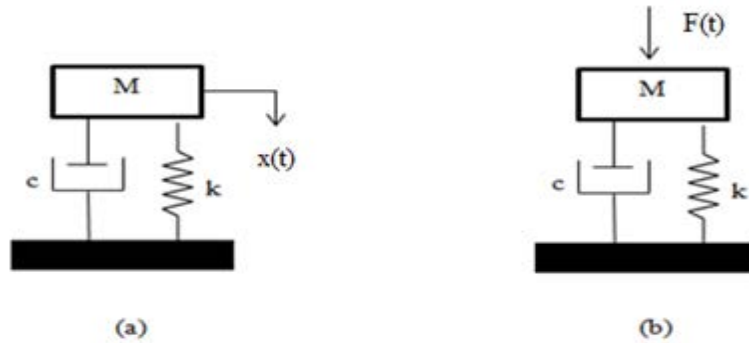


Figure 1.1: Free vibration (a) and forced vibration (b) with damping

Vibration in vehicle such as car, motorcycle and bicycle is an undesirable impact. It can cause numerous troubles such as increments in fuel utilization (car and motorcycle) and harms to vehicles component. Besides, it also causes vibration of roadside structures. Vehicle manufacturers should be concerned about the level of vibration that will be occurring on the body before produced it. It is not merely for the comforts of users but also for safety and health. High vibration that occurs in vehicle has potential to contribute fatigue to the driver or rider and affect lower back pain and heart rate variability (HRV). Most common problems associated with vibration for car and motorcycle user is engine. Basically, vibration are produced when some power such as combustion, reciprocating and rotational forces applies on engine. For bicycle, vibration happens on frame, fork, tire and gear/sprocket (Burdzik and Doleček, 2012).

Research on Noise, Vibration and Harshness (NVH) is very important aspect in vehicle industry. NVH are defined as studies about the sound and vibration characteristic of vehicle in order to reduce the noise pollution and improve comforts to driver and passenger. NVH occurs when the car are interact with road surface. Engine, tire and drivetrain those are main source of NVH in car. Based on driving condition in the city, the evaluation of vehicle noise and vibration should be implemented for refinement process of vehicle sound quality to achieve target of development satisfaction (Panza, 2015). Noise is the annoying sound for people that able to be heard in range of 20-20

kHz. Both sound and vibration level can be readily measured but for harshness, it is subjective impression and perception of humans towards driving condition on the road surface. For example, the driver expected noise and vibration level are low when through on smooth road surface. But when the drivers go through on rough road surface, the driver feels harshness. Sound pressure level (dB) is used as a measurement method in vehicle NVH to evaluate noise condition such as engine noise or road noise (Young, 2014).

## **1.2 Bicycle Vibration**

Nowadays, bicycle is not only being used for recreation or exercises but also for awareness of environmental protection (Liu et al. 2013). Due to its ability to reduce traffic jam within the cities, people are more attracted to cycling. It provides more economic than use other vehicle as a transport because no need to use fuel to move. The important aspect that should be emphasized by manufacturer is the user comfort and safety especially on new infrastructure of pathways today (Hölzel et al. 2012). Bicycle manufacturer should provide safety and comfort for the user on their product. The bicycle structure must be high quality in terms of strength and endurance to avoid from damage due to external loads. The suspension system also must be effective enough to decrease the level of disturbance when user through the rough road so it gives comforts to user. Many researchers are studies about cycling comfort such as comfort level of bicycle on different surface, effect of surface road condition on bicycle comfort, relation of dynamic characteristic of bicycle to the comfort level and etc. (Ismail et al. 2015). Bicycle has a very complicated system than other vehicle such as car and motorcycle because it involves more than 2000 component. Existing components on the bicycle can be divided by several subsystems which are frame, wheel, steering, fork and gear/sprocket (Mao and Chen, 2009).



Figure 1.2: Fixed bicycle part; 1.Steering 2.fork 3.frame 4.wheel 5.rear sprocket 6.front sprocket (State Bicycle, 2016)

### 1.3 Gear and Sprocket Vibration Analysis

Gears also known as cogwheel is a rotating machine part that have toothed elements which in contact with another toothed part. The main function of gear is to transmitting synchronous motion directly from one shaft to another. The efficiency of power transmission of gear can achieves until 98%. Due to standardize the tolerance of degree of gear, American Gear Manufacturers Association (AGMA) was established in 1916 to precise the manufacturing of gear (Marghitu, 2001).

Sprocket is a toothed wheel designed that used in the drive systems of machinery. The main function of sprocket is to engage and directly move the chain or belt. These mechanical parts are widely used in bicycles, motorcycles, movie projector, tanks and conveyor belt which to transmit rotary motion from one shaft to another. In manufacturing, the sprocket goes through heat treatment process to improve their

hardness so that the lifespan of sprocket increased. Today, many engineers either technologist is trying to develop a manufacturing process for more complicated sprocket shape by upgrading their fabrication efficiency. As a result, both gear and sprocket are quite different application. However, the main objective is similar which is to transmit power between two shafts (Thipprakmas, 2011).

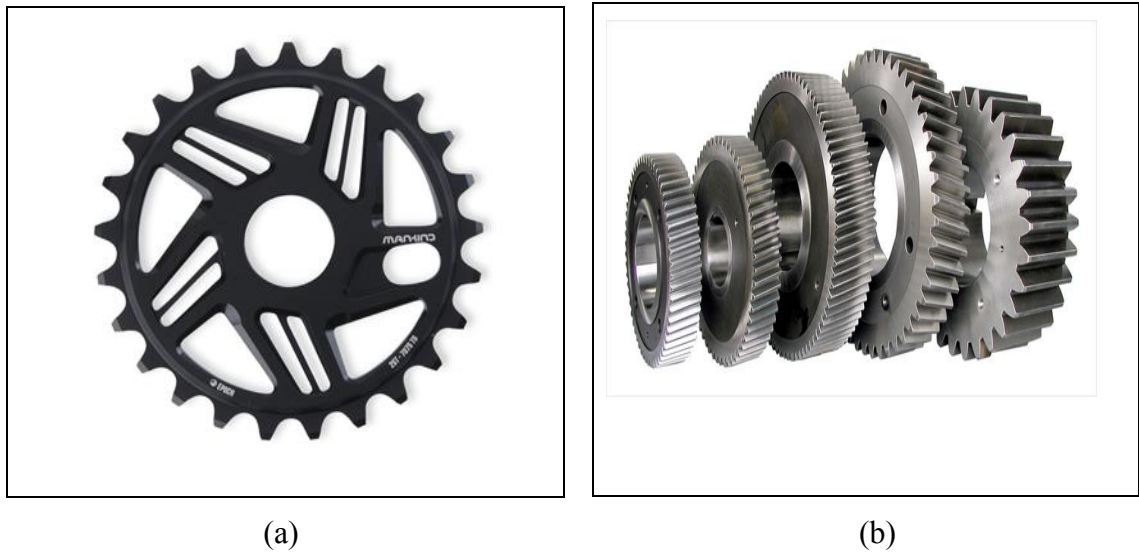


Figure 1.3: Sprocket (a) and Gear (b) (Mankind Bike, 2016 and Shanti Gears, 2015)

#### 1.4 Acoustic Emission

Acoustic emission is the one of more effective technique that has high applicability for detecting crack initiation and investigates damage propagation in the structure (Elforjani and Mba, 2009). According to Mostafapour et al. (2015), this technology generates transient elastic waves by the rapid release of strain energy from several sources such as cavitation, cyclic fatigue, friction, material loss, scratch, etc. and spread through material during crack propagation. The ability to operate directly on the component or material tested by using detector is the main advantage of the AE technique which is easy to detect any source of deformation location. (La Rosa et al.

2014). AE techniques today have been one of the best technologies applied in industry include the detection of fault in pressure vessels and piping system. Compared to non-destructive evaluation (NDE) method, AE function is to detect all activity inside the material but NDE method is to examine the internal structures of materials. Although AE is suitable technique for detecting fatigue on material, it still has some disadvantage. Capability AE is limited which can only estimate how much damage occur in the material and how long the components will last. So, other NDE method should be used to examine and provide more detailed result. Other disadvantages, AE signal is very weak and its service environments are too noisy (Huang, 1998).

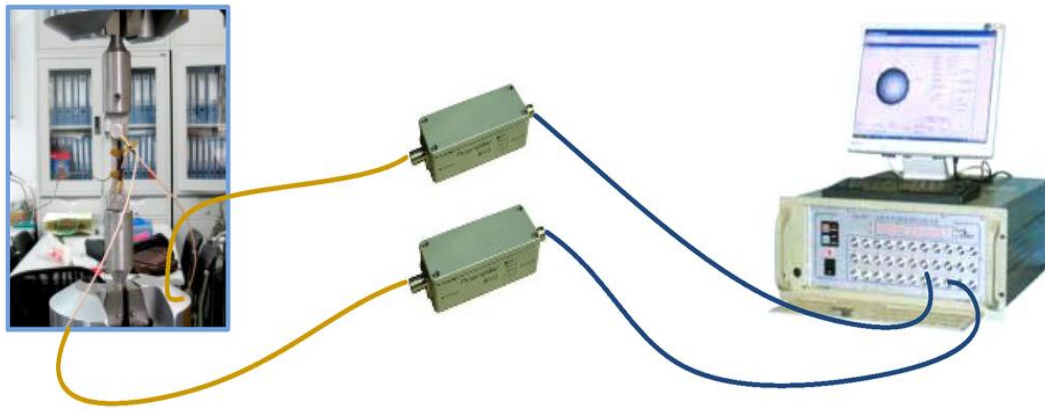


Figure 1.4: Investigation of Material Performance Degradation for High-Strength Aluminum Alloy Using Acoustic Emission Method (Ai, 2015)

## 1.5 Problem Statement

Rear sprocket of fixed bicycle has potential to fail or breakdown and this will result to personal injury or may cause loss of life. So, some early action should be taken to overcome this problem. Investigation, identification and correction are very important to personnel whose involve in maintenance field to enable the sprocket continued use and function. Although the sprocket goes through heat treatment process to improve their hardness, it still has possibility to fracture under repeated alternating or cyclic

stresses of intensity significantly below the normal strength. However, the failure of the structures of rear sprocket can be avoided by planning periodic inspections. Thus, it is imperative to propose new method to detect and investigate the internal state of damage of rear sprocket. The use of acoustic emission and vibration analysis are developed as a diagnostic tool to analyze the failures (Barile et al. 2016). Acoustic emission is one of technique that have good potential for recognition and location of dynamic defect under working conditions. AE is generally utilized for electrical hardware or equipment in industry. In the previous couple of years, AE has been use for the most part utilized for testing the underground power links. However, the use of AE is still limited and not comprehensive especially against research monitoring application on sprocket (Jabha et al. 2016).

## **1.6 Objective**

There are three objectives of this research:

1. To develop a new diagnostic method using Acoustic Emission and Vibration Analysis on rear sprocket of fixed bicycle
2. To test the prepared sample using Acoustic Emission and Vibration Analysis
3. To investigate the failure of rear sprocket of fixed bicycle

## **1.7 Scope**

A several scopes have been stated in order to achieve the objective:

1. Developing the use of acoustic emission and vibration analysis to analyze failures on rear sprocket of fixed bicycle
2. Testing the prepared samples with different size and crack condition
3. Investigating the samples using acoustic emission and vibration analyzer

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Bicycle Parts**

Bicycle is transport that has simple structure compared to automobile or motorcycle. Most of bicycle body are triangle-shape designed (Champoux et al. 2007). Bicycle is economical transport for long term because it not required fuel to move. Due to its smoke free behavior, it provides no air pollution. Besides, the utilization of bicycle also helps in improves humans health by cycling. In line with the modern world today, many researchers are making an effort to create and develop the new technology of bicycle which includes the design, material and dimension (Ismail et al. 2015). Mostly bicycle part is made from metal and can be recycled. Therefore, it can reduce the waste of environment. The major bicycle part can be classified as frame, fork, tyre and gear/sprocket (Mao and Chen, 2009).

##### **2.1.1 Frame**

Since the early twentieth century, bicycle frame has existed in various shape and design. As the main part of bicycle, frames are fitted with other component such as wheels, saddle and gear/sprocket. The objective of frames is to offer extraordinary strength with least weight. However, not all bicycle frames are made equivalent (Ruff,