Vol. 5, Issue 3 (July - Sept. 2017)
ISSN : 2347 - 8446 (Online)
ISSN : 2347 - 9817 (Print)

Analyzing Vibration in Automotive Drive Shaft and It's Reduction Methodology

P K Kumaresan
Professor Computer Science and Engineering, VMVK Engineering College, (Vinayaka Missions University), Salem, Tamil Nadu, India

Abstract

The paper discusses the automotive drive shaft or propeller shaft vibration problem with using different types of material alternatives as well as to find out vibration using methods like single cardan shaft measurement and double cardan shaft measurement in general to solve the problem of vibration in drive shaft.

The method of using CV (or Constant Velocity) joints are a class of joint which are designed to eliminate the variation in angular velocity that plagues u-joints, thus they are given the name Constant Velocity. The simplest CV joint is simply two u-joints connected end to end, usually the center section is called an H-yoke because of its shape. In this manner, the angular velocity variations of one joint are canceled by the joint on the other end.

I. Introduction

An automotive drive shaft, or propeller shaft, as shown in Fig. 1 transmits power from the engine to the differential gears of rear wheel drive vehicles. The torque transmission capability of the drive shaft for passenger cars, small trucks and vans should be larger than 3500 Nm and the fundamental natural bending frequency of the drive shaft should be higher than 6500 rpm to avoid whirling vibration [l]. The whirling of the drive shaft which is a resonance vibration occurs when the rotational speed is equal to the fundamental natural bending frequency, which is inversely proportional to the square of the shaft length and proportional to the square root of specific stiffness. Since the fundamental natural bending frequency of one-piece drive shafts made of steel or aluminum cannot be higher than 6500 rpm when the length of the drive shaft is longer than 1.0 m, the steel drive shaft is usually manufactured in two pieces. However, the two-piece steel drive shaft has a complex and heavy structure and produces noise and vibrations that are transmitted to the vehicle through a center bearing. [2]

The fundamental natural frequency of the carbon fiber composite drive shaft can be twice as high as that of steel or aluminum because the carbon fiber composite material has more than 4 times the specific stiffness than steel or aluminum PI, which makes it possible to manufacture the drive shaft of passenger cars in one piece [3].

The composite drive shaft has many other benefits such as reduced weight and less noise and vibration. However, the composite drive shaft requires reliable joining of the composite shaft to the steel or aluminum yoke of a universal joint [4], which is often the most difficult task.

In this work, the drive shaft was hybridly manufactured using both carbon fiber-epoxy composite and aluminum, in which the carbon fiber-epoxy composite increases the natural bending frequency and the aluminum sustains the required torque transmission capability. This method eliminates the joining problem between composite and metal because the yoke of a universal joint can be welded to the aluminum shaft or joined using a serration. Also, a preload was given to the aluminum shaft before co-curing the composite to the aluminum haft to reduce the thermal residual stresses.

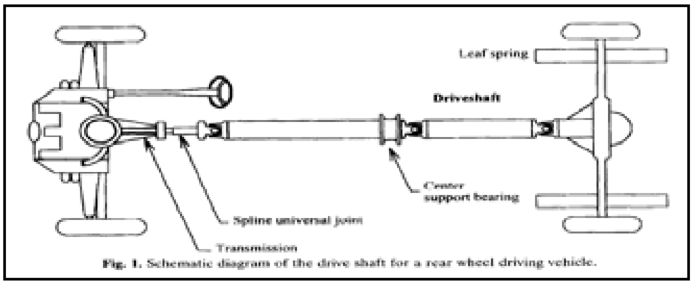

Fig. 1 : Automobile showing Driveshaft

II. Vibration in Drive Shaft

It has been noticed a vibration or rumbling noise when you are driving down the highway? If you have a lot of miles on your car, have modified the suspension or drive train in any way, you may be experiencing driveline vibration.

Ideally want the two ends of a double-ujoint drive shaft within 1-2 degrees of each other for maximum u-joint life and minimum vibration. This is actually the operating angle (under load) and not the angle of the drive shaft to the u-joints themselves (that has its own limit).

Since the rear pinion moves up under acceleration (unless you have anti-wrap control on the axle) ideally you set up the static pinion angle to be 1-2° below the transfer case output flange angle. This way, as the pinion twists up, it comes into a good alignment with the transfer case.

Installed a CV-style rear drive shaft and had to tip the pinion up to point directly at the transfer case, so there a longer shackle works to an advantage. Calculated would need an 8° shim with my 7" (3.5" longer than stock) shackle, but after installing everything, found pinion was about 2° high, so I made a custom 5° shim to place it 1° below the transfer case line.

III. Vibration on Single And Double Cardan Shaft

It is frequently asked question is about drive shafts and angles and so forth, It is required to X" of lift" or "Is Y° shim too much. In general answer to these general questions, rather the right answer is what works for that particular situation. For example, assuming that the driveshaft is aligned properly in a vehicle with stock suspension, if it is lifted with a block or spring lift, then everything should still be lined up, at least with a single-cardan driveshaft. It's like a parallelogram, the angles change, but the sides remain parallel. So the correct answer for how much to shim an axle to correct the driveshaft angles depends on how far off the angle is to begin with.

So, For measuring drivelines and angles at first glance it seems kind of difficult, but some easy techniques that make the job very easy. How you measure the angles depends on the type of driveshaft you have:

- Single Cardan Shaft Measurements
- Double Cardan Shaft Measurements

Assuming a single cardan driveshaft and want to check if the transfer case output and pinion flanges are close to parallel, just measure the distance between the top and bottom of each flange. If the dimensions are equal, the two flanges are parallel. If they are not equal, then each 1/16" difference is equal to 0.9° across the 4" diameter of the flange (which is the size Toyota uses) If 0.9° is too confusing for you, call it 1°, that is probably close enough for small differences. Other makes may use different size flanges and some may not use flanges at all, If no flanges are uses, then an angle finder must be employed to measure the angles Ideally, you would like the upper measurement to be 1/16-1/8" less than the lower measurement for a bit of static "down-angle". Then, as the axle (and pinion) tilt up under load, the angles will approach parallel. While this measurement can be done with the driveshaft in place, it may be easier to do with it off, in order to get more accurate measurements:

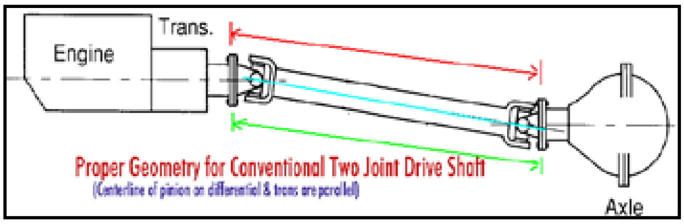

Fig. 2: Conventional Two Joint Drive Shaft

In the above figure, you can see dimension arrow on top of the driveshaft and the other dimension arrow on the bottom of the shaft showing the distance between the driveshaft flanges.

Pardon the crude ASCII art that is supposed to show a typical driveshaft:

```
 FT
-|\
-| \
FB\ \
  \ \
   \ \
    \ \RT
     \ |-
      \|-
      RB
```

The idea is to measure (FrontTop -> RearTop) and (FrontBottom -> RearBottom) If (FT-RT) is equal to (FB-RB) then the angles are parallel Ideally, (FB-RB) should be a bit longer than (FT-RT) at rest.

However, lets angle the two shafts to say 45 degrees. Now, look at the "cross" of the u-joint as it rotates. When the driving side of the cross is horizontal, it's ends are moving at the same speed as the yoke on the driving shaft. However, the driven side of the u-joint is 90 degrees offset from the driving side, but since the u-joint cross is rigid, all 4 ends are moving the same angular velocity, i.e. that of the driving shaft. However, since there is that 45 degree angle between the two shafts, the cross is also angled 45 degrees, meaning the effective length of that side is equal to the sin(45) times it's actual length or 71%. But, since it is moving at same angular velocity, the surface speed; which is equal to the angular velocity times the radius (or length); is now 71% of the speed of the driving shaft; i.e. the driven shaft is turning momentarily at 71% the speed of the driving shaft! Now, turn the driving shaft 90 degrees farther in it's rotation. Now the driving side of the cross is at 45 degrees, so it's effective length is now 71% and the driven side is 100%. Assuming the driving shaft speed is constant, then this means the driven shaft speed is now 1.00/0.71 or 1.41 times (or 141%) faster than the driven shaft. So, if you have the driving shaft turning at say 1000 RPM, the driven shaft will vary from 710 up to 1410 RPM as it rotates, averaging to 1000 RPM. This is what causes a driveshaft to vibrate.

For a double-cardan driveshaft, you really do need to work with angles directly, that is you need to know the angle of the driveshaft itself and of the u-joint at the end opposite the CV joint.

Fig. 3 Pinion Angle: 68°

Fig. 4 Driveshaft Angle: 23°

Above, you can see how It can measured the pinion flange angle, It can clamped a piece of flat bar to the flange and placed the angle finder on it, gauge reads 68° which is equal to 22° from vertical (i.e. 90 - 68 = 22). The driveshaft angle is 23° (from horizontal). The difference in the to angles is 23° - 22° = 1°, meaning the pinion is 1° below the angle of the driveshaft. One point to note is that my driveshaft doesn't really run at 23°, the above pictures and measurements were done on my sloping driveway, its about

ISSN : 2347 - 8446 (Online)
ISSN : 2347 - 9817 (Print)

8°, but it really doesn't matter, you don't need to be on a perfectly flat and level surface to do these measurements. Whatever angle the surface you are on is cancelled out, you only care about the difference of the two angles, not their actual values. If it has a double cardan drive shaft, want the end with the single cardan joint to be at right angles to the drive shaft itself. [6].

IV. Reduction of Vibration Using CV Joints

CV (or Constant Velocity) joints are a class of joint which are designed to eliminate the variation in angular velocity that plagues u-joints, thus they are given the name Constant Velocity. The simplest CV joint is simply two u-joints connected end to end, usually the center section is called an H-yoke because of its shape. In this manner, the angular velocity variations of one joint are canceled by the joint on the other end.

Fig. 5 U – Joint - Constant Velocity Joint

Since there are two joints, the operating angle capacity of the double cardan joint is twice that of a single cardan joint. More complicated CV joints utilize a multi-ball bearing assembly that rides inside a cup-shaped housing that allow the center section to rotate in a different orientation than the outside part. Further variations on CVs allow for "plunge" or in and out travel of the center section relative to the outer section. A combination of the two is often used in FWD applications, where a plunge-type CV is used on the transaxle and a ball bearing CV is used on the outside. The plunge capability allows the drive axle to lengthen and shorten as the suspension travels. The outer CV can handle greater angles to allow for both steering and suspension travel.

A CV joint often requires special lubrication, usually an EP moly grease that is very sticky. On exposed CVs, a flexible boot contains the grease, on internal CVs, like the enclosed Birfield-type joint on front axles, the grease is packed around the joint inside the steering knuckle.

V. Fixing Vibration Problems

If suspect vibration in the rear driveshaft, one way to isolate the cause of the problem is to remove the rear shaft, lock in the front hubs and test drive, assuming your transfer case and system allow this mode of operation. If the vibrations remain, just eliminated the rear shaft as the cause of the problem, its likely to be a bad bearing, bent axle, out of round (or balance) wheel/tire, or something in the engine. If the vibrations go away with the rear shaft removal, then its something in the rear drive train that is the cause, the transfer case output, rear shaft (and center bearing if present), the single and/or double cardan joints, the pinion bearing and rear differential could all be the cause. [6].

If so, you probably want to fix it. How to fix it depends somewhat on what led to the problem in the first place.

VI. Conclusion

1. If your drive shaft is has been damaged off-road (bent or dented) then this can cause vibration as well, a common problem is that the small balancing weights on the shaft can get scraped off on an obstacle.
2. If you have a leaf-spring suspension, then there are more options available. Among the options are shims, rotated spring perches, longer or shorter spring shackles, or driveline changes.
3. For slightly loose joints, try greasing the joint well and see if it (temporarily) fixes the looseness and vibration.

If recently lifted (or lowered) vehicle's suspension by changing springs, adding blocks or spacers, or changed spring shackles, all these can affect the driveline angles, which in turn can lead to vibration.

Reference

[1]. Mallick, P. K., Newman, S., Composite Materials Technology, Hanser Publishers, New York, 1990, Chapter 6.

[2]. Lee, D.G., Kim, KS. and Kwak, Y.K., Manufacturing of a SCARA-type direct-drive robot with graphite/ epoxy composite materials. Roboiica 1991, 9, 219-229.

[3]. Kulkami, S. V., Zweben, C. H. and Pipes, R. B., CompositeMaterials in the Automobile Zndu&y, The ASME winter annual meeting, San Francisco, California, December lo-15,1978.

[4]. Schmelz, F., Seherr-Thoss, C. and Aucktor, E., Universal Joints and Driveshafs, Chap. 4, Springer-Verlag, Berlin, 1992. Reimpell, J. and Stoll, H., The Automotive Chassis

[5]. Durk Hyun Cho, Dai Gil Lee, manufacture of one-piece automotive drive shafts with aluminum and composite materials.

[6]. www.4crawler.com and http://www.drive-lines.com