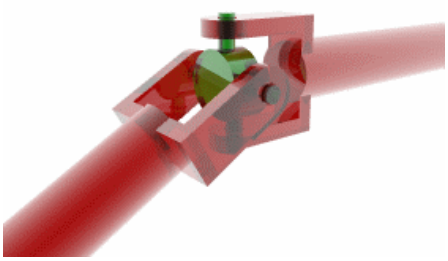
Universal Joints

By Jim Oaks

TRS Magazine
Summer 2008
CONTENTS



A u-joint (universal joint) is basically a flexible pivot point that transmits power through rotational motion between two shafts not in a straight line. The u-joint needs to be flexible to compensate for changes in driveline angle due to the constantly changing terrain under the vehicle.

The u-joint is considered to be one of the oldest of all flexible couplings. It is commonly known for its use on automobiles and trucks. A universal joint in its simplest form consists of two shaft yokes at right angles to each other and a four point cross which connects the yokes. The cross rides inside the bearing cap assemblies, which are pressed into the yoke eyes. One of the problems inherent in the design of a u-joint is that the angular velocities of the components vary over a single rotation.

The concept of the universal joint is based on the design of gimbals, which have been in use since antiquity. One anticipation of the universal joint was its use by the Ancient Greeks on ballistae. The first person known to have suggested its use for transmitting motive power was Gerolamo Cardano, an Italian mathematician, in 1545, although it is unclear whether he produced a working model. Christopher Polhem later reinvented it and it was called "Polhem knot". In Europe, the device is often called the Cardan joint or *Cardan shaft*. Robert Hooke produced a working universal joint in 1676, giving rise to an alternative name, the *Hooke's joint*. It was the American car manufacturer Henry Ford who gave it the name universal joint.

Single Cardan: Single Cardan is a term for a driveshaft with one universal joint at each end of the assembly. So actually there are two single cardan joints in a single cardan drive shaft.

Double Cardan: Double Cardan is a term used when describing a one piece driveshaft with three (or more) universal joints. What a double cardan will do, is split a universal joint operating angle into two separate angles that are exactly one half of the original angle. Normally a Double-Cardan (a.k.a. Constant Velocity or CV) style driveshaft is used in applications where it is not possible or practical to properly align the ends of a driveshaft for a single-cardan setup. Examples include where the operating angle would be too great over a single cardan joint (see below) a double-cardan allows the operating angle to be split across the two halves of the joint. It is also possible to use two CV joints on a driveshaft which is commonly used where it is not possible to align either end of the driveshaft, such as when both vertical and horizontal mis-alignment occur, or when mis-matched operating angles are present, such as in front wheel drive vehicles, where both up and down motion is present from the suspension travel as well as rotation about a vertical axis due to steering action. Drawbacks of multiple CV joints are their higher cost and complexity as compared to u-joints, their extra length and weight, and their decreased maximum operating angle limitations.

At the end of each output and input shaft is either a yoke and/or a flange. The yokes that hold the u-joint bearing caps are sometimes referred to as ears. The bearing caps of the u-joint are pressed into the yoke (ear) and held in place with a c-clip (half circle), an internal snap ring, or a full-circle snap ring. vehicles that see heavy off-road use should use an internal or full-circle snap ring. if c-clip-style u-joints are only available for your application you can have them modified by a qualified machinist to accept fullcircle clips. Over time and under harsh conditions c-clips have a tendency to wear into irregular shapes and fall out. When the c-clip falls out eventually the u-joints bearing cap will work its way out of the yoke. if left unattended the trunnion (pin) of the u-joint will damage the shape of the yoke. This damage is very difficult to repair and

usually requires the purchase of a new inner or outer axleshaft or costly driveshaft repairs.

(Double Cardan Driveshaft)

Operating Angles:

Standard u-joints aren't designed to run at extreme driveshaft angles unless they are specially constructed. as a rule of thumb, the angle of a driveshaft should not exceed 22 degrees. however, some manufacturers do make quality high-angle driveshafts that operate dependably from 22 to 80 degrees. Extreme-angle driveshafts are achieved by using a double cardan constant velocity joint. This is basically a joint with two u-joints.

Shaft RPM	Operating Angle
5000	3.25°
4500	3.67°
4000	4.25°
3500	5.00°
3000	5.83°
2500	7.00°
2000	8.67°
1500	11.5°

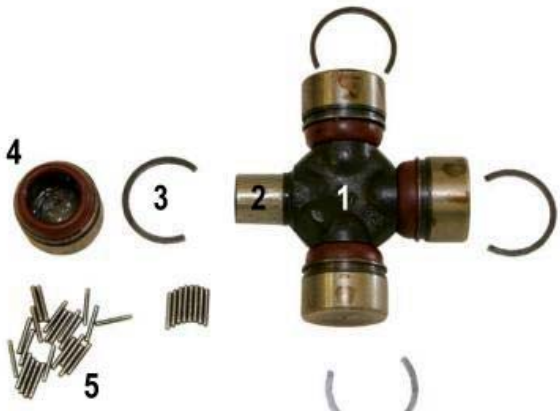
This table is based upon the joint at rated load and life. Going above the rated load or angle will decrease the u-joints life. As a general rule of thumb, for each doubling of the operating angle, RPM, or load, the lifetime of the joint is decreased by half. Rated lifetimes are on the order of 3000 hours.

In the typical off-road vehicle, a suspension lift is done to increase clearance and allow larger tires to be installed. To compensate for the larger diameter, lower gears are installed in the axles. Lets see what this does for the drive shaft, the lift increases the angle of the shaft and the lower gears means the shaft has to spin faster for a given axle speed, both things are working in the wrong direction on this chart. No wonder, driveshaft problems are common in vehicles modified for off-road use.

Anatomy Of A U-Joint:

Anatomy Of A U-Joint:

1. U-Joint Body (Cross)
2. Trunnion (Pin)
3. C-Clip
4. Bearing Cap
5. Needle



Bearings

How They're Mounted:

Here is a breakdown of how u-joints could be mounted:

Flange

Flange Yoke

Pinion Yoke (Uses U-Joint Straps Or U-Joint Bolts To Retain The U-Joint)

Weld On Driveshaft Yoke

U-Joint Straps

U-Joint U-Bolts

When I swapped in a 8.8-Inch rear axle in to my Ranger, I had the driveshaft built with a yoke at both ends. One end has a weld on style yoke. The other end is the same type of yoke (doesn't use u-joint straps or u-joint u-bolts) but is a slip yoke designed to slide in and out of the driveshaft to compensate for wheel travel. A u-joint attaches the u-joints on the driveshaft yoke to flange yokes. The flange yokes then bolt to a flange on the rear axle and transfer case. This gives me a strong connection without the use of u-joint straps or u-joint u-bolts.

As far as your axleshafts in the front of your truck go, they have a yoke similar to the weld on style above that attaches the axle shaft and stub shaft that allows the axles to turn with the steering.

One of the best upgrades you can do is the conversion of the u-joint 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. Some people have been able to drill out the holes in the yoke of their u-joint strap style yoke to insert u-joint u-bolts instead.

U-Joint Retention:

(Round Snap Ring Left - C-Clip Right)

The bearing caps of the u-joint are pressed into the yoke and held in place with a c-clip, an internal snap ring, or a full circle snap ring. Vehicles that see heavy off-road use should use an internal or full circle snap ring. If c-clip style u-joints are only available for your application, you can have them modified to accept full circle clips.

When pushed real hard with locking differentials & oversized tires, the joint's bearing caps often will try to 'spin' in the yoke as the joint operates. As it rotates, it often "spits" off u-joint c-clips and then the cap is free to walk out of the yoke, departing from the axle (if it doesn't get crushed by the balljoint stud first). The u-joint trunnion then rips apart the axle yokes, causing a catastrophic failure. Even if it doesn't break the yoke, it will still stretch them out so they won't properly hold the cap anymore.

To learn how modify your yokes for full circle snap rings, check out THIS page.

(Snap ring in place in the bearing cap groove to retain it in the yoke)

Maintenance & Inspection:

(what happens if your u-joint retaining clips come off the u-joint bearing caps)

U-joint maintenance isn't too much of a factor today for the occasional off-road enthusiast. Most over-the-counter u-joints are sealed and nongreaseable and require little maintenance. keep in mind that sealed, nongreaseable u-joints can be contaminated, which will greatly reduce their lifespan. They aren't the best choice for harsh off-road conditions. Greaseable u-joints will last far longer when properly maintained.

When performing general maintenance on your vehicle, it's not a bad idea to visually and manually check your u-joints for unusual wear, play, and missing clips. Engage your vehicle's e-brake and chock the tires. Place the transmission in Neutral, crawl underneath and rotate the driveshaft back and forth, stopping quickly. Also try to move the driveshaft forward and rearward. If the u-joints are worn you will be able to feel movement in the joint. A bad driveshaft u-joint can also be indicated by a clunk when accelerating or decelerating, especially while backing up. an unusual vibration while driving is also a good indicator that the u-joints should be checked.

Most Common U-Joints In 4-Wheeling:

(From Left To Right)

1310 (also 297X): The 1310 (shown) is a 1/2 ton u-joint used in driveshafts for many Jeep applications and is retained via external snap rings; the ones that slightly resemble a pretzel. The 297X u-joint is effectively the same size but with internal snap rings used for steering knuckle joints on most Dana 44 and Corporate 10 bolt front axles.

1330: This is a 3/4 ton driveshaft u-joint most often found at the pinion yoke going into Dana 60 front or rear axles. The 1330 shares the same cap size as the 1310 but with a larger cross.

1350: Most 1 ton trucks of yester-year used these joints (middle joint in picture) in their driveshafts but could be found in 3/4 ton and 1/2 tons occasionally. Note the cross is the same size as the 1330 to its left but the bearing caps, and therefore the trunions that they pivot on are larger, i.e. more strength.

1410: In recent years, the Super Duty line from Ford, and Chevy and Dodge H.D. series are using even beefier joints in their driveshafts. The 1410 can be considered a 1.25 ton joint and is appropriate when behind the torque monster diesel engines from the Big Three.

1480: This joint (farthest right) is most commonly a steering knuckle joint rather than a driveshaft u-joint and resides inside the knuckles of Dana 60 and 70 front axles. In a driveshaft application, it could be considered as a 2 ton joint. Keep in mind

that a steering knuckle joint sees 3-5 times as much torque as the driveshaft joints strictly from the ring and pinion reduction. It is further multiplied by having the steering turned to anything other than straight.

297X vs 760X: Spicer phased out the old reliable 297X u-joint and replace it with the new 760X. Shown is a new Spicer 5-760X replacement joint next to the old 5-297X. These joints are an updated design and have a cold-forged cross which has repeatedly been shown to be much stronger than the 297's hot-forged cross, with a much longer fatigue life. This should help to further put the brakes on broken u-joints.

297X vs 332X: Here's a 297X compared to a 332X from a Dana 60. This is an example why people upgrade to Dana 60 front axle.

Beefier U-Joints:

CTM Racing Products U-Joints:

This is CTM's high strength rebuildable u-joint. The joints are rebuildable because the seals, clips, and bushings can be replaced. u-joints like this are very expensive compared to over the counter parts store u-joints but, even under the harshest rockcrawling conditions, should be 10 times stronger than inferior joints if properly maintained. These U-joints are designed for use with full circle clips which means you will need to install them into some high quality chromoly axle shafts.

P/N 4-C144-1881

CTM U-Joints use a bronze sleeve that shows little or no wear. Keep these sleeves well greased using a needle adapter on your grease gun and abuse them worry free. Make sure you have all of your equipment set-up correctly to ensure a proper fit and superior strength to all other u-joints.

The Dana 44 u-joints (CTM P/N C144-1881) from CTM Racing Products replace the OEM stock P/N 5-297x.

The Dana 60 u-joints (CTM P/N C160-3750) from CTM Racing Products replace the OEM stock P/N 5-332x.

Visit them at www.ctmracing.com

Ox U-Joints:

Because the Ox (and the other super joints) has eliminated needle bearings (part of the secret to their strength), they are not ideal for continuous duty... such as with full-time four-wheel drive. Ox, however, is working on a design that will use needle bearings and be suitable for continuous duty, but it will be some 15 percent weaker. It may be available by the time you read this.

This u-joint from Ox is custom manufactured and features a very unique design. The trunnions of the joint press into the body of the joint and are locked in place with circular round keys. Maintenance can be performed through the side door of the u-joint body.

The Ox uses a multi-piece design, with a center body made of an 8620 alloy that has had some special and proprietary heat treatment. Instead of caps, the Ox has pins that insert through the axle yoke ear into the body and are retained inside a cavity in the body by a pair of 4340 alloy retainers. The pins are also 8620, but they get a different heat treatment than the body. The pins use an o-ring seal to keep water out.

So how strong is the Ox? The manufacturer has done destructive testing and found the unit can handle up to 22,000 lbs-ft. The new 760x cold forged Spicer is good for about 5,400 lbs-ft. The old 297s joint was good for about 4,600 lbs-ft. Ox claims their U-joint is nearly twice as strong as the next strongest super U-joint in the same sort of destructive tests. The Ox is so

sturdy that it actually helps hold the axle yokes together longer under a heavy strain as well.

As to applications, Ox currently offers units that will replace the 297/760 Spicer sizes, which covers Dana 44s, GM 10-bolts, some Dana 30s and Dana 35 IFS, among a few others. A 332x size, to suit the Dana 60 front, is almost done and may well be available by the time you read this. (get a list of joints)

A key element to keep in mind with regards to any super joint installation is that you must combine them with high alloy, beefy front shafts. Standard shafts won't last because they are no stronger than the OE U-joint and sometimes even weaker. The average Dana 44 outer shaft is good for about 4,000 lbs-ft. The necked down section of many inner shafts is usually only good for about 3,700 lbs-ft. High alloy shafts (usually 4340) are available from a variety of sources and we were interested to hear that Ox will soon be among them. Stay tuned. In some cases, installing a super joint may void the warranty on the alloy axles, so be sure to address that issue in your mind beforehand.

Visit them at www.ox-usa.com/ox/

Tom Woods Super Flex Joints:

The unique design of off-set trunnions sets the mating yokes further apart than a more conventional joint. This allows for 10 degrees more flexibility than would be otherwise obtainable. While 10 degrees may not sound like a lot, with a 30" drive shaft, this will allow more than 5" of additional droop at your axle prior to binding of the universal joint. Our testing shows that installing this universal joint into standard yokes, the drive shaft will flex to 40 degrees. With a little grind work on the yokes the drive shaft will flex to 45 degrees.

The "Super-Flex" universal joint was not designed to be a "cure all", but rather specifically to solve a binding problem that one may incur under situations such as full axle droop and spring wrap. Situations like a front drive shaft, where you have a lot of lift and have also installed buggy springs or revolver shackles in conjunction with your shackle reversal.

We have never made any secret of the fact that this joint does cause some vibration problems. (In fact we will not even sell it unless the customer is aware of its limitations). This is due to the introduction of the 3rd plane of operation, which will cause the drive shaft to run eccentric. The amount of eccentricity is a function of how steep the drive shaft runs to begin with.

Through a zero degree angle there is no eccentricity and as the angle increases the amount of eccentricity will increase. The amount of vibration you will experience will be factors of the angle and the weight of the drive shaft. In theory if your drive shaft weighed nothing there would be no vibration forces as a result of running the drive shaft running eccentric.

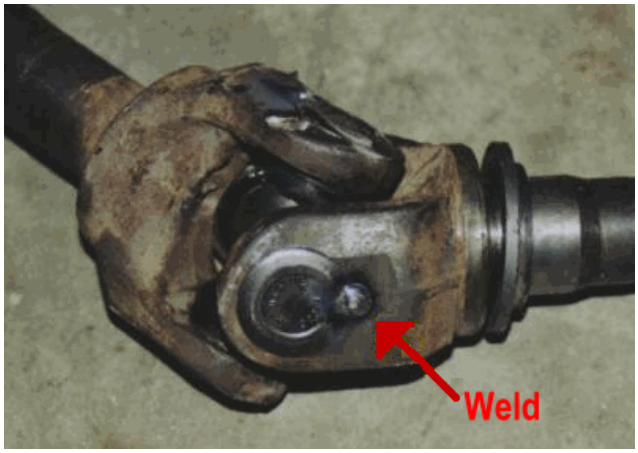
Visit them at www.4xshaft.com

Welding The Caps:

When pushed real hard with locking differentials & oversized tires, the joint's bearing caps often will try to 'spin' in the yoke as the joint operates. As it rotates, it often "spits" off it's clip and then the cap is free to walk out of the yoke, departing from the axle (if it doesn't get crushed by the balljoint stud first). The u-joint trunnion then rips apart the axle yokes, causing a catastrophic failure. Even if it doesn't break the yoke, it will still stretch them out so they won't properly hold the cap anymore.

The key to welding in the caps is weld enough material to hold the cap in place, but not hurt the operation of the universal joint. All that is required is a tack weld on the edge of the cap. The best place is in the middle closest to the splined end. The outside of the yoke is the weakest part and you don't want to damage the strength of it. If you weld on the sides, it can interfere with the installation of the shaft. Most knuckles and spindles have just enough room to install the shaft and a tack weld on the outside would make it difficult to impossible to install or remove the shaft. The weld should be as close to the

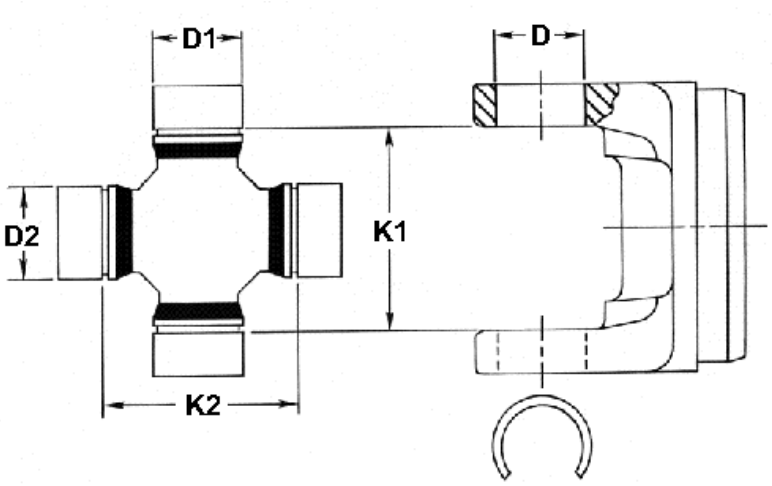
splined end as possible. Some people have welded the caps after installing the shaft. It's better to put a spot weld on before installing the shaft through the knuckle. This way, if it doesn't fit going back in, you can file some of the weld off until it will squeeze through.



If the other side of the shaft breaks or the u-joint breaks, the tack weld can be ground down with an angle grinder to remove the cap. When a new cap is welded in, any material that was ground away will be replaced. There are a limited number of times you will want to reuse the shafts. Even if a shaft doesn't break, only the other shaft breaks or the u-joint breaks, the yokes will stretch a little. The more times you reuse a shaft that has been in a past break, the more times you will break. A slightly stretched shaft is more likely to have a cap bind up or crack the weld. Once the weld is broken on a shaft that has a stretched yoke, the cap will walk out and make fatal contact with the ball joint. If the caps slide right in the yoke and don't require any hammering to install, throw the shaft away.

If you weld in your caps, inspect them regularly to see if the weld has broken.

U-Joint Dimensions Guide:



To search the Dana site for a universal joint part number by measurements, click HERE.

K1 Snap Ring Dimension	D1 Bearing Cap Diameter	K2 Snap Ring Diameter	D2 Bearing Cap Diameter	OEM Manufacturer	OEM Series	Convert This Series	To This Series	Part #	Notes
1.4430	.9380	1.5000	.9690	ROCK	L6N	1000	L6N	5-430X	
1.4820	.8860	1.4820	.8860	MAZDA				5-1514X	
1.4930	.9710	1.4930	.9710	ROCK	L6N			5-92X	
1.4960	.7870	1.4960	.7870	DAT-TOY				5-1500X	
1.5000	.9380	1.5000	.9380	SPICER	1000			5-170-1X	1
1.5000	.9380	1.5000	.9380	SPICER	1000			5-170X	
1.5000	.9380	1.5000	.9380	SPICER	1000			5-110X	
1.5000	.9380	1.5000	.9380	SPICER	1000SG			5-103X	
1.6400	1.0620	1.6400	1.0620	SPICER	1210WJ			5-456X	

1.7180	1.0000	1.7180	1.0000	SPICER	1100			5-105X	
1.7230	.9840	1.7230	.9840	MAZDA				5-1504X	
1.7340	.9840	1.7340	.9840	DATSUN				5-1501X	
1.8280	1.0620	1.8280	1.0620	ROCK	L12N	1140	L12N	5-242X	
2.0470	1.1420	2.0470	1.1420	TOYOTA				5-1510X	
2.0800	1.1420	2.0800	1.1420	CHEV LUV				5-1515X	
2.1250	1.0780	2.1250	1.0780	DETROIT	7260			5-1306-1X	1
2.1250	1.0780	2.1250	1.0780	DETROIT	7260			5-589X	2
2.1250	1.0780	2.1250	1.0780	DETROIT	7260			5-1306X	
2.1250	1.0780	2.6250	1.0780	DETROIT	7260	7290	7260	5-527X	
2.1880	1.0620	2.1880	1.0620	SPICER	1310WJ			5-74X	3
2.1880	1.0620	2.1880	1.0620	SPICER	1310WJ			5-260-1X	1
2.1880	1.0620	2.1880	1.0620	SPICER	1310WJ			5-260X	
2.1880	1.1880	2.1880	1.1880	SPICER	1310WJ			5-297-1X	1
2.1880	1.1880	2.1880	1.1880	SPICER	1310WJ			5-297X	
2.2000	1.0250	2.2000	1.0250	TOYOTA				5-1508X	
2.2080	1.1020	2.2080	1.1020	DATSUN				5-1505X	
2.3430	1.0620	2.3430	1.0620	SPICER	1310			5-350X	
2.3440	1.0000	2.3440	1.0000	MECH	2R			5-2011X	
2.3750	1.0620	2.3750	1.0620	CLEV	S55			5-1200X	
2.3750	1.0620	2.3750	1.0620	CLEV	S55			5-718X	
2.4530	1.4970	2.4560	1.4970	MER				5-1506X	
2.5200	1.2600	2.5200	1.2600	TOYOTA				5-1511X	
2.5620	1.1250	2.5620	1.2500	MECH	S44			5-3147X	
2.5630	1.1240	2.5630	1.1240	MECH	S44			SPL25-6X	
2.5630	1.1880	2.5630	1.1880	CLEV	R55			5-1205X	
2.6250	1.1250	2.6250	1.1250	DETROIT	7290			5-1309X	
2.6260	1.1240	2.6260	1.1240	DETROIT	7290			SPL25-9X	
2.7810	1.3120	2.7810	1.3120	ROCK	44R			5-431X	
3.0000	1.2310	3.0000	1.2310	DETROIT	5380			5-1301X	
3.0000	1.3750	3.0000	1.3750	SPICER	1480WJ			5-88X	3
3.1250	1.1880	3.1250	1.1880	CLEV	O55			5-1206X	
3.2500	1.1250	3.2500	1.1250	MECH	4R			5-4015X	

Notes:

1) Lube Fitting In Bearing Cap

2) Mercruiser Kit

3) Used In Closed End, Spicer Front Axle

U-Joint Cross Reference:

Are all the numbers confusing you? 1310 series, 1350 series, 5-297X and so forth? Here's a sizing chart:

The Dana 35 & Dana 44 front axles use Part# 5-297X which is a 1310 Series u-joint.

U-joint Series	U-Joint Width (inches)	Cap Diameter (inches)
1310	3.219	1.062
1330	3.625	1.062
1350	3.625	1.188
1410	4.188	1.188
1480	4.188	1.375

Conversion U-Joints:

Need to connect a flange(s) and/or yoke(s) together that each use a different size u-joint? Here's a list of Spicer conversion universal joints:

1310 to 1350 = Spicer 5-460X

1310 to 1330 = Spicer 5-134X

1330 to 1350 = Spicer 5-648X