

Failure Analysis of Automotive FWD Flexible Drive Shaft - A review

Anupam Singhal¹, R. K. Mandloi²

¹M.Tech.(Maintenance Engineering and Management) MANIT Bhopal (M.P.)

²Associat Professor (Department of Mechanical Engineering) MANIT Bhopal (M.P.)

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.

Key words: Drive shaft; Constant Velocity joints; Front wheel drive; Transmission system; Failure analyses.

1. 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. [4]

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.

1.1 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. [12]

1.2 Types of Constant Velocity (CV) Joints:

In front wheel drive operation, two universal joints (CV joints) are used for drive a shaft at constant angular velocity with a large misalignment angle. The inner end of the driveshaft has very little misalignment relative to the transmission housing, while the outer end of the driveshaft is attached to the front wheel and must continue to transmit torque whilst turning through angles up to 40 degrees. [9,10]

Constant velocity (CV) joints come in a variety of styles. The different types of joints can be referred to –

- By Position – Inboard or Outboard.

- By Function - Fixed or Plunge.
- By Design – Ball-type or Tripod



Fig. 3 Constant Velocity Joint (The type of joint more commonly used in front wheel drive cars).

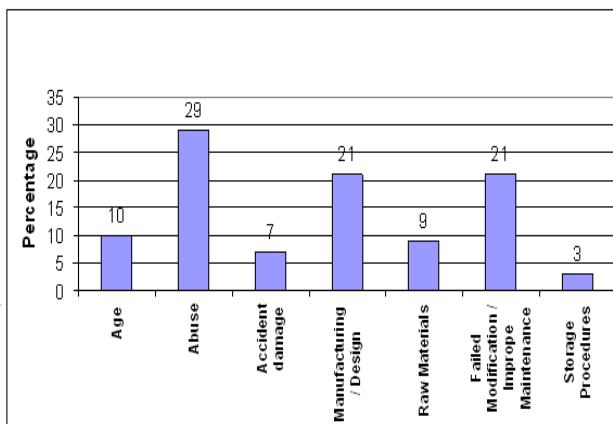
2. Analysis of FWD drive shaft

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.

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



- Misuse or Abuse.
- Road condition.
- Environment condition.
- Improper maintenance.
- Improper material.
- Poor storage condition.[14]

Fig. 4 The Distribution of causes of failure.[3]

2.2 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 etc. [11,13]

2.3 Inspection of drive shaft

When one of the problems outlined above is occurred then the first thing should be done by checking the shaft for damage or being bent, move the shaft, wheels, and other components to check for looseness. Check the joint for sticking while plunging it in and out. When the shaft seems to discoloring then heat may damage the shaft. To inspect the excessive play in wheels pull tire outward at the top and push inward at the bottom. Bearing noise will often increase when the vehicle is turned. When turning the joint up and down, left and right, and in the thrust direction looseness should be minimal.

A failed boot is the most common cause of a failed CV joint so check for cracks, damage or grease leaks, Rusted outer race, inner race, cage and balls, Worn splines, Water, foreign matter or rust deterioration on the joint boot. Also inspect the

ball joints for wear and operating condition. Inspect the dynamic damper for damage or cracking, oil seal for damage, hub for cracks and a defective bearing.[5-8]

3. 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.

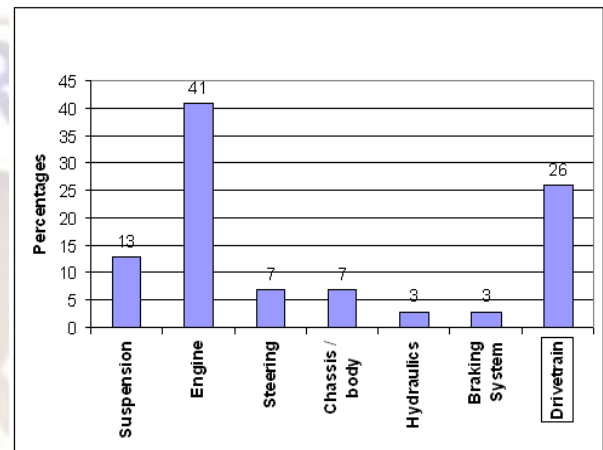


Fig.5 The percentage of failure of various components in automobiles. [3]

4. Conclusion

Each vehicle is designed and engineered by simulating a possible scenario of use. A joint designed and mounted on a city car will be used in a purely urban environment. Overloading shorten the life of drive shaft. When atmospheric temperature too high or too low, the rubber or thermoplastic material (which boots are made of) suffers and a premature failure of the boot occur which leads the joint to be exposed to the external environment, lose grease and consequently deteriorate very quickly. Similarly the use of the vehicle in saline (salty) environments has effects to increase the rate of corrosion that occurs naturally in the presence of normal weathering. This phenomenon often leads to premature degradation of the splines and threads, it is necessary to replace the joint. Taking relatively simple measures, as mention, will greatly improve component reliability without affecting manufacturing costs and prolong the life of components.

References

1. McEvily, A.J, "Metal Failures: Mechanisms, Analysis, Prevention", Wiley, New York (2002), pp. 303-307.
2. ASM (American Society for Metals), "Metals Handbook, Failure Analysis and

- Prevention”, 9th edition, vol. 11, Metals Park, OH (1986) pp. 13–65..
3. Heyes, AM, “Automotive component failures”, Eng Fail Anal, 1998, pp.129–141.
 4. Heisler, H, “Vehicle and engine technology”, 2nd ed, London, SAE International, 1999.
 5. Vogwell, J, “Analysis of a vehicle wheel shaft failure”, Engineering Failure Analysis, 1998, Vol. 5, No. 4, pp. 271-277.
 6. ASM metals handbook, “Fatigue and fracture”, vol. 19, Metals Park (OH), 1996.
 7. Bayrakceken, H, “Failure analysis of an automobile differential pinion shaft”, Engineering Failure Analysis 13 (2006), pp. 1422–1428.
 8. Asi Osman, “Fatigue failure of a rear axle shaft of an automobile”, Engineering Failure Analysis 13 (2006), pp. 1293–1302.
 9. Bayrakceken, H, Tasgetiren, S, Yavuz, I, “Two cases of failure in the power transmission system on vehicles: A universal joint yoke and a drive shaft”, Engineering Failure Analysis 14 (2007), pp. 716–724.
 10. Godec, M, Mandrino, Dj, Jenko, M, “Investigation of the fracture of a car’s drive shaft”, Engineering Failure Analysis 16 (2009), pp. 1252–1261.
 11. Wagner. ER., “Driveline and Driveshaft Arrangements and Constructions, "Universal Joint and Driveshaft Design Manual”, Chapter J, SAEAE-7. 1947, pp. 440.
 12. P. J. Mazziotti, "Universal Joint and Propeller Shaft”, Dana Corporation Bulletin J-1371, October 15, 1954
 13. H. I. F. Evernden, "The Propeller Shaft or Hooke's Coupling and the Cardan Joint, Proceedings of the Institution of Mechanical Engineers”, October, 1949. PP. 5-6.
 14. Halderman, James D, Mitchell, Chase d. (jr.), “Automotive Chassis System”, IInd edition, Prentice-Hall Inc.(1996-2000), pp. 280-289.