

# FAILURE ANALYSIS OF AUTOMOTIVE FRONT WHEEL DRIVE SHAFT

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**ABSTRACT** - Drive shaft is a mechanical part of transmission system which is used to transfer the power from engine to the wheel. It comprises two constant velocity (CV) joints and the actual shaft is almost universally used in front wheel drive (FWD) vehicles. 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. Some common causes of failures are manufacturing, design, maintenance, raw material, and the user originated faults. This paper presents the available literature of failure analysis of drive shaft and summarized the causes of failures of FWD drive shaft and analyzes the premature failure in drive shaft.

## I. Introduction

The movement of vehicles can be provided by transferring the torque produced by engines to wheels after some modification. The transfer and modification system of vehicles is called as power transmission system and have different constructive features according to the vehicle's driving type which can be front wheel drive. Most automobiles today use rigid driveshaft to deliver power from a transmission to the wheels. A pair of short flexible driveshaft is commonly used in cars to send power from a differential to the wheels.

Drive shaft is a mechanical part of transmission system which is used to transfer the power from engine to the wheel. It comprises two constant velocity (CV) joints and the actual shaft is almost universally used in front wheel drive (FWD) vehicles. Machine elements and assemblies in the cases of the to variable loads are subject to fatigue stress, which under certain circumstances can lead to fatigue fractures and ultimately machine failure. Analysis of failures caused by fractures shows that the majority of them can be attributed to material fatigue.

**Types of Drive Shafts** There are different types of drive shafts in Automotive Industry:

- One-piece driveshaft
- Two-piece driveshaft
- Slip in Tube driveshaft



Fig. 1 One-piece driveshaft.

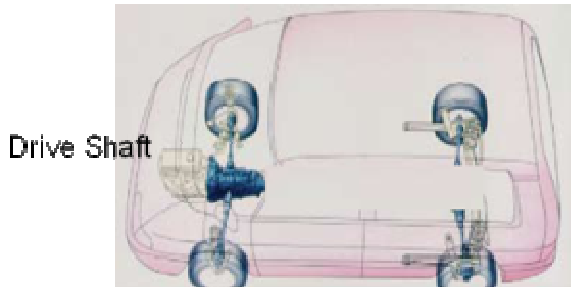


Fig. 2 Slip in Tube driveshaft.

Drive shafts are carriers of torque. They are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia.

### Specification of the Problem

The passenger cars, small trucks and vans should have the torque transmission capacity more than 3500 Nm and fundamental natural bending frequency must be higher than 6500 rpm to avoid whirling vibrations. From the theory of whirling, it has been found that the critical speed of shaft is inversely proportional to the square of its length. So the vibration problem could be solve by increasing the length of shaft but it cannot be permitted due to space limitations. So that there is only an option to manufacturers to manufacture the shaft in two pieces.



### II. Objectives

- To study Power transmission system of car.
- To find out failure parameters of Drive shaft.
- To Create Mathematical CAD -Model of front wheel drive Power transmission.
- To Analyze Drive Shaft for dynamic Loading conditions

### Analysis of FWD drive shaft

A failure analysis can have three broad objectives there are determining modes, cause, or root causes. Failure cause is determined from studies and knowledge of the component, its loading, and its environment. Comparative sampling or duplication of the failure is necessary to determine the cause. Root failure cause is determined using knowledge of the mode, cause, and particular process or system. Determining the root failure cause require complete information about the equipment's design, operation, maintenance, history, and environment.

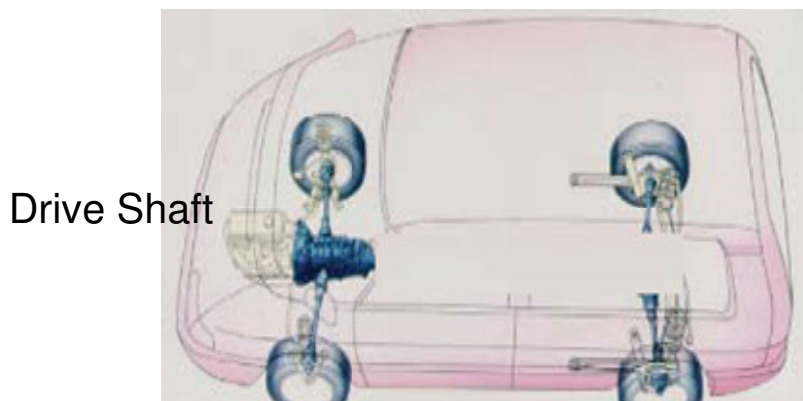


Fig. 3

### 2.1 Causes of Failure

Failure analysis is the process of collecting and analyzing data to determine the cause of a failure and how to prevent it from recurring. Failure analysis and prevention are important functions to all of the engineering disciplines. 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. 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. [1,2,7] The common causes of service failure are

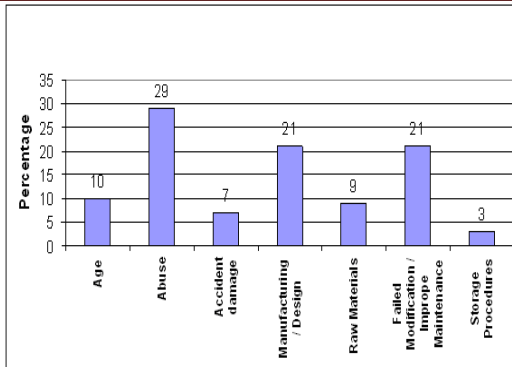


Fig. 4 the Distribution of causes of failure

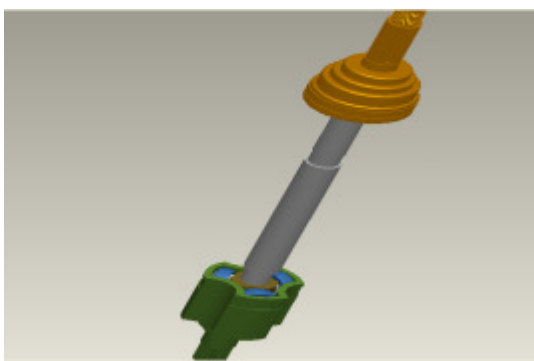
**Misuse or Abuse**

- Road condition.
- Environment condition.
- Improper maintenance.
- Improper material.
- Poor storage condition.

**Symptoms and probable causes of failure in drive shaft**

When the inspection of car occurs then many problems detected by visual and by hearing. So there are many symptoms like vibration, vehicle pulls to one side, front wheel shimmy, excessive noise, bent cage, galling, cracked inner race, etching, brinelling, heat discoloration, fatigue spalling, steering wheel vibration, car lead/pull etc. It can be determined by probable causes such as wear, damage or bending of drive shaft, drive shaft rattle and hub serration, sintering of wheel bearing, galling of drive shaft ball joint, defective front suspension and steering, improper wheel balance, front wheel is worn, hub bearing failure, defect in front lower ball point, cage damage due to improper handling, metal smears on roller end due to overheating, lubricant problem or overloading, race cracked due to improper fit, poor bearing seats, bearing surfaces appear gray or grayish black in color with etching of material usually at roller spacing, heat discoloration is dark blue resulting from overload or no lubricant (yellow or brown color is normal), surface indentations on race surface caused by rollers either under impact loading or vibration while the bearing is not rotating, flaking of surface metal resulting from fatigue, worn the splines of drive axle shaft or joint shaft, worn joint by grease leakage, poor assembly of boot clamp, torn boot

**III. Modeling of Drive Shaft**



**Analytical Calculation**

**1. Maximum Shear Strain ( $\phi$ ) :**

$$\phi = \frac{T.L}{G.J}$$

Where;  
T= Torque  
L=length

J=Polar moment of inertia

G=constant

Therefore;

$$\phi = 0.0036$$

**2. Total Deformation ( $\delta$ ) :**

$$\delta = \phi \cdot l$$

Where;

$$l = L/2$$

Therefore;

$$\delta = 0.0584 \text{ m}$$

**3. Maximum Shear Stress ( $\tau$ ) :**

$$\tau = \frac{T \cdot D}{J}$$

Where;

T= Torque

D=Maximum diameter

J=Polar moment of inertia

Therefore;

$$\tau = 2.73e8 \text{ Pa}$$

**4. Normal Stress ( $\sigma_1$ ) :**

$$\sigma_1 = \frac{F}{A}; F = \frac{T}{r}$$

Where;

T=Torque

r=radius of curvature

A=area

Therefore;

$$\sigma_1 = 5.32e7 \text{ Pa}$$

**5. Equivalent stress/von Misses stress :**

$$\sigma_{eq} = \sqrt{\sigma_{bmax}^2 + 3(T_{max})^2}$$

Therefore:

$$\sigma_{eq} = 4.89e8 \text{ Pa}$$

**6. Endurance strength**

$$S_e = K_{load} \times K_{size} \times K_{surf} \times K_{temp} \times$$

$$K_{reliability} \times K_d \times K_{stress \text{ concentration}} \times S'_e$$

$$K_{load} = 1 \text{ (Bending load)}$$

$$K_{size} = 1.24d^{-0.107} \text{ for } 2.79 < d < 51 \text{ mm} = 0.78$$

$$K_{surf} = 4.51 S_{ut}^{-0.265} = 0.82$$

$$K_{temp}=1 \text{ for } T < 450^{\circ}\text{C}$$

$$K_{reliability} = 0.90$$

$$K_d = 1/k_f = 1/1.89 = 0.53$$

$$K_{stress\ concentration} = 1 + q(K_f - 1) = 1 + 0.82(1.89 - 1) = 1.73$$

$$S_e = 167\text{MPa}$$

#### IV. Number of Cycles

Estimated Fatigue Life

Infinite Life- 10000 RPM (Average operating speed)=16.66 cycles/second  
5 year life @ 7 hour operating time per day approximately 48384000 seconds of use  
16.66\*48384000=8.068\*10<sup>8</sup> cycles to failure for infinite life  
 $N = (sf/a)^{-1/b}$

$$a = \frac{(fS_{ut})^2}{S_e}$$

$$b = -\frac{1}{3} \log\left(\frac{fS_{ut}}{S_e}\right)$$

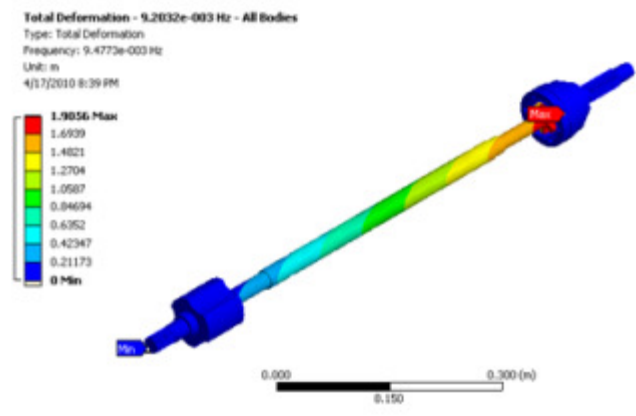
#### Fatigue Damage Factor

Fatigue damage factor = expected life cycle/actual life cycle=0.4

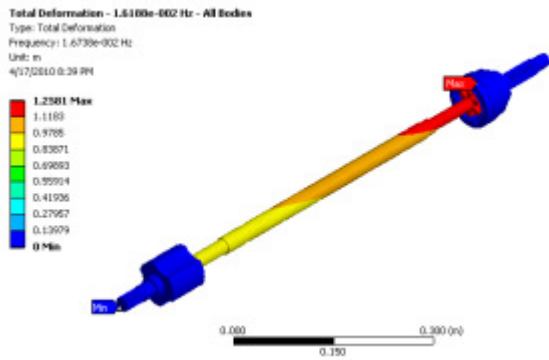
#### Analysis

Modal analysis is used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed. Modal analysis is used to determine the natural frequencies and mode shapes of a structure or a machine component. The rotational speed is limited by lateral stability considerations. Most designs are sub critical, i.e. rotational speed must be lower than the first natural bending frequency of the shaft. The natural frequency depends on the diameter of the shaft, thickness of the hollow shaft, specific stiffness and the length.

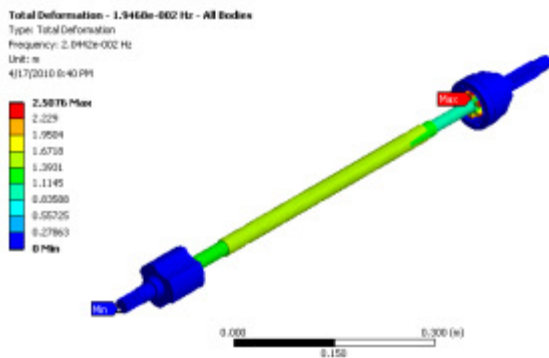
#### Model > Modal > Solution > Total Deformation - 1.191e-002 Hz - All Bodies > Figure



#### Model > Modal > Solution > Total Deformation - 1.6188e-002 Hz - All Bodies > Figure



Model > Modal > Solution > Total Deformation - 1.9468e-002 Hz - All Bodies > Figure



## V. Discussion

FWD drive shaft can be solid or tubular, equal or unequal length, come with or without damper weight. Equal length shafts are used in some vehicles to help reduce torque steer. The intermediate shaft is used as a link from transaxle to the half shaft. The outer ends have a support bracket and bearing assembly. Looseness in the bearing or bracket can create vibrations. The small damper weight is called torsional damper, that is sometimes attached to one half shaft serves to dampen harmonic vibrations in the drivetrain and to stabilize the shaft as it spins, not to balance the shaft.

The outer joints generally wear faster than inner joints because of the increased range of operating angles to which they are subjected. Inner joint angles may change only 10 to 20 degrees as outer joint can undergo changes up to 40 degrees in addition to jounce and rebound as the wheels are steered. That's why outer joints have a higher failure rate. On average, nine outer CV joints are replaced for every inner CV joint. All CV joints are encased in a protective rubber (neoprene, natural and silicon) or thermoplastic boot. The job of the boot is to retain grease and to keep dirt and water out. The importance of the boot cannot be overemphasized because without its protection the joint does not survive. Once CV joint packed with grease and installed, it requires no further maintenance. A loose or missing boot clamp, or a slit, tear, or a small puncture in the boot itself allows grease to leak out and water or dirt to enter. A milky or foamy appearance indicates water contamination. A gritty feeling when rubbed between the fingers indicates dirt. It Results, the joint is destroyed. Countries, where the average atmospheric temperature is approximate 40 degree, the failures mainly occur by changing the properties of grease. Grease must change its property on increasing of temperature because of changing in chemical composition. Grease becomes hard and thick on high temperature and does not operates normally. Oil present in grease may leak or vaporized which results failure of joint.

On the other side, road conditions are firmly effect the drive shaft. Domestic cars are manufactured on the basis of smooth road conditions but some developing countries have very rough road conditions so that premature failure may occur. A rough road condition causes the drive shaft work continuously on bumps and dips. Rough road have more dirt and dust particles, which are accumulated on the boot and in the grease. Which results abrasion of balls or tripods and joint may fail before time.

Generally it seems that 80 % of the problems in CV joints are caused by a change in the working distance of the side shaft, 8 % by faults or negligence during installation. 8 % come from cracked axle boots which lead to a loss of lubricant, resulting in soiling of the joint. Only the remaining 4 % of all joint failures have been caused by jolts and normal wear and tear of the parts.

**VI. Reference**

- [1] Hibbeler, R. C. (2003), Mechanics of Materials, SI Edition, Prentice Hall, Upper Saddle River, New Jersey.
- [2] Leslie, J. C., Troung, L., Blank, B. and Frick, G., (1996), Composite driveshafts: technology and experience, SAE Special Publications 1203, pp. 43-52, Paper No. 962209.
- [3] Rastogi, N. (2004), Design of composite drive shafts for automotive applications, SAE, Technical Paper Series, 2004-01-0485.
- [4] Jones, R. M., (1999), Mechanics of Composite Materials, 2nd edition, Taylor Francis, Philadelphia.
- [5] Mallick, P. K. (1997), Composite engineering handbook, Marcel Dekker, New York.
- [6] Rangaswamy, T., Vijayarangan, S., Chandrashekar, R. A., Venkatesh, T. V. and Anantharaman, K. (2004), optimal design and analysis of automotive composite drive shaft, International Symposium of Research Students on Materials Science and Engineering, India.