Wear behaviour of helical gear in a power recirculating configuration under torsional loading

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ABSTRACT - Helical gears have a high load carrying capacity and is most commonly utilized in high speed applications. Condition monitoring is performed in order to obtain an efficient component replacement of a machine to prevent failures. One of the techniques of condition monitoring is through wear debris analysis where particles removed through wear is analyzed from the lubricants. The focus of this research is to investigate the wear behavior of carbon steel helical gear operating in a power recirculating and torsional loading. Helical gears were tested on a power recirculating gear test rig with constant loads of up to 40 Nm and speed of 1000 rpm. The samples were analyzed using wear debris analysis and particle count analysis. The wear behavior exhibits stage of wear modes at certain point in the gear cycles which varies slightly than a typical gear meshing under uniform loading.

1. INTRODUCTION

Gears are the mechanism to transmit power by two surfaces that are in contact with each other which are common in most machines that utilizes mechanical transmission. Even the most properly designed, well fabricated, and installed gears will generally experience failure to fatigue of the meshing [1]. Wears are vital to be identified and analyzed to estimate the life of the gear. Numerous past research has focused on the study of wear of the gear utilizing condition monitoring tools [2-4].

A prolonged operating life for machine components is an ideal condition for a system thus an important technique of condition monitoring is considered as a necessity. Wear-debris monitoring is one of the categories of condition monitoring which in this study involves the lubricant extraction. Lubricant is introduced to the component which in time will gradually be contaminated with particles due to wear of the machine component. The mechanism of wear-debris analysis is to analyze the shape and composition of the particles progressively thus monitors the wear of the machine components [6]. Particle counter is also a part of the wear-debris monitoring where particles are distinguished by its respected sizes and it has been used to predict failure in helical gears [7].

There are few studies regarding torsional loading or better categorised as a non-uniform loading which focuses on the stress distribution of the gear tooth [10] as well as a study on torsional load on helical gear in a parallel configuration through vibration signature [11].

This study focuses on the characterization of wear through the particle size and shape. The objective of this study is to investigate the effect of torsional loading in a power recirculating configuration to the wear behaviour of helical gear.

2. RESEARCH METHODOLOGY

2.1 Helical gear and lubrication specification

The tested helical gears are lubricated as shown in Table 2.1 and are in a meshing configuration and the test is conducted at ambient condition.

Table 2.1 Helical gear and lubricant specification

Specification	Value
Gear material	AISI 4140, Carburize
No. of teeth	35
Helix angle	17.75°
Pitch diameter	110.25 mm
Lubricant	Dexron III ATF

2.2 Power recirculating gear test rig

The test rig as shown in Figure 2.1 is constructed to deliver approximately 40 Nm of load and rotational speed of 1000 rpm. Torsional coupling is introduced into the closed loop system to apply the intended loading with through torsion of the shaft. Torque transducer is installed to ensure the loading is accurate as possible.

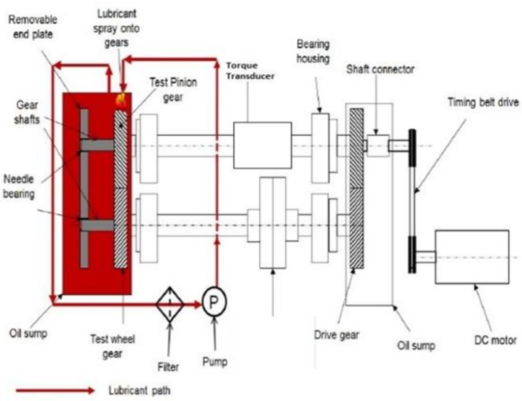

Figure 2.1 Gear test rig schematics

Oil sampling were conducted every hour for 80 hours collected through peristaltic pump directly from the oil sump while running the test rig. The samples collected were sealed in a container in order to prevent contamination from exposure towards the atmosphere.

2.3 Wear debris and particle count analysis

Each lubricant sample were analyzed through the use of Spectro 5200 Trivector which complies to the ASTM Standard Practice D7416 which is inclusive of the quantification of the concentration of the ferrous particles. Wear debris analysis conducted was obtained in an analysis grid with which complies with the ASTM D7684. The analysis software of the Spectro 5200 Trivector Analyzer contains an atlas of characterized image which was compared and matched with the samples analyzed.

Average size and maximum size refers to the size of the particles in compliance with the ASTM D7416 standard. Aspect ratio describes the ratio of minor dimension to major dimension of particles in the sample. Shape classification describes the particles profiles which can be used to determine the wear mechanism. The texture grid classifies the particles surface texture which can determine the condition of the particles. The severity grid determines the wear severity through the qualitative and quantitative classification of other grids.

3. RESULTS AND DISCUSSION

3.1 Wear debris analysis

The result for the wear debris analysis is highlighted on ferrous content and the type of wear from the particle shape are characterized [8 and 9].

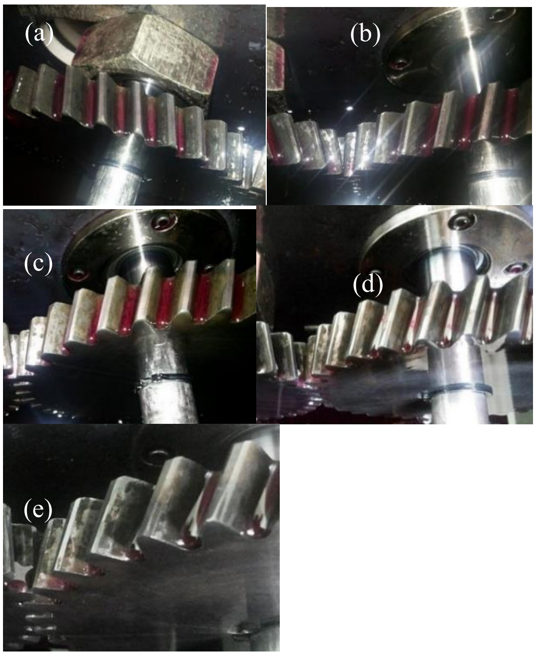

Figure 3.1 Meshing helical gear (a) 1st hour (b) 20th hour (c) 40th hour (d) 60th hour and (e) 80th hour

As seen in Figure 3.1, no visible defects could be observed from the helical gear meshing for the 1st, 20th and 40th hour. As the machine cycle enters the 60th hour, visible minute defects were observed as indicated by the red circles particularly at the edges of the gear teeth. At the 80th hour, the defects worsen as most of the edges of the gear teeth experiences material removal. It is also particularly noted that minor scuffing is observed at around the 60th hour.

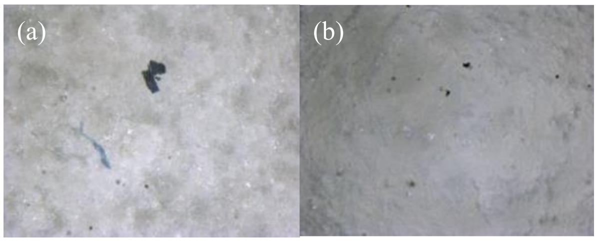

Figure 3.2 (a) chunks (b) platelets

The type of shapes obtained from the stereoscopic microscopy through the experiments is generally of chunks and platelets as seen in Figure 3.2.

3.2 Particle Count Analysis

The particles count results were obtained per 10th hour till the 60th hour. The particles are categorised into small size particle and large size particle.

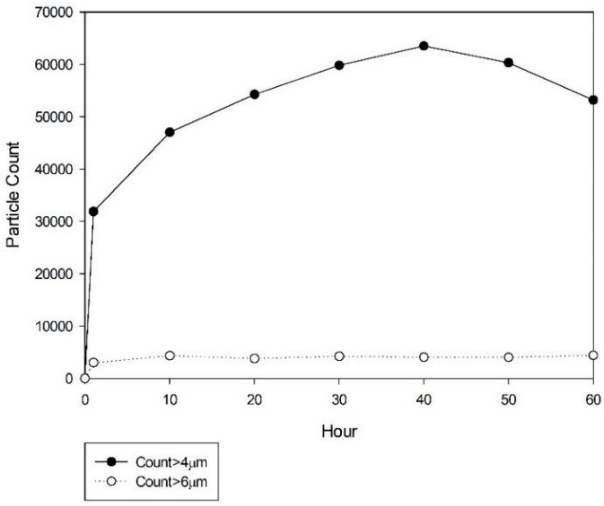

Figure 3.3 Small size particle count analysis

As observed in Figure 3.3, particle size of 4 µm increases significantly initially until it reaches a peak of 63504 particles count of which it is then decreased rapidly. Multiple modes of wear are involved to produce this scale of particle which is mainly of abrasive and surface fatigue wear.

The behaviour of the particle also coincides with the results from wear debris analysis whereas time progresses the machine cycle reaches an optimum life condition. No significant changes can be observed from the 6 µm particle size.

From Figure 3.4, it is observed that for the large size particles, only of particle size 14 µm and 22 µm is observed to have significant changes progressively. It is noted that the generation of small size particles are decreasing and a gradual increase in large size particles. This suggests that the helical gear which have reached an optimum life condition, but is progressing to a steady severe wear which involves a larger removal of surface material of the helical gear as the large particles of the 14 µm, 22 µm, 38 µm and 70 µm increases from its initial condition steadily.

It is noted that the behaviour of the gear varies slightly under torsional loading as the gear experiences stages of wear modes as compared to the wear behaviour of gear under uniform loading. Gear meshing under uniform loading exhibits a linear increase in wear rate per time as demonstrated by Flodin [12].

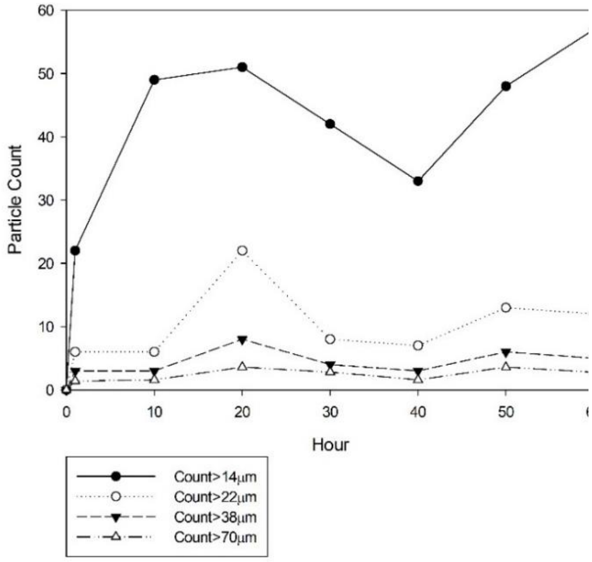

Figure 3.4 Large size particle count analysis

4. SUMMARY

The experimental study shows the wear behaviour of helical gear under torsional loading experiences stages of wear modes which is characterised through wear debris analysis. The generation of small wear debris is high at the beginning of the life of the gears whereas the big size particles are increasing towards the end of experiment showing the gear degradation.

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