FAILURE ANALYSIS OF DRIVESHAFT OF TOYOTA SEG

SHUHAIZAL BIN MOHD NOOR

A report submitted in partial fulfilment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

NOVEMBER 2007

ABSTRACT

Power transmission system of vehicles consist several components which sometimes encounter unfortunate failures. Some common reasons for the failures may be manufacturing and design faults, maintenance faults raw material faults, material processing faults as well as the user originated faults. In this study, fracture analysis of a drive shaft of an automobile power transmission system is carried out. Hardness measurements are carried out for each part. For the determination of stress conditions at the failed section, stress analyses are also carried out by the finite element (ALGOR) method. The fatigue test experiment had been done to see how long the drive shaft can be stay before had any failure. By compare the hardness number and the properties of material, the driveshaft is make from medium carbon steel. It has higher endurance limit compare to mild steel, brass and aluminum (pure).

ABSTRAK

Sistem pemindahan kuasa kenderaan terdiri daripada beberapa komponen yang kadang kalanya akan menghadapi kegagalan atau kerosakan. Beberapa sebab yang kebiasaannya menyebabkan berlakunya kegagalan adalah seperti kegagalan reka bentuk, kegagalan pada bahan mentah, kegagalan memproses bahan begitu juga dengan kegagalan awal pengguna yang mengendalikan alat tersebut. Dalam projek ini, analisis keret akan pada batang pemacu pemindahan kuasa kenderaan telah dijalankan. Pengukuran kekerasan telah dibuat bagi setiap komponen di dalam pemacu. Bagi mendapatkan kepastian dalam menguji ketegangan di bahagian yang gagal, analisis ketegangan telah dijalankan dengan menggunakan proses ALGOR. Ujian kelesuan telah dijalankan untuk mengetahui sejauh mana pemacu dapat bertahan sebelum mengalami sebarang kegagalan. Dengan membuat perbezaan antara tahap kekerasan dengan kandungan dalam sesuatu bahan, pemacu tersebut diperbuat daripada karbon keluli kelas pertengahan. Ia mempunyai tahap daya ketahanan yang lebih tinggi berbanding dengan keluli biasa, loyang dan aluminium tulen.

TABLE OF CONTENT

3 METHODOLOGY

4 RESULT AND DISCUSSION

5 CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

SEM	Scanning electron microscope
NDE	Non-destructive examination
"HR"	(Hardness Rockwell)
ASTM	(American Society for Testing & Materials)
EDS or EDX	Energy dispersive X-ray spectroscopy
MnS	Manganese sulfide
FeS	Iron sulfide
AISI	American Iron and Steel Institute

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

A driveshaft, driving shaft, or also known as Cardan shaft is a mechanical device for transferring power from the engine or motor to the point where useful work is applied.

Most engines or motors deliver power as torque through rotary motion: this is extracted from the linear motion of pistons in a reciprocating engine; water driving a water wheel; or forced gas or water in a turbine. From the point of delivery, the components of power transmission form the drive train.

In automobiles, axle shafts are used to connect wheel and differential at their ends for the purpose of transmitting power and rotational motion. In operation, axle shafts are generally subjected to torsional stress and bending stress due to self-weight or weights of components or possible misalignment between journal bearings. Thus, these rotating components are susceptible to fatigue by the nature of their operation and the fatigue failures are generally of the torsional, rotating-bending, and reversed (two-way) bending type.

1.2 Problem Statement

Nowadays, there are many vehicle involved in accident. After an accident, there are many part was damaged. One of that is drive shaft. Drive shaft is a mechanical device for transferring power from the engine or motor to the point where useful work is applied. There are many failure were happen to the device especially after an accident, like fatigue failure, torsional stress, bending stress and etc.

People often ask what are the hardness of material that use in drive shaft and how longer the shaft can stay use if the car not involved in accident.

This project is to study about the failure that happens to the drive shaft. First, identify the failure cause and condition of the drive shaft. Then do the hardness test to know how hard the material that use in drive shaft. After that we can make an analysis and we try to solve the problem.

1.3 Objectives of Project

Analyze the failure of drive shaft that used in Toyota SEG due to the hardness testing to determine the hardness of material, fatigue testing to determine endurance limit of the material and stress analysis to determine the maximum stress that can be stand by the driveshaft.

1.4 Project Scope

Basically, this project has divide by three scopes as a guide to achieve the objective.

1.4.1 Focus on the drive shaft of Toyota SEG
1.4.2 Study on hardness, fatigue and stress analysis of driveshaft
1.4.3 Analysis using application of machine and software

1.5 Problem overview

Drive shaft is one of the component parts of car that use to transmit the motion from differential to the wheels. The shafts work with the vehicles motion. Torsional, bending and normal forces occur during the working of the shaft. Some common reasons for the failures may be manufacturing and design faults, maintenance faults, raw material faults as well as the user originated faults. Because of the rotating of drive shaft, failure can occur that means fatigue and torsion failure. There are many type of material use to make a drive shaft to improve from the failure occur. So the manufactured choose high hardness and strength material to make sure the drive shaft can hold on a long time.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Drive shafts are carriers of torque; they are subject to torsion and shear stress, which represents the difference between the input force and the load. They thus need to be strong enough to bear the stress, without imposing too great an additional inertia by virtue of the weight of the shaft.

Most automobiles today use rigid driveshaft to deliver power from a transmission to the wheels. A pair of short driveshaft is commonly used to send power from a central differential, transmission, or transaxle to the wheels.

There are different types of drive shafts in Automotive Industry:

- 1 piece driveshaft
- 2 piece driveshaft
- Slip in Tube driveshaft

The Slip in Tube Driveshaft is the new type which also helps in Crash Energy Management. It can be compressed in case of crash. It is also known as a collapsible drive shaft.

Front-wheel drive is the most common form of engine/transmission layout used in modern passenger cars, where the engine drives the front wheels. Most front wheel drive vehicles today feature transverse engine mounting, where as in past decades engines were mostly positioned longitudinally instead. Rear-wheel drive was the traditional standard and is still widely used in luxury cars and most sport cars.

2.2 Failure analysis

Failure analysis is the process of collecting and analyzing data to determine the cause of a failure and how to prevent it from recurring. It is an important discipline in many branches of manufacturing industry, such as the electronics industry, where it is a vital tool used in the development of new products and for the improvement of existing products. However, it also applies to other fields such as business management and military strategy.

Failure analysis and prevention are important functions to all of the engineering disciplines. The materials engineer often plays a lead role in the analysis of failures, whether a component or product fails in service or if failure occurs in manufacturing or during production processing. In any case, one must determine the cause of failure to prevent future occurrence, and/or to improve the performance of the device, component or structure.

A failure analysis can have three broad objectives there are determining modes, cause, or root causes. Failure mode can be determined on-site or in the laboratory, using methods such as fractography, metallography, and mechanical testing. Failure cause is determined from laboratory studies and knowledge of the component, its loading, and its environment. Comparative sampling or duplication of the failure mode in the laboratory may be necessary to determine the cause. Root failure cause is determined using knowledge of the mode, the cause, and the particular process or system. Determining the root failure cause require complete information about the equipment's design, operation, maintenance, history, and environment. A typical failure analysis might include fractography, metallography, and chemical analysis.

The failed component is examined and its condition documented. If appropriate, scale or deposits are collected and any fracture surface features are documented. A scanning electron microscope (SEM) is often used to evaluate fracture surfaces for material defects, determine fracture modes, and measure fracture features and particles precisely.

Metallography is particularly powerful when combined with typical non-destructive examination (NDE) methods such as ultrasonic testing, eddy current, magnetic particle testing, or liquid penetrant testing.

Failure of a component indicates it has become completely or partially unusable or has deteriorated to the point that it is undependable or unsafe for normal sustained service. There are some of typical root cause failure mechanisms such as fatigue failures that cause by repeating cycle, corrosion failures, stress corrosion cracking, ductile and brittle fractures, hydrogen embrittlement, liquid metal embrittlement, creep and stress rupture.

It is possible for fracture to be a result of multiple failure mechanisms or root causes. A failure analysis can provide the information to identify the appropriate root cause of the failure. The common causes of failure are like misuse or abuse, assembly errors by manufacturer, improper maintenance, design errors, improper material and heat treatment process for the material, and manufacturing defect like unforeseen operating condition and inadequate environmental protection or control.

Figure 2.1: Sample of failure

2.3 Shaft

Shafts function in wide ranging service conditions, including corrosive environments, and both very high and very low temperatures. Shafts may experience a range of loading conditions. In general, shafts may experience tension, compression, bending, torsion, or a combination of these loading conditions. Additionally, shafts may experience vibratory stresses. Wear is a common cause of shaft failure. Abrasive wear is one of the forms of wear failures. Abrasive wear, or abrasion, is caused by the displacement of material from a solid surface due to hard particles or protuberances sliding along the surface. Abrasive wear can reduce the size and destroy the shape of a shaft. Some examples of abrasive wear of shafts are foreign particles such as sand, dirt, metallic particles, and other debris in the lubricant. This debris can damage a shaft by wear. Failures may occur due to misalignment. One cause of misalignment is the mismatch of mating parts. Misalignment can be introduced during original assembly of equipment. Misalignment can be introduced after an overall or repair of equipment. Deflection or deformation of supporting components in service may also cause misalignment. Misalignment can cause vibration resulting in a fatigue failure of the shaft.

2.3.1 Linear Shaft

Linear shafts are elongated, rod-shaped devices that provide linear or rotary motion for power transmission applications. They are used as axles, pistons, and rollers in heavy machinery. Some linear shafts have axial or radial holes for mounting to support structures. Others are grooved for the placement of snap rings or channeled for keyways. Solid or hollow linear shafts with male or female threads and stepped or chamfered ends are also available. Most linear shafts are made of aluminum, alloy steel, carbon steel, stainless steel, composite materials, or plastics.

Alloy steel is harder than carbon steel and provides superior durability. Stainless steel is well-suited for applications in which corrosion resistance is an important consideration. Aluminum linear shafts provide good electrical and thermal conductivity, high reflectivity, and resistance to oxidation. Composite materials are often made of carbon fibers bonded together by resins. They are not as strong as metal shafts, but are light weight and help reduce energy requirements. Linear shafts are usually coated or hardened to improve durability. Anodizing is a protective surface coating process used mainly with aluminum products. Black oxide coatings are applied to steel or stainless steel shafts to prevent ion corrosion. Ceramic coatings provide a wear-resistant finish while chromium coatings improve corrosion resistance and reduce friction.

Linear shafts with nickel or nitride coatings are also available. Teflon®, a registered trademark of DuPont Dow Elastomers, is a class of fluoropolymer resins that is resistant to high temperatures, chemical reactions, corrosion, and stress cracking. Linear shafts that are coated with PTFE are used in a variety of applications. Some steel shafts are case-hardened with carbon or nitrogen. Others are through-hardened to ensure that the entire shaft has the same hardness. There are several ways to measure the hardness of linear shafts. The Rockwell hardness test presses a steel or diamond cone against a test sample and measures the depth of the resulting indentation. Higher measurements indicate harder materials. For linear shafts, common Rockwell hardness ranges are 50 to 59, 60 to 69, and 70 to 79. The

Brinell hardness test subjects a test material to a load of 3000 kg with a hardened steel or carbide ball that is 10 mm in diameter. The Knoop hardness test also measures a material's hardness through its resistance to indentation. The Vickers hardness test indents a test material with a diamond indenter that is shaped into a right pyramid with a square base and an angle of 136° between opposite faces. Important specifications for linear shafts include shaft diameter or width, maximum length, weight, height, and tolerance. Most linear shafts have circular or square cross sections and are produced in standard lengths that can be cut to size for specific applications. Weight is measured in per unit distance, typically pounds per feet. Height is the distance from the guide or rail base to the center of the guide or rail. Ultra precision shafts have a very tight tolerance. Standard grade and precision grade linear shafts are also available.

2.4 Fatigue failure of shaft

One of the more common causes of shaft failure is due to fatigue. Metal fatigue is caused by repeated cycling of the load. It is a progressive localized damage due to fluctuating stresses and strains on the material. Metal fatigue cracks initiate and propagate in regions where the strain is most severe.

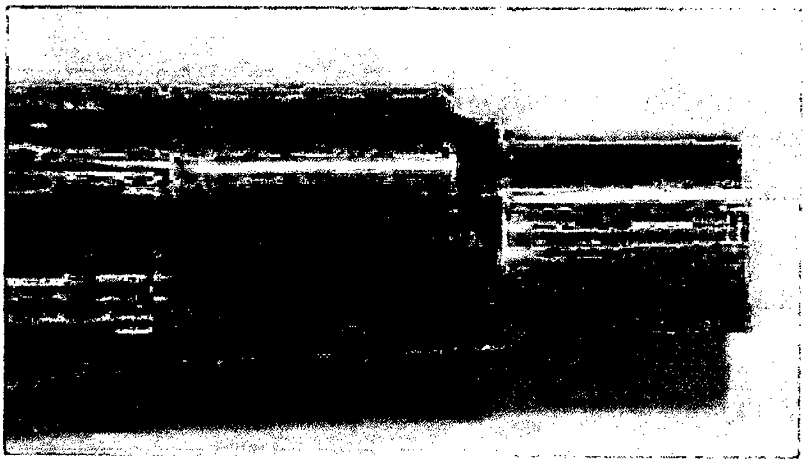

Figure 2.2: Shaft failure

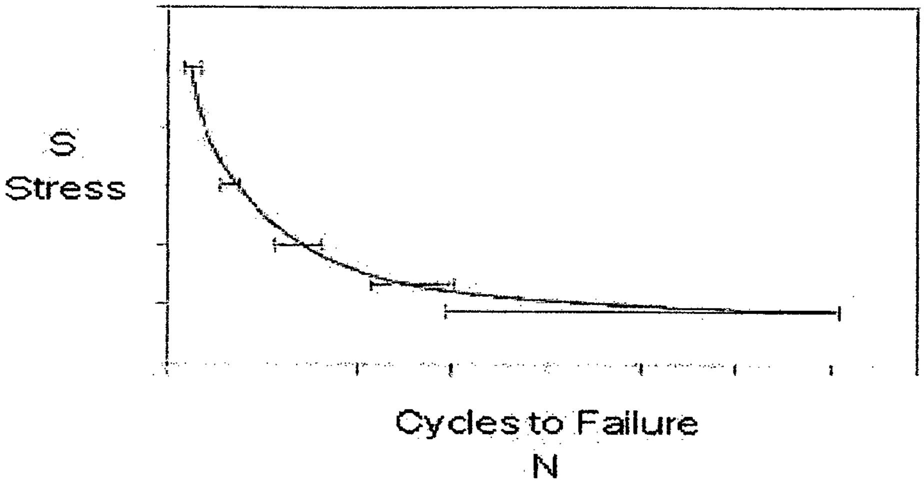

Figure 2.3: S-N curve, showing increase in fatigue life with decreasing stresses.

The concept of fatigue is very simple, when a motion is repeated; the object that is doing the work becomes weak. For example, when you run, your leg and other muscles of your body become weak, not always to the point where you can't move them anymore, but there is a noticeable decrease in quality output. This same principle is seen in materials. Fatigue occurs when a material is subject to alternating stresses, over a long period of time. Examples of where Fatigue may occur are: springs, turbine blades, airplane wings, bridges and bones.

There are 3 steps that maybe view a failure of a material due to fatigue on a microscopic level:

1. Crack Initiation: The initial crack occurs in this stage. The crack may be caused by surface scratches caused by handling, or tooling of the material; threads (as in a screw or bolt); slip bands or dislocations intersecting the surface as a result of previous cyclic loading or work hardening.
2. Crack Propagation: The crack continues to grow during this stage as a result of continuously applied stresses

3. Failure: Failure occurs when the material that has not been affected by the crack cannot withstand the applied stress. This stage happens very quickly.

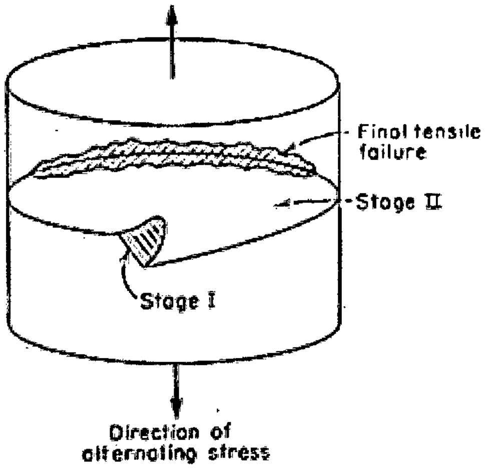

Figure 2.4: Location of the 3 steps in a fatigue fracture under axial stress

One can determine that a material failed by fatigue by examining the fracture sight. A fatigue fracture will have two distinct regions; One being smooth or burnished as a result of the rubbing of the bottom and top of the crack (steps 1 & 2). The second is granular, due to the rapid failure of the material. These visual clues may be seen in Figure 2.5:

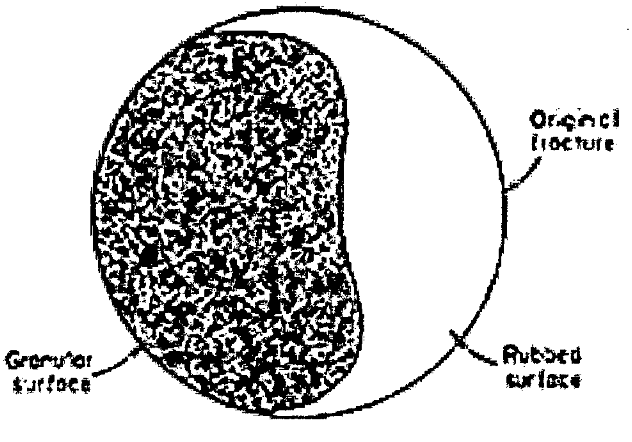

Figure 2.5: The surface of a fatigue fracture.

Other features of a fatigue fracture are Beachmarks and Striations. Beachmarks, or clamshell marks, may be seen in fatigue failures of materials that are used for a period of time, allowed to rest for an equivalent time period and the loaded again as in factory usage. Striations are thought to be steps in crack propagation, were the distance depends on the stress range. Beachmarks may contain thousands of striations. Visual Examples of Beachmarks and Striations are seen below in Figure 2.6 and 2.7.

The most effective method of improving fatigue performance is improvements in design:

- Eliminate or reduce stress raisers by streamlining the part
- Avoid sharp surface tears resulting from punching, stamping, shearing, or other processes
- Prevent the development of surface discontinuities during processing.
- Reduce or eliminate tensile residual stresses caused by manufacturing.
- Improve the details of fabrication and fastening procedures

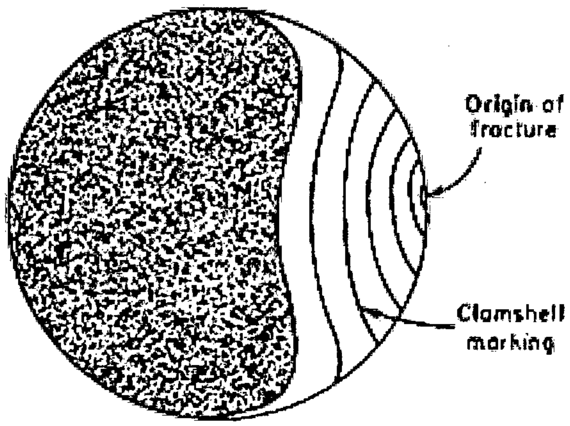

Figure 2.6: An example of beachmarks or "clamshell pattern" associated with stress cycles

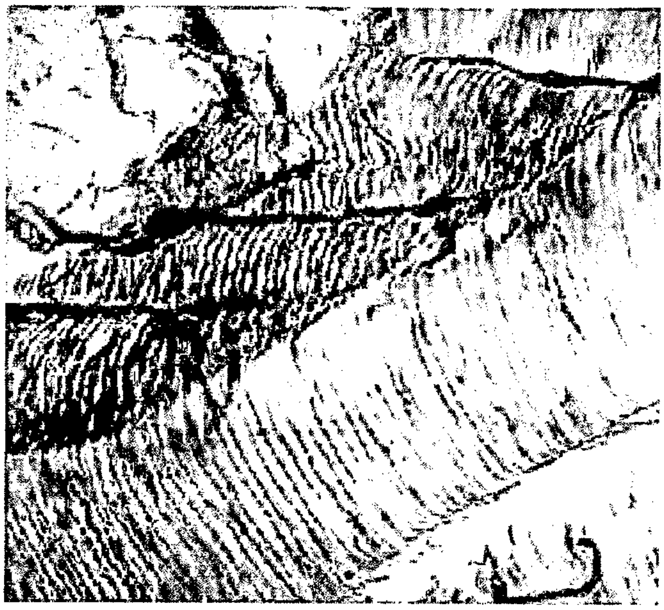

Figure 2.7: An example of the striations found in fatigue fracture.

Metal fatigue is a significant problem because it can occur due to repeated loads below the static yield strength. This can result in an unexpected and catastrophic failure in use. Because most engineering materials contain discontinuities most metal fatigue cracks initiate from discontinuities in highly stressed regions of the component. The failure may be due the discontinuity, design, improper maintenance or other causes. A failure analysis can determine the cause of the failure.

2.5 Fatigue failure of the drive shaft

This experiment has done by H. Bayrakceken, S. Tasgetiren and İ. Yavuz from Afyon Kocatepe University, Technical Education Faculty, Afyon 03200, Turkey. From their experiment of drive shaft, a schematic technical drawing and a photograph of the analyzed failed shaft is given in Figure 2.8. The complete fracture is occurred between the bearing and flange (Figure 2.9).