PREDICTION OF HELICAL GEAR LIFE USING WEAR DEBRIS ANALYSIS

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DECLARATION

"I acknowledge the work is my own work except for quotations and a summary and the accompanying expression which have been duly recognized"

Signature :…….………………….............

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ABSTRAK

Hampir semua mesin yang digunakan di industri melibatkan komponen mekanikal. Antara komponen mekanikal yang akan terlibat dalam kajian ini ialah gear.Masalah pada gear boleh menyebabkan kos penyelenggaraan dan operasi meningkat.Jadi dalam kajian ini, pelajar akan mengkaji bagaimana hendak meramal kegagalan set gear helix dengan menggunakan kaedah wear debris analisis.Kaedah untuk menganalis kegagalan gear yang akan digunakan ialah kaedah matematik modeling dan meggunakan kaedah experiment. Kaedah matematik modeling yang digunakan ialah standad BS ISO 6336-2 yang akan digunakan untuk meramal jangka hayat sesuatu gear bagi menganalisis secara teori. Dengan menggunakan maklumat daripada pembuat gear, janka hayat sesuatu gear helix akan di tentukan. Selain itu, kajian ini juga mengkaji bagaimana mekanisma dan fenomena haus terhadap gear helix semasa beroperasi melalui gear test rig experiment. Melalui kaedah ini, pandangan terhadap kehausan gear adalah lebih jelas. Projek ini menerangkan tentang objektif dan skop projek secara terperinci bagi memberi pandangan yang jelas terhadap kaedah yang digunakan serta mekanisma oleh set gear sebelum dibuktikan kegagalanya pada hadnya.

ABSTRACT

Almost all machines used in industry involve mechanical components. Among the mechanical components that are involved in this study was gear. Problem in gear can increase the cost of maintenance and operation increased .So, this study try to predict the failure helical gear sets using wear debris analysis .Methods to predict failure of gear to be used are mathematical modeling and experiment methods. Mathematical modeling method used is based on BS ISO 6336-2 standards used to predict the lifespan of a gear to analyze theoretically. By using information from manufacturer, life of a helical gear will be determined.BS ISO 6336-2 calculation is based on the contact stress at the pitch point of the meshing gears, or at the inner point of single pair tooth contact. BS ISO 6336-2 also states the contact stress shall be less than it permissible stressed for preventing failure. In addition, this study also examines how the mechanism and wear on the helical phenomenon while operating through gear test rig experiment. The physical inspection is use to assertion the deterioration of helical gear during experiment. Through the calculation, the result to start pitting is after 46 hours after run the machine for 30kg applied load. In experiment, the gear start to have micro pitting defect after 12 hours run the gear test rig. The number of pitting defect was increase proportionally with time during experiment. The experiment result use to validate the result of the calculation using BS ISO 6336-2.

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LIST OF SYMBOL

σ_{HO}	=	Nominal contact stress
KA	=	Application factor
KHα	=	Transverse load factor for contact stress
KHβ	=	Face load factor contact stress
KV	=	Dynamic factor
ZB	=	Pinion single pair tooth contact factor
ZL	=	Lubrication factor
ZNT	=	Life factor for contact stress
ZR	=	Roughness factor
ZV	=	Velocity factor
ZW	=	Working hardening factor
ZX	=	Size factor
SHmin	=	Safety factor
εβ	=	Overlapping ratio
σH	=	Contact stresses
σHO	=	Nominal contact stresses at the pitch point
σHP	=	Permissible contact stresses at the pitch point
σHlim	=	Allowable stress number

LIST OF EQUATION

NAME OF EQUATION	LIST OF EQUATION
Equation 4.1	$\sigma_H = Z_{B.} \bullet \sigma_{HO} \bullet \sqrt{K_A \bullet K_V \bullet K_{H\beta} \bullet K}_{H\alpha}$
Equation 4.2	$\sigma_{HO} = Z_H \bullet Z_E \bullet Z\varepsilon \bullet Z\beta \bullet \sqrt{\frac{F_t}{d_1 b} \bullet \frac{U+1}{U}}$
Equation 4.3	$Z_H = \frac{2\cos\beta_b \cos\alpha_{wt}}{\cos^2 \alpha t \sin\alpha_{wt}}$
Equation 4.4	$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}$
Equation 4.5	$\varepsilon_\alpha = \frac{g_a}{p_{bt}}$
Equation 3.6	$p_{bt} = (m_t \cos\alpha_t)(\pi)$
Equation 4.7	$m_t = \frac{m_n}{\cos\beta}$
Equation 4.8	$g_a = \frac{1}{2}\left[\sqrt{\left(d_{a1}{}^2 - d_{b1}{}^2\right)} \pm \sqrt{\left(d_{a2}{}^2 - d_{b2}{}^2\right)}\right] - \alpha \sin\alpha_{wt}$
Equation 4.9	$Z_\varepsilon = \sqrt{\left(\frac{4-\varepsilon_\alpha}{3}\right)}\left(1-\varepsilon_\beta\right) + \frac{\varepsilon\beta}{\varepsilon\alpha}$
Equation 4.10	$\varepsilon_\beta = \frac{b \bullet \sin\beta}{\pi m_n}$
Equation 4.11	$Z_\beta = \sqrt{\cos\beta}$
Equation 4.12	$\sigma_{HP} = \frac{\sigma_{H\lim}(Z_{NT})(Z_L)(Z_V)(Z_R)(Z_W)(Z_X)}{S_{H\lim}}$

CHAPTER I

INTRODUCTION

1.1 Research Background

In recent years, rapid industrialization in the country becomes a phenomenon. Many factories use machinery or equipment involving mechanical components. Among these are the gears. Gears are used to transmit energy, power and torque to be converted into mechanical energy. Some of the gear in use is the helical gear. Helical gear use as mechanical component or rotating machine part that used to transmit power, energy, force and torque that convert into mechanical energy. However, until at the certain time or period the helical gear life reaches the limit. So it will be a challenge in maintenance engineering to make sure the life of gear is suitable to operate before the gear failure. Hence, this project helps the maintenance sector to predict gear life using several methods. Then, the comparison of the result from the method that will be used in this project.

1.2 Research Overview

The project main objective is to predict onset of failure of helical gear life using wear debris analysis. The research about how to predict helical gear life using identified method. The method could involve in this research should be theoretical and experimental method. Then, the comparison about the result of both methods should give the efficiency view.

By using wear debris that obtains from the test, it used to analyze and then come out with several data and result to predict the helical gear life. Regarding wear debris obtain, it could determine the mechanism of wear. In this research also contain a study about the failure onset helical gear during the test. Then, the finding and understanding about of the helical gear failure will be cover during the research. Then, the observation on the behavior of the helical gear wear mechanism is a part of research activities. From there, several types of wear mechanism should be defined based on the wear debris obtains. The studies about type of wear mechanism also cover to determine helical gear life.

In theoretical method, gears wear mathematical modeling that allows approximate to predict gear life will be useful. Using BS ISO 6336-2 standard formulation is used to predict helical gear life under pitting condition. The used formulation estimation is validated by using wear quantitative feature analysis which is able to provide actual gear wear trends.

1.3 Problem Statement

Gear is an important component in a machine or equipment. The rubbing and rolling action in the gear meshing will normally generate wear debris. However, the increase in abnormal loading due to misalignment will increase the risk of unpredicted gear failures. These failures will result in the unexpected lost of production and increase of maintenance cost. Hence, it is recommended to predict the onset of failure of the gear to allow replacement at the right time before catastrophic failure occurs.

1.4 List of Objectives

- To study the phenomena and mechanism wear of gear.
- To predict the onset of failure of helical gear using Wear Debris Analysis technique.

1.5 Scopes of Project

- Laboratory gear test rig
- Study on the helical gear failure.
- Wear debris analysis.

CHAPTER II

LITERATURE REVIEW

2.0 Literature Review

2.1 Introduction

Nowadays, research and development in the manufacturing process were rapidly improved day by day. The improvement of research and development in manufacturing process give to many advantages in manufacturing industry especially. Research and development in the maintenance sector improved a lot in manufacturing industry. Maintenance research and development has been looking as important part as the problem needs to solve in manufacturing or production process. The problem occurs will cause waste in the industry especially will affect to the core of business itself.

Since then, there is growing involvement in study of wear on a manufacturing process. Wear is a physical damage on the surface of solid surface that reduce the mechanical efficiency and a retrievable loss of material in the form of wear debris. Wear at moving solid body is a normal phenomena in any application The result from that contact surface between two solid surfaces that moving and experience wear will obtain particle or wear debris that will be used in analyzing the wear phenomena and mechanism of gear.

2.2 Typical defect in Gear

The majority of problems associated with things as well as moving component bearings begin because local stage flaws in touch areas in between getting in touch with physiques. Equipment problems tend to be started within the teeth meshing area as well as showing problems within the moving get in touch with areas. Defect of gear possible to identify as well as identify could be categorized within 3 classes regarding their own cause:

1. Installation defect.
2. Defects develop in operation.
3. Defect on the neighboring element which produce dynamic load on bearings and gears.

Crack and also spalls will be the many radical problems inside the stand. Spalling is actually brought on by the higher, nearby, get in touch with tension levels local beneath the actual get in touch with area. Typically any split will be trigger info substance introduction positioned through this zoom regarding large tensions. The particular split moves along as a result of duplicated cyclical packing in the course of equipment functioning. With a specific period the particular split actually reaches a crucial dimension as well as the progress grows to be unstable.In the unstable phase the crack rapidly grows and eventually reaches the surface, and a piece of material comes loose, creating a spall. All defects in table modify the characteristic vibration signature. One of the main tasks of machine monitoring is to identify and localize these defects from measured signatures. There have several typical defects in gear such as:

1. Localized surface damage
2. Wear or inadequate lubrication
3. Tooth root cracks, missing tooth
4. Pitch error
5. Eccentricity

2.3 Type of Gear Damage

Gearing is a crucial part of several components in many machines. The particular extensive application regarding gears in the machine and also mechanism, which includes high speed and also heavy duty to operate with lower temperatures and also high temperature and also beneath exposure to any excessive load cause damage and also catastrophic failure with their tooth result in simply by transmitting load, rotation speed or perhaps thermal therapy along with manufacture and operating condition .The result of gear damage majority associated with typical of gear damage. [A. M. Goman et.al., 2000]

Since there is increasing engagement in examine regarding gear damage inside manufacturing process, the effect coming from gear damage obtain particle or perhaps wear debris which will be found in examine the wear phenomena and also the mechanism of gear. Then, through the process operation the damage of gear were identified into several types.

The type of damage classification is due to the gears in the machine and mechanism, including high speed and applying load on the system .The main damage of gear is state bellow [A. Miltenovic, 2011]

1. Pitting
2. Scoring
3. Scuffing
4. Wear

Study on gear damage give use more advantage to prevent the failure in gearing system. The research of gear damage gives more information about the process and the causes of gear damage. Hence, the damage on gear can prevent in term to reduce the phenomena of gear failure cause by the abnormal load during the operation.

2.3.1 Pitting and Micro pitting.

Pitting or macro pitting can be surface damage through cyclic contact to strain transmit by having a lubrication that may be throughout as well as at the elastohydrodynamic plan. Pitting is just about the most common reasons behind gear failure. Then, it also influences antifriction bearings, cams, and also other appliance factors through which materials experience rolling as well as sliding off the contact under excessive load. Pitting is definitely the result of repeated contact stresses that cause gear surface and also subsurface fatigue and detachment with a material fragment from gear tooth surface types which will surface types undergo rolling or sliding under excessive load [Hermann Siebert, Michael Hochman, 2012].

Pitting happens when exhaustion crack tends to be initiated about the tooth surface or simply below the surface. Usually pits are caused by surface crack brought on by metal to metal get in touch with of asperities or even defect because of low lubrication layer on the surface that cause the lubricant viscosity was reduced through the operation. High speed gears along with smooth area and large lubricant layer may encounter pitting because of subsurface break.

Pits tend to be formed whenever this breakthrough with the tooth surface and since the particle obtain. Pitting may also cause through contamination associated with lubricant. These contaminants create surface stress focus points which reduce the lubrication film thickness to create pitting [K. Gopinath, 2012]. Table below shows the picture types of pitting damage on gear through the operation. Those types of pitting damage are:

1. Pitting and micro pitting
2. Pitting through hardened gear
3. Pitting on carburized gear
4. Surface failure of nitride gear

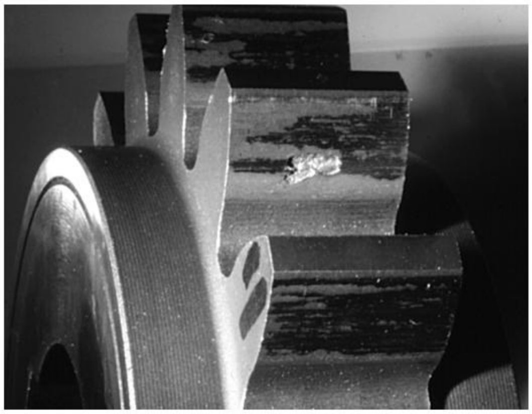
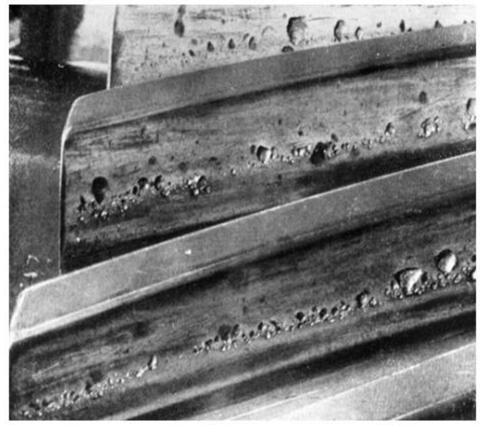
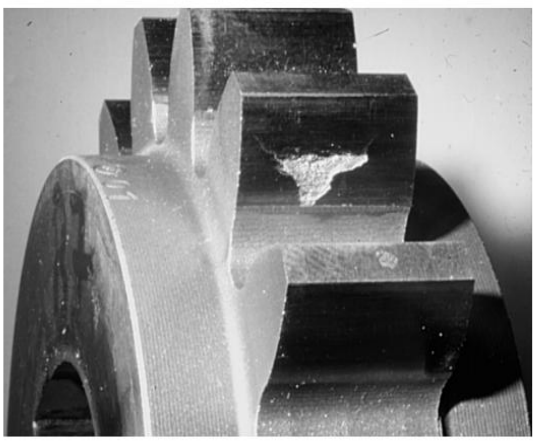
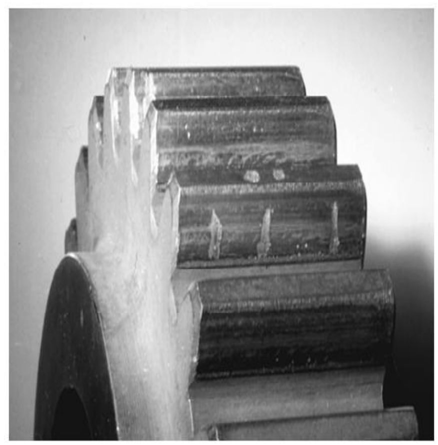
 pitting and micro pitting	 Pitting through hardened gear
 Pitting on carburized gear	 Surface failure on nitride gears

Table 2.1: Pitting Damage (*Source: Dr. Ing. Klaus Michaelis, 2011*)

A huge pressure in surface does not lead to the sudden failure on gear surfaces, but at the time, small holes (pits) emerge inside shape involving shell in tooth flank. Pit peak always points inside sliding route. This destruction occurs by having a cyclic fatigue on account of repeated elastic and plastic deformations in the surface. The holes occur only from a sufficiently numerous overruling. Only when initial pitting is present, the situation is just not dangerous but if destructive pitting destroys occurs on the flank along with cause of failure due to noise along with fatigue.

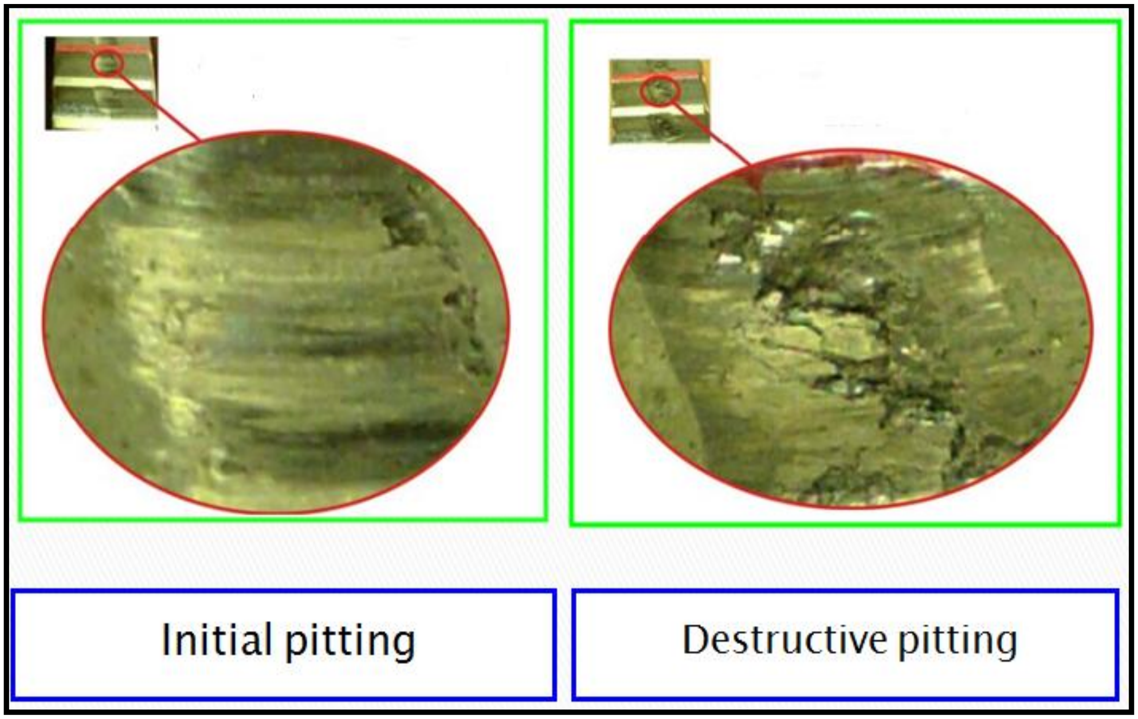


Figure 2.1: Initial and Destructive Pitting *(Source: A. Miltenovic, 2011)*.

The Figure 2.2, describes the condition of the gear. From the figure the initial pitting is not dangerous. Since the initial pitting occurs, it will generate destructive pitting on the gear surface. Destructive pitting Destructive pitting destroys the flank and causes failure due to noise and fatigue.

2.3.2 Scoring

Scoring is a result of combination associated with two unique activities: Firstly, lubrication failure within the contact area and second, establishment associated with metal to metal surface contact. Later upon, welding as well as tearing action caused by metal surface contact by removing the actual metal quickly and continuously so far, speed as well as oil heat remain in the same level. The rating is categorized into preliminary, moderate as well as destructive [K. Gopinath, 2011].

Scoring damage mark is stick to the course of motion on the bearing surface. The scoring damage marks start the contact surface where the dirt particle connects the motion layer and form a consistent mark around the end with the gear surface area, the trailing edge around the right with the pad inside the Photograph, or stop having an embedded particle. Scoring is among abrasive wear, adhesive wear gives discontinuous tears as opposed to clear uninterrupted scores.

2.3.2.1 Initial scoring

Initial scoring occurs in the high places left through previous machining. Lubrication fails at these types of spots results in initial rating or scuffing because shown within table 2.2. Once these types of high places are eliminated, the stress boils down as force is distributed on the larger region. The scoring will stop when the load, pace and heat of essential oil remain the same or decreased. Initial rating is non-progressive and it has corrective action related to it [K.Gopinath, 2011].

2.3.2.2 Moderate scoring

Moderate scoring occurs if the Scoring progresses at tolerable rate. After initial scoring if the load, speed or oil temperature increases, the scoring will spread over to a larger area. It is shown in table:

2.3.2.3 Destructive scoring

After the initial scoring, if the load, speed or even oil heat increases substantially, then serious scoring sets in with heavy metal torn areas spreading rapidly throughout as shown within table below. Scoring is usually predominant within the pitch collection region because elastohydrodynamic lubrication may be the least from that area. In dried running areas may grab [K.Gopinath, 2011].