Failure Analysis of Drive Shaft

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Abstract

A car's engine cannot power all of the wheels alone. That's why the drive shaft is necessary to propel the vehicle. To propel the drive wheels it is necessary to take power from engine and send it to drive wheels by means of a drive shaft (half shaft). As it is transmitting the torque from the engine to the wheels, the drive shafts are subjected to the torsional stress and shear stress, which cause the failure of drive shaft. Any break down in drive shaft will cut the power flow from engine to the drive wheels. That's why it is indispensable to analysis the drive shaft. The properties required to the drive shaft are hardness on the surface to resist the wear and toughness in the core to resist the deformation that can be achieved by doing the heat treatment.

Keywords:*Drive shaft, failure analysis, heat treatment, hardness,*

1. Introduction

Heat energy produced by the combustion of gasoline fuel and air in the engineis converted into the mechanical energy which is used to propel the vehicle.

But the power produced in the engine that is the rotation and torque produced by the engine which is at the crank shaft is too high, which cannot be use for driving the car, As the speed of crankshaft is around the 10k – 15k which is also depend on the type of engine, We cannot drive the vehicle at that speed, and hence the transmission plays the major role in it, which increases the torque coming from the engine as per the requirement, also it vary the engine RPM by means of a transmission system. And the final output of transmission is redirect to the drive wheels assisting it with drive shaft.

To do the failure analysis of drive shaft it is inevitable to consider the two branch of engineering. Mechanical engineering which is familiar with the engine and transmission system help to know about these things, on the other hand to do failure analysis it required study of heat treatment, testing methods, material science which contributes towards the metallurgical field.

Drive shaft is a mechanical part of transmission system which assists power flow from engine to the drive wheels. The usage of drive shaft as a power transmitter in automobile is more convenience because it is less likely to become jammed or broken compared to chain-drives. In operation, drive shaft is generally subjected Torsional and bending stress due to which fatigue and fractural failures may occur. Fatigue failure because of continuously rotating at uneven speed, which put the drive shaft in loading unloading condition and contribute for fatigue failure in it, also as the drive shaft is used as driving element in vehicle it sustain the more torque. Some common causes of failures are manufacturing, design, maintenance, raw material, and the user originated faults. To avoid the failure of drive shaft it is necessary to know the reasons of failure which will get from the failure analysis.

Heat treatment which is used to avoid the failure of drive shaft is mostly hardening followed by tempering, flame hardening, induction hardening. This gives the hardness at surface and toughness at the core, and thus the drive shaft can survival in the high torsional area. And because of high hardness value which is normally martensitic layer at the surface gives better wear resistance

2. Purpose of Using the Drive Shaft

A car's engine cannot power all of the wheels alone. In a front-wheel drive vehicle, for example, the engine under the hood of the car cannot reach the rear wheels. It is therefore connected under the hood to a transmission, which then must be linked to the car's rear axle via a long drive shaft running the length of the car.

This drive shaft, sometimes known as a propeller shaft, is connected to the final drive of the transmission, sometimes called the differential, located on the rear axle. This rear differential is responsible for redirecting the engine's force 90 degrees each way, to the opposing rear wheels. It also allows the wheels to turn at different speeds. The shafts running from the rear differential to the back wheels are sometimes known as half shafts, but are technically also drive shafts since they drive the turning motion of the wheels.

The drive-train mechanism, which includes the drive shaft, is a complex part of any car. The terms used to refer to its parts vary depending on make, model and mechanic. The basic function of any drive shaft, regardless of its name or location, is to transfer rotational power across distance under the car.

Location of drive shaft in vehicle

3. Reasons why they fail

- There are many such reason why drive shaft are fail. But the major reason is that they are subjected to high torsional stress while transmitting the power from the engine to the wheels.
- Due to improper assembly of drive shaft they are prone to fracture under shear.
- Due to improper heat treatment of drive shaft they are going to fail.
- Improper designs of drive shaft are going to fail during service.
- Presence of cyclic over-loads
- Stress concentration. They may be due to production or operation causes e.g. under cuts, machining, traces, notches etc.
- Wrong adjustment of bearing, insufficient clearances.

3.1 Remedies

- Do the proper design and manufacturing of drive shaft.
- Assembly of drive shaft is important parameter so do proper assembly of drive shaft.
- Do the heat treatment as per the material. And as per the properties required.
- Avoid the stress concentration
- Make sure that surface of drive shaft should be free from the cracks, which are prone to fatigue failure of shaft

4.Failure Analysis

Failure analysis is the process of collecting and analyzing data to determine the cause of a failure. Any failure can have a number of causes. So it is important to identify the major problem of failure to avoid the future failure of that part.

A shaft is a rotating member usually of circular cross-section which is used to transmit power and rotational motion from the engine to the final drive. Most shafts are subjected to fluctuating loads of combined bending and torsion with various degrees of stress concentration.
Failure analysis can have three broad objectives.
1. Determining modes
2. Failure Cause
3. Root causes.
Failure mode can be determined on-site or in the laboratory, using methods such as fracture mode, metallographic, macroscopic examination and mechanical testing. Failure cause is determined from laboratory studies and knowledge of the component and 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.

Failed drive shaft under running condition

5. Case study

A drive shaft used in FSAE car of 20mm diameter and 320mm length is failed in running condition of vehicle. This brings us to do its failure analysis.

- Problem statement
- Hardness testing
- Proper heat treatment

5.1 Problem statement

- The drive shaft of 20mm diameter and 320mm in length is shear out from the splines.
- Do the failure analysis of the shaft
- Find the solution.

Drive shaft used in FSAE car

5.2 Hardness testing

While analysis the problem it is found that the hardness of drive shaft Is dropped because of normalizing. It is dropped up to the 17 HRC. It can found by checking the hardness on Rockwell hardness test machine.

Rockwell hardness testing machine

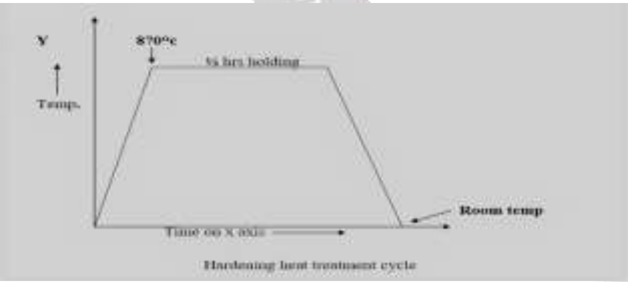
The actual hardness of EN24 material is 26 HRC, but because of faulty heat treatment the hardness drooped to the 17 HRC, this is the main reason because of that the drive shaft is failed.

5.3 Heat Treatment

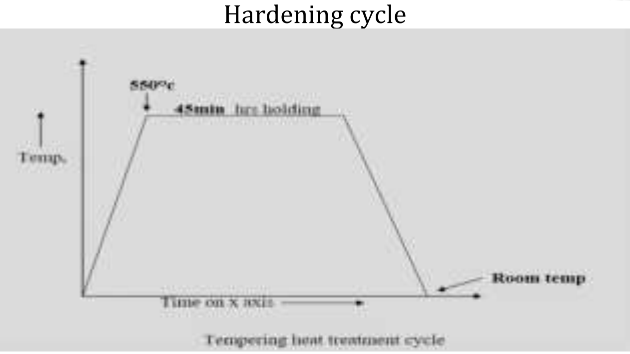
It is found that the problem with the drive shaft is dropping its hardness to the 17 HRC. Therefore with the proper and right heat treatment the hardness of the drive shaft can be raise. Hardening heat treatment which is followed by the tempering is done which gives 32HRC hardness. For any drive shaft it is important that the hardness should be in the range of 30 to 35 HRC. That can be achieved by hardening heat treatment

Muffle furnace

The heat treatment which is given to the failure part is hardening heat treatment. In this the part is firstly heated to its austenizing temperature at 880^{o}c then that part is hold at this temperature for half an hour then the cooling is done in a water bath for high rate of cooling. This is required for martensitic formation. Now the hardness is 55HRC this hardness is reduces by high temperature tempering.

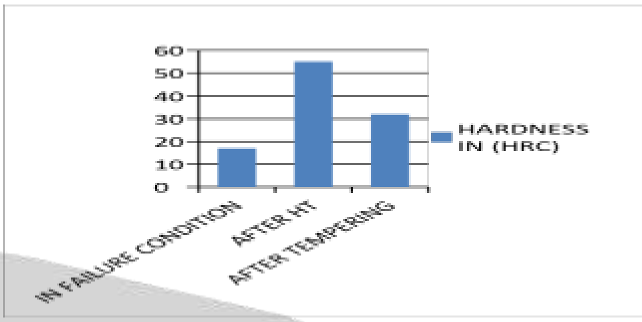


Hardening cycle



Tempering cycle

Although high hardness gives good wear resistance but, too much hardness is not applicable to drive shaft,because with increasing the hardness it also increases the brittleness of material. This is not the applicable in engineering filed.
In this case study, the hardness is checked three times as shown in graph below,



Hardness variation with heat treatment

The hardness in initial case (in failure condition) is observed 17 HRC which is too low for drive shaft, and hence it is decided to do the hardening heat treatment to the drive shaft. This gives the hardness value of 55 HRC, this hardness value after the hardening process is too high because it is increasing the brittleness also. And after the tempering the hardness is drooped to the 32 HRC which is required to the drive shaft.

The drive shaft with 17HRC was failed in first 90 laps in our design track. This shows very bad result. Then it was decided to do heat treatment (hardening followed by tempering) which is mentioned above and put the drive shaft in safe zone with 35HRC at surface, And this drive shaft ran approximate 320 laps on the same track.

We should always prefer case hardening for drive shaft. But the problem was the first material which was selected for the drive shaft according to the mechanical properties did not show good response to the case hardening as EN28 has more carbon already. Hence we shifted to a new material AISI 8620; this shows good response to the case hardening especially carburizing. After manufacturing the new drive shaft we did carburizing heat treatment on it.

And result of this is, still we are using that drive shaft for propelling our vehicle without any failure.

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