



Driveline

Deliverance

We tap driveshaft guru Tom Wood for the real skinny on Jeep driveshaft upgrades, fitment and performance

by Tom Wood and the J Rats

Whether you are upgrading your Jeep's suspension, swapping axles, changing trannies or modifying your transfer case, one component of your Jeep almost always demands attention—the driveshaft. It's the critical link in your driveline, and a sensitive one at that. A little off here, a little off there, and if you're not careful, you could find yourself in big trouble somewhere you can least afford it.

Proper driveshaft fitment is an arcane science to many folks, and little wonder. Often Jeep enthusiasts rely on "close enough" guessing and good 'ol fashioned Kentucky windage to get their driveshafts fitted following a suspension upgrade or other driveline modification. The results are sometimes less than predictable.

To help clear up some of the confusion, we decided to pose the questions you have to the No. 1 name in Jeep driveshafts—Tom Wood of Tom Wood's Custom Drive Shafts.

Let's start with the most basic scenario. Assume a Jeep owner maintains his stock suspension components and the only modification is a slight upgrade in tire size. The Jeep sees daily driving use and occasional moderate-to-difficult off-road driving (given trail ratings of easy, moderate, difficult and extreme). What, if any, driveshaft modifications would you suggest?

Stock driveshafts are typically strong enough in most of these scenarios. It seems to be that how you drive in these situations is more important than where you drive. If you're climbing a hill and the wheels start to bounce hard, is your answer more gas or to back up and try a different line? The usual failure of the driveshaft in these situations is twisting of the tube. A stock CJ rear driveshaft is two inches in diameter and .083 inches in the wall thickness. It is also a less-expensive cold-rolled electric-welded (C.R.E.W.) tube. The front driveshaft is a bit thicker at .120 inches, but only 1-1/4 inches in diameter. When push comes to shove, these driveshafts are known for twisting or bending.

For practical purposes we can call the YJ, TJ, XJ and ZJ the same since they are all similar in construction, just different lengths. The rear driveshafts are made with a 2.5-inch diameter tube and a .083-inch wall thickness. Again, this tube is the C.R.E.W. type. Having a bit larger diameter and a relatively thin wall thickness, they seem to be susceptible to rock damage more than a heavier wall tube. For most of these applications, if we build a new driveshaft, we will build it with a 2-inch diameter, .120-inch wall thickness and use a drawn over mandrel (D.O.M.) tube. Size for size the D.O.M. tube will have nearly double the yield and tensile strength of a comparably sized C.R.E.W. tube. It is really a bit thicker than most frame rails and seems to hold up against the

rocks much better than the thinner tubes. Longer wheelbase vehicles (such as Cherokees) tend to have a few more problems with broken or damaged driveshafts than would a shorter (Wrangler) application. I think a lot of this is due to the increased exposure of the driveshaft and the added weight of the vehicle.

Most people do as I probably would—wait until the old driveshaft becomes unusable due to damage, vehicle modifications or is just worn out before replacing it with a better driveshaft.

Moving to the next level, a Jeep owner installs a modest 2- to 2.5-inch suspension lift and jumps the wheel and tire package a couple of notches. Does the driveshaft become an area of concern at this point, and if so, what are the problem spots?

The answer here seems to be more subjective in nature than anything else. There is no hard and fast line that you cross. I often refer to things as a “sliding grey scale.” There is black on one side, white on the other and a wide band of grey in the middle.

What the owner expects in terms of longevity, smoothness of operation, and where and how they intend to drive are all factors. If it is simply an off-road-only vehicle, seldom seeing sustained high-speed use and, when it does, you don’t mind a little vibration, the same thoughts would apply as to an unmodified suspension as outlined above.

Now, let’s say you do care how smooth things run because this is a daily commute vehicle and you want to be able to jump in it and drive the freeway for longer distances. You are now in the area where you should at least consider and budget for a different type of driveshaft. Most of the time I will tell people to go ahead and install their lift (if it’s in this range) and see what happens. Remember the subjective part? After the lift is installed they will know if the increased amount of vibration is livable for them. In a worst case, any problems of length or vibrations should not be so severe as to make the vehicle undrivable (for the near term, anyway).

You would think that in shorter wheelbase vehicles the need for a different type of driveshaft should come into play sooner



Front is a double cardan shaft with a conventional two-joint shaft in back. A reverse slip driveshaft (not shown) will have the slip yoke at one end. The reverse slip is the type of shaft used with the OE 231 transfer case.

than would a longer wheelbase vehicle. Theoretically, this would be correct, since the same amount of lift with a longer driveshaft will affect the angles less than it would on a shorter driveshaft. But there are a couple of other factors to look at.

With a CJ, YJ or TJ, the owner may think “it’s just a Jeep” and it never did ride that smooth to begin with. On the other hand, the Cherokees, and especially the Grand Cherokee, can be a pretty nice ride (again, the subjective part). Vibrations that come into play on these vehicles tend to be more noticeable to the driver. Keep in mind, too, that on the Cherokee applications there are no frame rails that would tend to stiffen the vehicle. I also believe that the box-shaped construction of the body tends to resonate more freely than would the open box of other Jeeps. Either would make it more susceptible to noticeable vibrations.

Despite the various handling issues involved, many folks go for the 4- to 6-inch suspension lifts and mondo wheel and tire combos for their daily driver/weekend warrior rigs. Driveshaft modification certainly becomes an issue here. What are those issues and what are your recommendations for solving them?

I talk to a lot of people who claim to have put on large amounts of lift and claim “they never had a problem.” But then, if they never had a problem, why would they be calling? Some people will drive down the road until their driveshaft falls out and, with others, if it doesn’t ride like a sofa, they’re unhappy. My personal thoughts on this are, if you are in this lift range and haven’t done anything to address your driveshaft issues, you’re asking for trouble.

(Right) A typical double cardan shaft. The double cardan joint is at the bottom, with a conventional U-joint at the top.



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With any Jeep vehicle in this lift range, I suggest running a double cardan (CV) driveshaft. I'll go off on a bit of a tangent here, but I see no better time to explain something.

A double cardan driveshaft is really what we are speaking about. It will have two universal joints at the transfer case end and a single joint at the differential end. It does not actually deliver a true constant velocity as would a true CV. When referring to the double cardan driveshaft as a CV, it is actually a misnomer. A true CV will have a round housing with a cage and balls on the inside. This is exactly as used on almost every front-wheel drive axle half-shaft. There are some applications that do use a true CV in the driveshaft, most notably the new JK Wrangler. I'm not one to argue with the world and will often refer to the double cardan as a CV (like most people).



This illustration shows the proper geometry for a driveshaft featuring a double cardan joint and conventional U-joint.

Whenever installing a double cardan driveshaft it is important to position the differential to attain minimal joint angle at the differential end of the driveshaft (we'll get into the reasons later). Admittedly, "minimal" is an ambiguous term. How much is allowable depends on what you expect and the type of suspension you have. Spicer suggests a minimum of 1/2 degree and a maximum of 1-1/2 degree. If you shoot for the middle (by their recommendation), this leaves you 1/2 degree for a margin of error. This works great on a drawing board, but it's not too practical in the real world. I generally suggest 1 to 3 degrees. If you have a leaf spring suspension, the differential will wrap under load. If you have a coil spring suspension, there will be a lot less wrap, but you

will still have some because of flexing of the control arms and the resiliency of the bushings.

To define this minimal joint angle a little better, I suggest that with a leaf spring suspension you should leave a net joint angle of 1 to 3 degrees, and with a coil spring suspension 1 to 2 degrees. Keep in mind that you want to leave the pinion a little down rather than up.

To restate this, I'll give an example. If the slope of the driveshaft is 15 degrees, leave the slope of the pinion at 12 to 14 degrees with the leaf spring suspension and 13 to 14 degrees for a coil spring suspension. I want to emphasize: *This is an example only; your exact settings will probably be different.*

On a CJ application, installing the double cardan driveshaft is easy. You simply need to change the rear output yoke on the transfer case by removing the nut and washer that holds the old yoke on. This nut is in the center of the output yoke, and you will probably want to have an impact wrench available to change this. The new yoke will be the same length as your old yoke, so changing this will not affect the length of the driveshaft. The reason it needs to be changed is the double cardan driveshaft installs with bolts that pass through from the transfer case side of the yoke and screw into the driveshaft. The bolt holes need to be in the correct location to do this. They are not on a U-bolt or strap-and-bolt type yoke.

With newer Jeeps that run the 231 or 242 transfer case, installing a double cardan driveshaft will require a modification to the transfer case (if you want to do it right)—commonly called Slip Yoke Eliminators (SYE), Fixed Yoke Kits or Tail Shaft Conversions.

I will often refer to these as Slip Yoke Eliminators, but the truth is they don't really eliminate a slip yoke. You always need to have some provision for compression and extension of the driveshaft (slip yoke). This is to allow for the different lengths between the transfer case at each point as the suspension moves through its range of travel.

With the 207, 231, 242, 247 and 249 transfer cases this provision for compression and extension of the driveshaft is a



The slip joint in a driveshaft (left) is designed to accommodate changes in shaft "stroke" due to suspension and chassis flexing. As with the greasable U-joints (right), the slip joint must also be liberally greased to ensure proper operation.

function of the output on the transfer case and the driveshaft. These types are called reverse slip driveshafts. After modifying the transfer case, the provision for compression and extension becomes a function of the driveshaft only—the transfer case would then have a fixed yoke on the output.

Suspension lifts used to be all about increasing axle-to-chassis distance. Now, with long-travel suspension systems being all the rage, there are even more variables influencing suspension dynamics, further complicating the driveshaft equation. What are these issues and how do you address them?

One of the biggest problems people have with huge amounts of lift and/or extremely flexible suspensions is a binding problem under axle droop. On a rear driveshaft, installing the double cardan driveshaft will generally help. This is not so much because the double cardan driveshaft will flex more than a conventional two-joint shaft but the combined effect of pitching the differential upward, which lessens the net joint angle at the transfer case end (a lower starting point equals more droop on the differential prior to bind).

Typically a 1310 series (the most common Jeep size) driveshaft will flex to about 30 degrees prior to binding. If you need to have more than this, there are some things that can be done to the parts prior to assembly that will normally allow for about 35 degrees of flexibility to the CV before binding.

Doing this will allow the most flexibility possible. It may be that you still experience a binding problem in certain circumstances. After installation of the driveshaft at the transfer case end, I suggest the following test. Jack up the vehicle and let the suspension hang freely. Check to make sure the driveshaft will connect to the pinion and still rotate by hand with no binding. If you do have a binding problem at this point, try configuring a single limit strap directly over the center of the differential. This will still allow for a near full-wheel articulation, but prevent the entire differential from dropping to the point where you would experience a binding problem with the driveshaft.

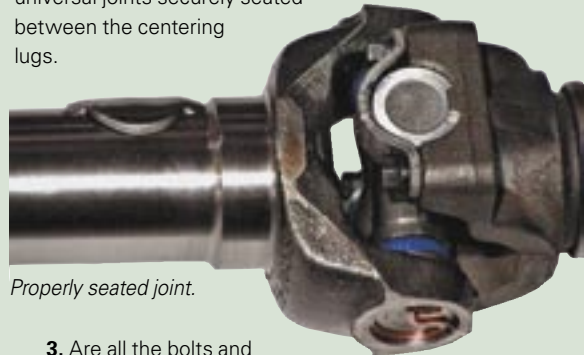
Pitching the differential to run a double cardan driveshaft on the rear is easy. It can be done with adjustable control arms (coil springs), shims or rewelding the spring perches (leaf springs). On the front, though, it becomes more problematic. This is because unless you cut and reweld the axle tubes, anything you do to correct for driveshaft angles will adversely effect the steering caster.

With a CJ application, because it has locking hubs and is not normally used for high speed with the front end engaged, the front driveshaft is usually a non-issue. With a YJ and the disconnect axle, the front driveshaft tends to not be an issue, either. However, if a non-selectable locker is installed in a YJ and the owner wants the smoothest ride, we generally suggest converting to a double cardan driveshaft, which is the same type as the TJ, XJ and some ZJs will use from the factory. Oddly enough, on most TJ and XJ applications, the length or stroke of the stock driveshaft is OK after lifting the vehicle. I believe the reasons for this are that the driveshaft is so long to begin with the lifts will usually pull the front differential rearward somewhat (this counteracts the

Tom Wood's Top Driveshaft Maintenance Tips

1. Paramount is to make sure you have the right type of driveshaft for your application before you ever go out on the trail.

2. Make sure the driveshaft is properly installed with the universal joints securely seated between the centering lugs.



Properly seated joint.

3. Are all the bolts and nuts tight? I suggest a thread-locking compound such as Loctite on all threads. I also suggest that it has a temperature rating to about 250 degrees.

4. Double-check that the driveshaft has enough stroke and flexibility through its entire range of motion.

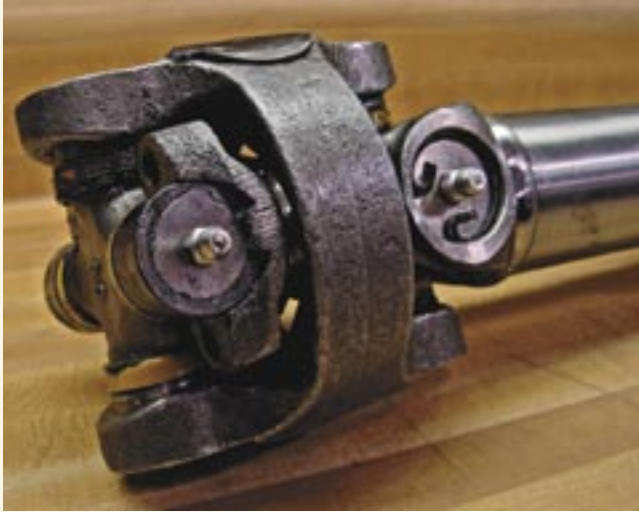
5. Check for worn or loose components. With the vehicle in neutral, try to twist or move the components laterally. Any motion, which can be detected independent of its mating part, is too much. Rust-colored grease or film around the seals is a good indicator that the parts have begun to rust and fail. Greasing may temporarily eliminate a squeak, but it is not a fix for the problem. Replace any loose, worn out or damaged parts as necessary.

6. Look for visible signs of damage, like dents or a tube that is beginning to twist. A dented tube will be weaker than a nice straight, round tube. A tube that has started to twist will usually have a circumferential crack in the paint or surface oxide next to the weld.

7. Proper greasing is important. I actually suggest this be done after your four-wheeling trip but before you expect any sustained high-speed use of the vehicle. This is because dirt, water and crud can enter past the seals while you're out 'wheeling. If allowed to stay in place, debris can promote the corrosion that causes the parts to fail. When greasing, it is important to pump grease until you see clean grease purge out past *all* the seals on the universal joints. When greasing a slip yoke and spline stub, make sure grease flows past the wearing surfaces.

Doing this will flush contaminants out and away from the parts you're looking to maintain. Now is also a good time to recheck those things as outlined in points 3, 5 and 6. By addressing these issues now you'll have time to take corrective measures and be better prepared for the next time you go out 'wheeling.

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Close-up of a typical double cardan joint.

expected length change) and that with many applications the front driveshaft actually gets shorter as the suspension drops.

With a Cherokee application, vibrations that come into play from the front driveshaft can be a tough nut to crack. Without the benefit of a custom front differential (high pinion and/or locking hubs), it may require what we call a multiple double cardan driveshaft. This would have a double cardan at each end of the driveshaft. Even with this you may not be able to attain the luxury ride that the vehicle had from the factory.

With binding problems that arise from having extreme suspension travel, such as those encountered with a shackle reversal system in combination with buggy springs, longer shackles or revolver shackles, we have our “Super-Flex” universal joint. With this universal joint the trunnions (journals) are offset, which places the yoke ears 1/4-inch farther apart. In turn, this allows for 10 degrees more flexibility through the driveshaft before it binds. It is important to note, though, that this offset causes the driveshaft to run through an elliptical path. The greater the angle, the more eccentric the driveshaft will run. It’s really a lot like having a bent driveshaft. You certainly wouldn’t want to use this in anything other than a low-speed application, like a front driveshaft with locking hubs or an off-road-only crawler.

The stroke of the driveshaft, or the amount that it can effectively compress and extend, can also become an issue with highly modified suspensions. Especially so on the front driveshaft. On most rear driveshafts, stroke is not much of a problem. This is because the driveshaft and the suspension travel through near the same arc, and as the suspension moves upward, it also moves rearward. These things counteract each other and yield a fairly stable length on the driveshaft.

The front driveshaft can be another story, though—especially with a shackle reversal system in combination with buggy springs, longer shackles or revolver shackles. In this situation the things that affect the length of the driveshaft work in tandem. As the suspension drops, the differential also moves forward, and vice

versa. If these things apply to you, we suggest you measure for length at the static ride height, full suspension droop and full compression. Even with this, some “fudge” factor will need to be allowed for. For example, when you’re climbing a hill, the front end wants to walk away from the vehicle. The pinion will also dive toward the ground, and if the suspension drops (usually when you crest the hill), the driveshaft will actually get longer than you can measure at full suspension droop.

Aside from installing a different length driveshaft to accommodate a suspension lift, longer travel suspension or other driveline modifications that may lengthen or shorten the required driveshaft length compared to stock, what are some other reasons for driveshaft upgrading?

Strength would probably be the No. 1 reason to upgrade if these other factors were not a consideration. A good number of people will have that “stock-ish” Jeep with bigger tires and really want go out and play hard. It can take some of the joy out of your day if you’re crawling in the mud or rocks to have to stop and remove a twisted up stock driveshaft. Taking care of this ahead of time is recommended.

Assuming an otherwise stock suspension and driveline configuration, what, if any, are the driveshaft weak points, what are your recommended upgrades and why?

Beyond the tube, as previously discussed, I’d have to say it would be the conversion of the strap-and-bolt attachment of the universal joint to the transfer case and/or differential yoke(s) to a U-bolt type yoke. The bolts with the strap-and-bolt attachment are only 1/4 inch in diameter and are somewhat prone to breaking. With a U-bolt type yoke, the U-bolt is 5/16-inch stock, which tends to hold up much better.



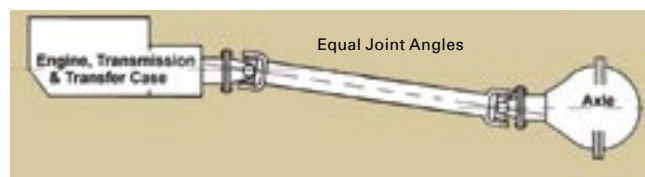
U-joints that use straps and bolts (top) are weaker than the more conventional U-bolts.

What are the ideal driveshaft-to-pinion angles or settings?

We touched on this briefly regarding the joint angle for the

double cardan type driveshaft and the universal joint at the differential end. If you're looking for "ideal," it may never happen in a lifted Jeep since some applications run at only 3 degrees from the factory. If we change the goal from ideal to acceptable and mechanically sound, I do have some general guidelines that I share and use on a daily basis.

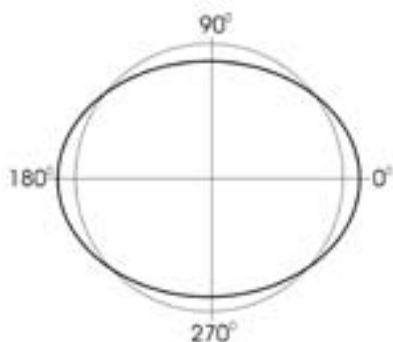
With a conventional two-joint driveshaft you need to keep the output of the transfer case and the pinion parallel within 1 degree (again, better to have the pinion a little down for axle wrap). In relationship to either, the driveshaft should be running at absolutely no greater than 15 degrees. This is a pushed limit and should be held much closer (probably less than half of this) in vehicles that are expected to run reasonably smooth and vibration free on the highway.



Proper geometry for a conventional two-joint driveshaft.

To understand why there is an upper limit, we need to know two simple concepts of a universal joint's operation. The first being, as the universal joint runs through an angle, the path of the bearing caps is actually elliptical. Because the universal joint runs through each of the quadrants of this path in the same amount of time, the driveshaft will speed up and slow down two times per revolution. If the second universal joint angle is equal to the first, the second joint will be decelerating at the same time and near the same rate that the first universal joint is accelerating, netting a smooth power flow to the differential (within limits).

Second to this is that the rates of acceleration and deceleration are not reciprocal numbers. That is, the second universal joint does not decelerate at exactly the same rate as the first universal joint is accelerating. The rates of velocity change are a function of the cosine of the angle. Multiply by the cosine of the angle to get minimum velocity, and divide by the cosine of the angle to get the maximum velocity.



Here's a diagram that clearly illustrates the elliptical path of U-joints.

To better understand this, imagine that the surface speed, or mean driving velocity, of the universal joint on the transfer case end is 1,000 feet per minute and the cosine of the angle is .900. Then the minimum velocity is 900 feet per minute, but the maximum velocity would be 1,111.11 feet per minute. We now have a difference of an 11.11 feet-per-minute variable that has to be

accounted for somewhere. So where does this motion go? It quite simply translates into a torsional vibration. That is the building and releasing of torque two times per revolution.

Minimal variables can be taken up with internal clearances between the driveshaft components. Beyond that, it will transmit directly through to the differential. This is why, with bad joint angles, you will feel that shudder under higher torque situations. When you get up to speed and there is less torque, the shudder will usually diminish. This is because there is a little more "float" between the drive and coast side of the gearing to allow for this non-uniform motion. If the joint angles are too far out there, you can expect a fair amount of gear clatter under light- to no-load operation. This is because you no longer have the free space between the gears, but the gears will be slapping back and forth between the drive and coast sides. This happens throughout the entire powertrain—transmission, transfer case, driveshaft and differential, or anywhere there are internal clearances to allow it to happen. You're not imagining things if you think "this can't be good."

How much "play" is acceptable in the driveshaft-to-pinion angles

Measuring Proper Driveshaft Length

Which way is best could be a matter of point of view. We like the method we use because it has some standardization, and it seems to be easily communicated to the customer. I think it is better to measure from the vehicle to determine the correct driveshaft length. If you measure your old driveshaft (uninstalled) and it was an incorrect length, your new driveshaft would, more than likely, have the same problem.

Most Jeep applications will have a fixed yoke on the output of the transfer case, or a reverse slip and a fixed yoke on the differential. It is important to have a measurement that will be correlating between fixed points on the transfer case, differential and driveshaft.



Here you can see the points for measuring driveshaft length, depending on your yoke configuration.

If you have the fixed yoke on the transfer case and at the differential end, measure from the flat face of one yoke to the flat face of the other. This will be the same as measuring the centerline of one universal joint to the centerline of the other universal joint.

With a reverse slip driveshaft we suggest measuring from the end of the output shaft (or the outer lip of the seal) on the transfer case to the face of the pinion yoke (centerline of joint) at the differential end.

These measurements should be taken with the suspension normally loaded. Again, if you have an extremely flexible suspension, you may want to measure at full suspension compression and full axle droop, too.

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from a Jeep's OE setting? For example, if a TJ owner installed a 2.5-inch suspension lift, how many degrees one way or the other from the stock setting would be acceptable before driveline vibration, excessive wear or component damage become problematic?

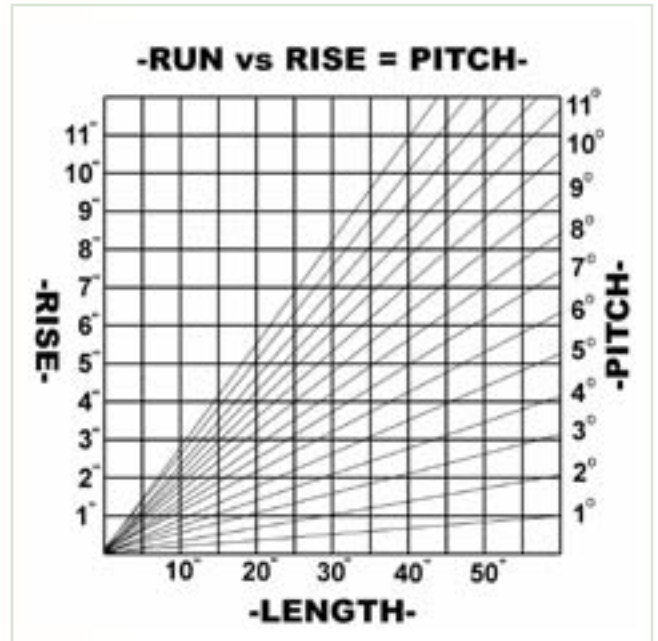
This gets back again to the subjective nature of what is acceptable, which tends to vary from person to person. It's a complicated formula, and I won't bore you with the math, but by my calculations, I believe that the hard upper limit for a conventional two-joint driveshaft, with equal angles at each end of the driveshaft, would be 15 degrees. At 15 degrees the differences in rates and distances traveled through the universal joint are .0015-inch per occurrence. At this point I believe there are enough clearances through the universal joints, the slip yoke in the driveshaft and enough modulus of elasticity with the components to accommodate this. Beyond this point the components must flex and return to shape two times per revolution. Over time this repeated flexing will cause what is known as a fatigue failure. In this scenario the universal joints or other components will fail (most likely break) under a nominal load and with no advance notice.

With a double cardan driveshaft, the single joint end would be as outlined previously. At the double cardan end (transfer case end) of the driveshaft, factory specifications are usually about 15 degrees maximum. I believe this can be pushed to about 24 to 25 degrees.

I base this upper limit on a number of things. First is the life expectancy of the double cardan itself. With the double cardan driveshaft there is a center pivot point. This center pivot point is usually a ball-shaped element that flexes by riding against a seat. With no joint angle there is no sliding contact (wear) between the ball and the seat. As the net operating angle of the double cardan increases, so does the amount of sliding contact. Beyond the additional wear due to this increased sliding contact, there will be increased heat.

If you will, remember the hard upper limit of 15 degrees for the conventional two-joint design driveshaft. This will be a bit easier to understand. A double cardan works pretty much the same except the angles are equal because they are intersecting (at the center pivot point) rather than being equal because of parallel driving and driven shafts. Keep in mind that the double cardan does not deliver a true constant velocity. If the double cardan is running at 24 degrees, each universal joint in the double cardan assembly is actually working at 12 degrees. Twelve degrees is near what I would call the "pushed limit" for a universal joint.

The final reason for the upper limit of a double cardan is the flexibility issue. Again, most double cardan driveshafts will flex to about 30 degrees prior to binding. If you are starting at 24 degrees, you then have an additional 6 degrees before you have a binding problem. Six degrees of additional flex on a 20-inch driveshaft correlates to about 2-1/4 inches of droop on the differential before you have the binding problem. This simple run and rise chart can help determine how much droop you can expect before you get a



binding problem, or how much that additional lift will affect the slope of the driveshaft.

What are the five most common driveshaft problems customers come to you with, and what are the solutions you recommend?

1. Certainly has to be vibrations due to lifts. The most common solution is a double cardan driveshaft.
2. Length and/or which driveshaft type is correct for a given application due to vehicle modifications such as engine, transmission, transfer case or differential swaps. We always talk (sometimes at great length) about what the customer wants and expects from the vehicle, along with getting the geometry information for the driveshaft so we can make sure the driveshaft will meet all the mechanical requirements.
3. Strength issues. The most common solution is simply better parts. After that the next option would be to upgrade/increase the size of the components for larger/stronger universal joints.
4. The stroke or range of travel of the driveshaft by either flexibility or the length of the driveshaft through its range of motion. Flexibility issues are usually addressed with conversion to a double cardan driveshaft, a different type of driveshaft that gives more flexibility or, as a last resort, our "Super-Flex" universal joints.



Sometimes it's tough to get a straight driveshaft under a modified Jeep without interference or clearance issues. In such instances, a custom two-piece shaft is the ticket.

Measuring Pinion Angle

For clarity purposes, let's define the slope as the relationship of a single line or plane in relationship to the horizon, and an angle as the relationship of one slope to another. Of course, what we are really concerned about would be the net angle between the driveshaft and the transfer case or pinion. It is possible (but difficult) to get a direct angle reading using a machinist protractor, but I believe it's a lot easier to measure the slopes of each component and then determine the net angles with a little addition or subtraction.



Add a string and plumb bob to an inexpensive protractor and you have a perfectly suitable tool for measuring driveshaft slope.

You will need some sort of tool to measure the slopes. There are a number of inexpensive ways this can be done. You could purchase an "angle finder" at most hardware stores (about \$8 to \$10). It will have at least one flat base and a circular face, graduation around its perimeter and a weighted plumb bob in the center. Or you could get a plastic protractor like you may have used in junior high school. You'll need to have one with a flat base and a hole at the zero point. If you tie a short piece of thread or dental floss (six inches or so) through the hole at the zero point and a small nut at the other end to serve as a weighted plumb bob, when placing the flat base of the protractor against a flat surface the thread-line will indicate the slope.

Any flat, machined surface on your engine, transmission, transfer case or differential will be either perpendicular or parallel to the centerline.

You can place the protractor against the driveshaft to determine its slope. If you have no driveshaft in the vehicle, simply tie a stringline from the output yoke on the transfer case to the pinion yoke on the differential. This will simulate the slope of the driveshaft.

My experience has shown that the easiest way to determine the slope of the pinion is by measuring off of the flat, machined surface on the inspection cover side of the differential. This surface will be just to the right or left of the inspection cover and will be perpendicular to the centerline of the pinion. You could also measure off the flat surface of the pinion yoke.

As a final note on this subject, I am often asked; "Does the vehicle need to be parked on level ground"? The answer to this is, no. Since the angle is what we are trying to determine, we only need to get the relationship of one part to another.



An angle finder can be placed on the transmission pan or any other machined flat surface of the engine, tranny, diff or transfer case that's parallel or perpendicular to the centerline.



Tom Wood prefers to measure pinion slope by placing the angle finder on this machined portion of the axle housing. Several angle finders, ranging from dirt cheap to quite pricey, will do the job.



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5. Clearance issues, such as those encountered when running an automatic transmission with a Dana transfer case. In these situations there is minimal space to run the driveshaft. This often requires using a specialty driveshaft with a small diameter to clear the corner of the transmission pan or, in some cases, a two-piece driveshaft to go around the corner.

What is the purpose of a CV, or double cardan joint, conversion?

Simply stated, to transmit torque more smoothly through greater angles than with a conventional single joint.

Does a double cardan allow you to, within limits, forgo pitching pinion angles? In other words, can you get away with greater operating angles with a CV joint than you can with a conventional U-joint, or is this a myth?

It's a myth. A double cardan or a conventional universal joint will usually incur a binding problem at about 30 degrees. A double

cardan will transmit torque through greater angles more smoothly than will a conventional single joint. Unless you pitch the differential properly (to avoid the acceleration and deceleration of the single U-joint), the double cardan driveshaft can create a vibration problem.

Talk for a minute about conventional U-joints. Most factory joints are small and have no grease fittings. Beefier joints can be purchased that are both stronger and are greasable. At what point in terms of suspension/driveline upgrades and/or trail difficulty is the switch to heavy-duty greasable U-joints recommended?

We could write pages and pages on this subject alone. There are legitimate arguments that a non-greasable universal joint is actually stronger than a greasable universal joint. It is my opinion that the location and orientation of the grease fitting can substantially reduce or eliminate this strength difference. In all but the most extreme circumstances, I believe that a good quality universal joint is adequately rated for most Jeep applications. In the extreme cases, larger/stronger universal joints are in order. To

Tom Wood's Custom Drive Shafts...The Expert Source



I grew up in one of the poorer suburbs of Salt Lake City, Utah. Pretty much the nerd...did well in school, honor roll student, and I especially liked the sciences. After graduating from high school in 1976 I attended a couple quarters at the local technical college studying auto mechanics. It really wasn't for me. After that, I kicked around for a while working various jobs and looking to meet girls.

I was about 19 years old when I started working at a local driveline shop in 1978 or '79. At the time it was more or less a "McJob." In my mind I thought, what kind of "bohunk" place could this be since I couldn't remember my father changing a universal joint. Boy, was I wrong. Never was there a day that there wasn't more than enough to do. With the exception of about 18 months when I worked for an industrial power transmission supply company, I worked at the local driveline shop

building driveshafts for nearly 20 years. Adding this to the eight years I've been in business for myself, I see that I've been in the business for nearly 28 years. My, how time flies.

During the years with the other company, I had built a reputation for the company and myself. I had always had the pipe dream of being in business, and as things so often happen in corporate America, office politics were the underlying cause for my decision to leave and start my own company.

In 1999 I laid my neck on the line and opened up shop, hoping to feed my family. I rented a small (less than 900 square feet) shop in the low-rent area of Ogden, Utah. Not having much money, I cajoled some suppliers to provide a minimal inventory on favorable terms and built most of my own equipment. I was now in business for myself.

Having only limited finances and inventory, I knew I couldn't be the company that does all types of driveshafts. I decided to be one of the few driveshaft companies that truly specializes in one product. Since I had established a reputation in the four-wheel drive market and this was something I knew about and liked, 4X4 driveshafts are all we do.

I was my only employee for about a year. My son would come in after school to package and ship driveshafts. Business grew and after about one year I hired my first employee. At the end of the next year I had four employees. It was time to move out of the small rented building, so we moved our business in 2001 to our current location with 2,400 square feet of shop space and an equal amount of warehouse space. The increase in business dictated new high-efficiency equipment, which we think is among the best anywhere. We currently have nine on the payroll. I'm still feeding the family. It has just become bigger.

do this, though, requires changing the yoke on the transfer case and differential, along with a larger (more expensive) driveshaft. I think it is important to consider the strength of the mating components. With many applications, it's easy to make a driveshaft that is stronger than the output of the transfer case. But if push comes to shove, what would you rather change: a universal joint or an output shaft on the transfer case?

With the exception of a highway-only (read: clean environment) vehicle, I believe a greaseable universal joint is the best way to go. The reason for this is that the sealing element on the universal joint is a sliding contact. With a sliding contact there is absolutely no way you can ensure that all the grease stays where it belongs and all the contaminants stay out of the joint. With a greaseable joint you have the ability to flush out the crud that will enter past the seals.

Serious off-road Jeep enthusiasts are all about increasing low-end torque output, horsepower and gearing. How does increased grunt and torque application affect driveshaft performance and durability, and what are your observations in this area?

I'll call these observations and personal thoughts based on the practical and available engineering information.

To begin with it is important to understand the difference between torque and horsepower. Horsepower (hp) is the amount of energy required to do a given amount of work in a specific amount of time. We could go on for a long time explaining the formulas, but for practical purposes torque is what we are really concerned with when building the driveshaft.

Most people have a good idea how much horsepower their engine develops, or at least peak horsepower at a specific RPM, but they really don't know how much torque they will be transmitting through the various points of the drivetrain. Torque is, quite simply, twisting effort, usually expressed as pound/feet (lbs-ft).

Universal joints and the rest of your drivetrain are rated for torque. Torque is a function of input horsepower and RPM. Input horsepower will continually vary through the speed range of the engine, and it would be unusual to run an engine in an off-road situation where it develops peak horsepower. Without surrounding ourselves with horsepower curve charts for a particular engine, it would be impossible to exactly determine torque delivered through the drivetrain.

Here's the math: torque = hp x 5252 /rpm. For the sake of simplicity let's just say the engine delivers 200 hp @ 3,000 rpm. The torque at the flywheel would then be 114 lbs-ft. Now let's say you have a gear reduction through the transmission of 3:1 and a 2.5:1 ratio through the transfer case. In this situation, the output on the transfer case would be turning at only 400 rpm. Using the same formula, the torque at the output of the transfer case now increases to a whopping 2,626 lbs-ft.

Now if we multiply this number by the differential gear ratio, we can determine how much torque you're putting through the axles. For example, if you have a 4:10 ratio differential and the same numbers as above, you could theoretically be putting 10,766 lbs-ft of torque to the ground. A key word here is "theoretical" since, short of bolting the wheels to the ground, you will get wheel

slip well before you ever reach this point. We also hope that you're not really wedged between the rocks and dumping the clutch while in first gear, low range and 3,000 rpm on the engine. If you are, please have the courtesy to let anyone standing nearby to get away from the vehicle because parts are going to fly.

To give an idea of what your stock and aftermarket components are capable of you need to have some idea of the torque rating of the various universal joint sizes. Keep in mind that the following is based on published information from a major driveshaft component manufacturer and is for the universal joints themselves. The strength of the related components may be greater or less than those shown. There will also be considerable variables from manufacturer to manufacturer.

Under a load, all the parts in your drivetrain will flex and distort somewhat. The greater the load, the more they will flex and

TD= Tire Diameter in Inches
 DR= Differential Ratio
 DS= Drive shaft RPM @ 60 MPH

$\left(\frac{20,168}{TD}\right) \times DR = DS @ 60 MPH$

Drive shaft RPM @ 60 MPH X 1.25 = Drive shaft RPM @ 75 MPH
 Drive shaft RPM @ 60 MPH X 1.50 = Drive shaft RPM @ 90 MPH

Example using 33" tire diameter & 4.10 ratio differential:
 20,168 / 33 = 611.15
 611.15 X 4.10 = 2,505 = Drive shaft RPM @ 60 MPH
 2,505 (DS RPM @ 60 MPH) X 1.25 = DS RPM @ 75 MPH (3,131)
 2,505 (DS RPM @ 60 MPH) X 1.50 = DS RPM @ 90 MPH (3,757)

Driveshaft rpm calculator

distort. Once a component has flexed to the point where it will not return to its original shape when unloaded, it has been stressed beyond its minimum elastic limit. The numbers expressed here are a minimum elastic limit and not a designed operating load.

A 1310 series, which is the absolute most common Jeep universal joint, has a minimum elastic limit of 1,600 lbs-ft torque. The next practical size to upgrade to would be a 1350 series, which is rated for 2,260 lbs-ft. With modified or aftermarket transfer cases it may be possible to increase to a 1410 series, which is rated for 2,700 lbs-ft torque. With these numbers in mind and the torque potential of most vehicles, it's easy enough to see that it is impractical, if not impossible, to build something that cannot break. Here is a fairly simple way to determine how fast your driveshaft is turning at a given speed of the vehicle. Six mph would be 10 percent of the speed at 60 mph.



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