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Research Update

U-Joints versus Constant Velocity Joints:

What's the best choice for a driveline?

Power Take Off (PTO) drivelines transfer heavy torque loads from a power source such as a tractor to an attached PTO-driven implement. To allow for cornering, up-and-down motion along the driveline and any difference in the vertical alignment between the tractor output shaft and the input on the implement, flexible joints are used to permit the continued transfer of power even when the driveline from the tractor to the implement is operating at an angle. The most common types ofjoints are the familiar universal joint (Cardan joint) and the Constant Velocity (CV) joint.

What's the Difference?

How you choose the type of joint in a driveline depends on the speed and angle the joint is meant to operate under. CV joints will operate at a much larger angle than Cardan joints, but are more expensive. An operator may choose to switch to a driveline with CV joints in situations where original equipment has been modified or is operated with a larger driveline angle than it was originally designed for.

In the case of new equipment, the choice of joint is predicated by the overall machine design. Original equipment manufacturers should supply the appropriate joint with a machine.

Which One is Better?

Choosing between a Cardan joint and a CV joint is not so much a question of which one is better. Rather, the question is "Which one do I need?" In general, CV joints are no longer considered optional equipment. In modern applications, the decision is largely dictated by the design of the machine, and particularly the hitch geometry.

Constant Velocity (CV) joints and Cardan joints may be used alone or in combination. In all applications, there are a number of common considerations:

- Joint life is a function of the bending angles. It can vary depending on the type of joint and the application.
- Critical speed. Resonance may occur when shaft velocity hits a certain point. This critical speed is dependant on weight and length of the shaft and may be quite different for various PTO shafts.
- There must be enough clearance for articulation of PTO drive shaft.
- There is proper shielding on the tractor and all equipment.

Table 1, on page 5, provides some guidance in helping the machine operator match a joint type or combination joint to general applications.

Cardan Joint

Until fairly recently, Cardanjoints (Figure 1) were the only option available for agricultural applications, and are still very common today. A single Cardan joint consists of a pair of U-shaped yokes on the ends of the adjoining shafts joined through beatings to a metal cross.

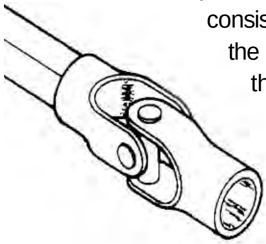


Figure 1. Typical Cardan Joint.

However, a single Cardan joint is limited to a 15° deviation from a straight line before fluctuations in drive shaft speed and/or vibration begin to occur. The useful life of the Cardan joint can be drastically reduced because of vibration. They are usually used in pairs to increase the maximum operating range to 30° and to minimize speed fluctuations and vibration.

With older square telescopic drive shafts, it was possible to connect the shaft so that the Cardanjoints were out of phase (rotated 90° to each other). This could create a significant vibration problem. However, modern drive shafts are designed so that the telescopic shaft will only fit together by turning the sections in increments of 180°, ensuring the joints are always in phase (see Figure 2).

It was also important that the vertical and horizontal angles of the two Cardanjoints was equal to further reduce velocity fluctuation and associated driveline vibration. This could be accomplished by modifying the drawbar and machine hitch lengths so that the distances between the hitch point and the ends of the output and input shafts were equal. A more detailed explanation of PTO vibration can be found in the PAMI publication, *Gleanings, 441.*

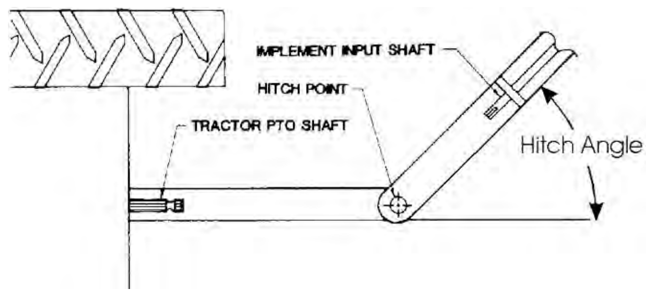


Figure 4. The life of a typical double Cardan joint drive shaft is reduced when operating at angles that deviate from a straight line.

The life of a typical double Cardan joint drive shaft is reduced to 75% for 200 deviation from a straight line, and is halved when operating at a straight-line deviation of 30°.

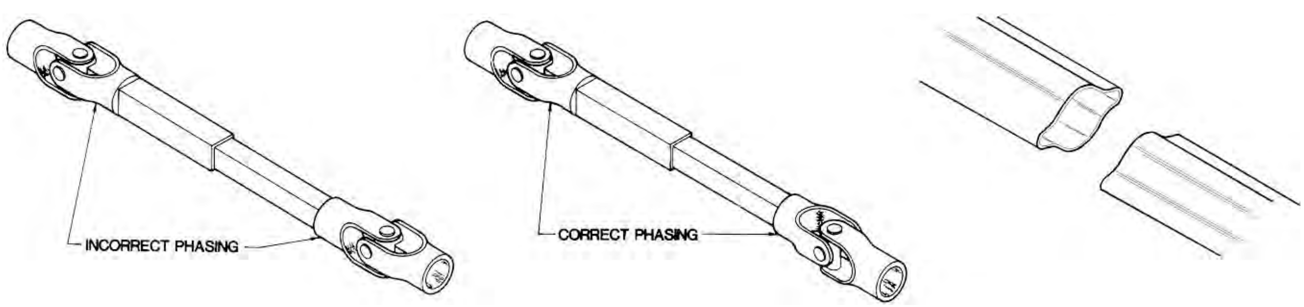


Figure 2. With older square telescopic drive shafts, it was possible to connect the shaft so that the Cardan joints were out of phase (rotated 90° to each other), creating a vibration problem (left). Modern drive shafts (far right) are designed so that the telescopic shaft will only fit together by turning the sections in increments of 180°, ensuring the joints are always in phase.

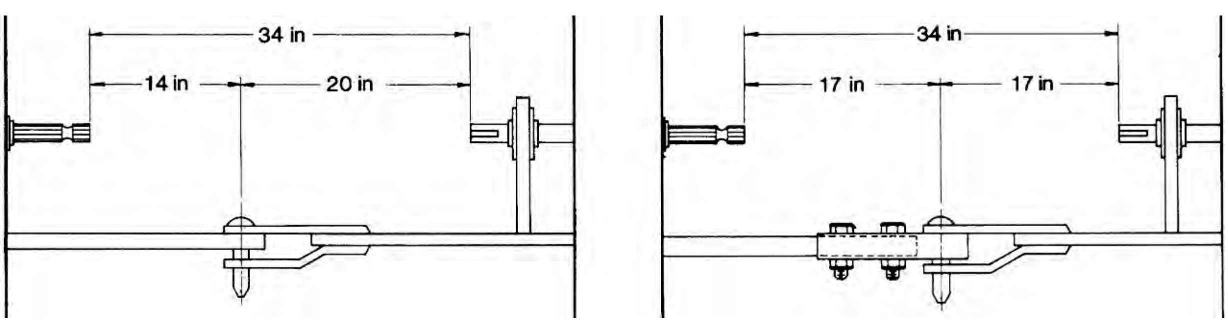


Figure 3. Cardan Joint: When the hitch point is not centred between the output and input shafts, an unequal angle is created when cornering or operating on uneven terrain (left). This situation causes driveline velocity fluctuations and vibration. Centreing the hitch point (right) allows for equal angles, and minimizes velocity fluctuations and vibration.

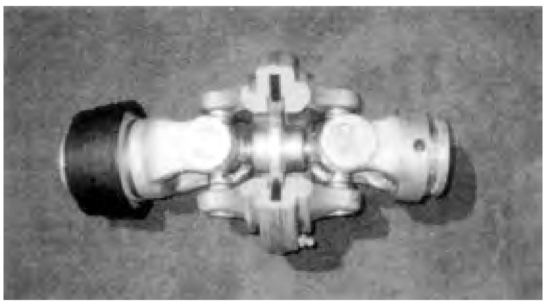
Constant Velocity Joint

The development of Constant Velocity (CV) joints has greatly improved the angle at which a driveline may operate from a straight line before loss of power and/or vibration occurs.

The Constant Velocity joint's driving members are steel balls constrained in curved grooves between the forks of the joint. The design is such that a CV joint may operate efficiently up to a 80° deviation from a straight line. By operating in pairs, the angle can be increased accordingly (see Figure 5).

As with the Cardan joint, the effective life of a CV joint will be shortened as joint angles increase. While equalization of joint angles is still important, it is less of a concern for CV joints by their nature. For large angles, there still may be some vibration if the joint angles are not equal.

Some new equipment designs require drivelines that have large joint angles. This is where wide-angle Constant Velocity joints shine. CV joints are necessary for high velocity power transmission and for axles and kingpins of steered traction wheels on modern farm machinery.



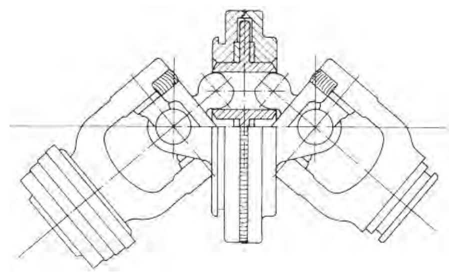


Figure 5. A Constant Velocity joint's driving members are steel balls constrained in curved grooves between the forks of the joint (photo at left). These joints are also called Double Cardan joints. This design operates efficiently up to a 80° deviation from a straight line (illustration at right).

(Illustration source: Walterscheid)

Tips From The Field

Lorne Henry grows potatoes and grain in the Portage la Prairie area. He has had over 30 years of driveline experience on his farm. Here is his driveline design wish list, along with a few operator tips:

- *I'd like to see a bigger range of CV joints for higher output machines. These heavy duty CV joints should be designed for a full range of movement for h,fting and lowering, and for turning at headlands so that the operator does not have to turn off the PTO for these operations.*
- *Better lubrication is needed for telescoping drive shafts. Make it greasable (maybe via a tube) from the same location as the joint lube points.*
- *I'd like to see a rubber boot (similar to automotive CV joints in front-drive cars) to protect joints in ag applications, including the telescoping shaft. This would protect these parts from wear and seizure. The ideal situation is to grease only once at the start of the season.*

Tips:

- *Teflon coated telescoping shafts are a good idea, but are easily ruined in abrasive, sandy conditions.*
- *Seized telescoping shafts can take out a tractor PTO -- a $5,000 repair on one of my tractors. The telescoping shaft should be disconnected and lubed every three to four days of use. It is an onerous task that usually takes two people, but it's worth saving a $5,000 repair and lost time in the field.*

Cost Considerations

Constant Velocity Joints are more expensive than Cardan joints. But replacing Cardan joints over time may in fact, become more expensive than an investment in the more versatile CV joint.

CV joints are necessary where high velocity power transmission is required and operating angles are acute. Paired Cardanjoints are not able to transmit power properly where angles exceed 30° without losing power and/or causing vibrations. Cardanjoints pressed into operation where they are unsuitable results in dramatically reduced life of the joint.

PTO Safety Tips

Make safety an important part of your everyday routine.

- Make sure that the safety shield on your power takeoff is kept on at all times. Replace immediately if broken or damaged.
- Always shut off the PTO before getting off the tractor.
- Never reach over the back of the tractor to adjust the PTO or the throttle.
- Never step over the revolving shaft of the PTO even if it is shielded.
- Always wear clothes in good repair, even a shielded shaft can catch hold of a shoelace or a flapping cuff. Tuck in your shirt, and button your sleeves. Replace your work gloves if they are frayed.
- Read the safety section of the machine's operator manual. Make sure anyone who is running that machine has also read the safety section.
- Never let a child operate a PTO. Teach kids to stay away from tractors and machinery
- *See Canadian Coalition for Agricultural Safety & Rural Health for more information (www.ccasrh.org)

The Constant Velocity Mystery

Constant velocity in PTO drivelines is an ideal operating condition, and can be achieved with both Cardanjoints and constant velocity joints. But there is more than one method of achieving constant velocity in drivelines.

A typical driveline with Cardan joints at each shaft end will have constant velocity if the operating geometry is arranged so:

- that the yokes on the intermediate shaft are in phase (See Figure 2), and
- the hitch point is centred between the PTO output shaft on the tractor and the PTO input shaft on the implement (See Figure 3).

Another method of achieving contant velocity is through the use of Double Cardan joints, which overcome the limitations of PTO drivelines that have two or more sets of single Cardan joints. Double Cardan joints are typically used where operating angles are too large for single cardan joints. A Double Cardan joint is essentially two single Cardan joints connected by a coupling yoke that contains a centreing mechanism. This centering mechanism keeps the input and output shafts in the same plane, regardless of the operating angle. A Wide-angle Double Cardan joint uses a centreing mechanism comprised of a flat disc with sockets that support the ball stud yokes. This centreing mechanism compensates for velocity fluctuations of the two Cardan joints, thereby providing a constant velocity output (See Figure 5).

Other Double Cardan joints use centering mechanisms that incorporate a ball and stud mechanism, or a ball and seat mechanism. Double Cardan joints with these centreing mechanisms are considered to be *near* constant velocity joints because their centreing mechanisms do not split the misalignment between the shafts equally for all operating angles. Consequently, these joints do not produce true constant velocity output - except at the design angle. (All joints are designed to transfer power efficiently up to a maximum angle - the design angle. Operation beyond the design angle results in excessive vibration.) For practical purposes, the resulting velocity fluctuation is negligible.

In comparison, the centreing mechanism in a Wide-angle Double Cardan joint always splits the misalignment between shafts equally. As a result, the wide-angle Double Cardan joint has a true constant velocity output at all operating angles up to the design angle.

Double Cardan joints with ball-and-stud or ball-and-seat mechanisms are typically designed for higher speeds than are Wide-angle Double Cardan joints. The Wide-angle Double Cardan joint is most commonly used where speeds do not exceed 1000 rpm.

Table 1. Applications of Joint Types

Joint Type	Design Characteristics	Typical Application	Considerations
Paired Cardan Joints	• Hinge angle of 90° when not in operation • High power transmission with a small straight-line angle deviation	• Where joint angles are balanced • Three-point hitch • Where sufficient allowances are made overlapping of telescoping sections	• Reduced cost compared to CV joints • Adverse operating conditions affect life • Maintenance
One 50° CV joint and one Cardan joint	Articulation of CV joint: • In short-term use up to a maximum of 50° • Maximum 50° when not in use	• Used when the Cardan joint is, for the most part, in line during operation • Unilateral angularity of a maximum 50°	• CV joints more costly than universal joints • Hitch geometry/power transmission/acute operating angles will demand a CV joint • CV joints are heavier to put in place on machinery
One 80° CV joint and one Cardan Joint	Articulation of CV joint: • In short-term use up to a maximum of 80° • Maximum 80° when not in use	• Use is dictated by hitch geometry • Used when the Cardan joint is, for the most part, in line during operation • Unilateral angularity of a maximum 80° • Short hitch • In-built drive shafts	• CV joints more costly than universal joints • Hitch geometry/power transmission/acute operating angles will demand a CV joint
Two CV joints (combinations of 50° and 80° joints)	• PTO drive shafts • CV joint at both ends	• Use is dictated by hitch geometry • Used where operating angles are large and unequal • Drawbar hitch • Short hitch • In-built drive shafts	• CV joints more costly than universal joints • Hitch geometry/power transmission/acute operating angles will demand a CV joint • CV joints are heavier to put in place on machinery

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