What You Need to Know About Propeller Shafts and Couplings

- Craig Johnston, S/V Sequoia

There are many aspects of our boats that are too technical or obscure for the average boater to master. Nevertheless, what you don't know can become a big problem, especially when under way far from home port. **In the last few months, three SIYC yachts have become disabled while underway by problems with prop shafts and transmission couplings.** In each case, they lost engine propulsion and required a tow. These could have turned into life-threatening situations but fortunately all were safely resolved. But the expense in each case, not to mention the anxiety, was substantial.

Parts of the Drivetrain

Cruising sailboats with inboard engines generally have either a direct drive shaft from the engine to the prop or a saildrive, a vertical driveshaft that exits through a large hole in the boat and looks somewhat like the lower end of an outboard motor. This article covers the direct drive shaft and its important parts. These are:

1. The transmission coupling, a flanged assembly that bolts onto the output of the transmission and clamps onto the driveshaft. (see Figures 1,2 and 3)
2. The driveshaft, which transmits the power from the engine to the prop.
3. The shaft log which seals around the driveshaft where it penetrates the hull.
4. A cutless bearing (Fig.4), which constrains the driveshaft just forward of the prop and is contained either in a strut or the trailing edge of a full keel. It operates underwater using rubber fingers as bearing surfaces.

Figure 1. Solid transmission shaft coupling. Note the keyway and the two locking screws which should bear on depressions in the shaft and be seized with wire.

Figure 2. Split transmission coupling. Ideally, both pinch bolt nuts and the setscrew should be drilled for seizing wire.

Figure 3: Cutaway view of a tapered shaft coupling. The locking nut and washer provide positive retention when backing down pulls on the shaft.

Figure 4. Cutless bearing. This is pressed into a strut or the back of the keel and held in place with setscrews.

5. The propeller, which is fixed to the end of the driveshaft. (see Figure 5, prop end of shaft).

Figure 5. Prop end of shaft. Note that the threaded end is smaller diameter than the body of the shaft. These threads are right-handed, but beware, some shafts have left-handed threads.

Design Requirements

The three SIYC yachts all had problems after fouling the prop on rope or grass and stalling the engine. In two cases this caused failures at the engine coupling, and in one case a lost prop. One of the boats broke motor mounts. To understand these catastrophic (and expensive) failures it is necessary to look at the way the shaft is connected to the engine and prop.

The transmission shaft coupling must satisfy three requirements:

1. Clamp the shaft rigidly in relation to the engine and transmission.
2. Couple the rotation of the transmission's output to the shaft.
3. Keep the shaft from pulling out when motoring in reverse.

The shaft at the engine coupling may be either straight or tapered but usually has a key, a square metal bar that rests in slots (called keyways) half in the shaft and half in the transmission coupling. This locks the shaft to the engine rotationally. The coupling may be solid or split into two halves, with bolts to clamp it onto the shaft. Additionally, there is a bolt that bears on a hole or dimple in the shaft to keep it from pulling out. If the shaft is tapered to fit into a matching taper in the coupling, there will typically be a bolt through the center of the coupling into the end of the shaft that prevents the shaft from pulling out.

The shaft log keep water from entering the boat where the shaft passes through the hull. These are of two types: adjustable packing or dripless. Without going into detail, it is important that each type be set up correctly. The adjustable packing should only be tightened enough to allow 2-3 drips per minute; otherwise it will overheat and damage the shaft. Here is a link to see a dripless shaft seal.

The cutless bearing uses the unusual properties of rubber as a low friction bearing surface when flooded with water. Cutless bearings are remarkably durable but need periodic replacement when worn.

The propeller is fit onto a taper at the end of the shaft, with a key and one or two nuts to hold the prop on when reversing. A correctly fitted prop will jam onto the taper so tightly that a puller is necessary to

remove it. Because of the taper, the threaded part on the end is smaller diameter than the shaft. For a US standard shaft of 1.5 in. diameter, the standard thread is 1 1/8 - 7.

Getting into trouble

The failures our Club members' boats suffered each started when the prop and shaft were jammed by a line or flotsam. For *S/V Mapache,* that broke one of the 40-year-old engine mounts, and days later the resulting vibration from the misalignment of the shaft chewed up the transmission coupling key. Once the key breaks, the shaft can spin in the coupling under load, so engine power may only be available at low rpms or not at all. For *S/V Julia Max,* hooking a crab pot line pulled the shaft out of the transmission coupling and the key was lost into the bilge. Even though the shaft was forced back into the coupling, without the key the setscrew was unable to keep the shaft from slipping**.**

The keys are designed to shear off before the other parts of the system are damaged. Thus while the shafts are made from special high-strength stainless steels (about twice as strong as the type 316 alloy used for underwater fastenings and rigging), the keys on a boat's driveshaft can be made of brass, bronze or stainless steel. You *want* them to break before the prop, shaft, transmission, or engine mounts, but not corrode or wear under normal operation. For the transmission coupling, the best choices are bronze or 316 stainless – brass will work but if there is any looseness in the coupling, brass will eventually distort or get chewed up. For the prop key, brass is a poor choice because of corrosion in saltwater. In general, bronze or 316 stainless are the best key materials for both locations.

The third Club boat lost its prop after wrapping some dock lines. The boat, made in France, is supposed to have a keyed washer under the prop nut that is bent after installation to lock the nut in place. This was not installed correctly during the last refit. Fouling the prop probably loosened it on the taper, and after hours of operation, the nut vibrated off and the prop was lost the next time the engine was put into reverse.

Recommendations

Before working on the drivetrain or ordering parts, it is important to know:

1. The diameter of the shaft and whether it is Imperial or metric. Typical on our boats would be 1-1/4, 1 3/8, or 1 ½in. A metric shaft might have a diameter of 35mm, which is just a wee bit larger than 1 3/8in but uses a different taper and nut. **It is important to know whether the shaft is imperial (SAE standard) or metric (ISO standard), as the taper, key, threaded section and nut are different for each.**
2. The prop nut threads may be either right-handed or left-handed. (This derives from old thinking that the prop's rotation should *tighten* the nut. Some transmissions rotate clockwise in forward, some anti-clockwise. But since all props rotate in both directions (forward and reverse), other means of locking the nut are necessary. **But it is *crucially* important to know which way to unscrew the nut before putting a two-foot breaker bar on it and heaving away.**
3. The nut may be locked on by a cotter pin through slots (castellations) in the nut, by having a second *jam* nut next to the prop, or other means such as a soft washer that is indexes on the keyway and is bent over the nut after it has been tightened. But there **must** be some method of locking the nut on—otherwise, following a shock such as the prop striking a piece of driftwood

or wrapping up some kelp or a crab-pot line, the next time reverse is engaged the prop may depart for Davy Jones' locker.

Most of us have wrapped up some sea grass or the odd crab pot line at some point in our cruising. To avoid hazardous situations and expensive repairs, here are some pointers for handling this situation:

1. Take the engine out of gear as quickly as possible. Do not try to power through it.
2. Try a very brief jog into reverse (one second at idle) to see if it can be unwrapped.
3. Turn off the engine, put it in neutral and, after checking for navigational hazards, go below and try to turn the prop shaft by hand. If you can't, stop trying and work instead on sailing into port or to an anchorage. In calm water, it may be possible to dive to free the prop, but this is dangerous in a seaway and has resulted in numerous fatalities.
4. Know how your prop shaft is fastened at the engine and prop, and carry spares:
    a. Properly sized keys for both the engine coupling and prop.
    b. Spare prop nut(s), setscrews or washers as required.
5. If you do end up removing the prop, you will probably need a special size of socket and a breaker bar or a very large adjustable end wrench to remove the nut, and probably a puller to force it off of the taper.

Prop removal can be done in the water by a diver but is much easier out of the water. While removing the driveshaft must be done on the hard, it is often possible to work on the transmission coupling in the water.

If you normally rely on a boatyard for repairs of the drive train, it might not seem necessary to have these spares and know how they all fit together. But whether the you do your own repairs or hire the work out, it is quite likely that the yard or local chandlery will not have that left-handed bronze nut, bronze key of the correct size, or special washer needed for the repair, and doubly so if they are metric. So it really pays to know how it all goes together and have the replaceable bits on hand.

Finally, remember that you have a *sail*boat. The engine is an important but secondary system. While it may be hard to sail into a tight inlet or marina slip without the motor, it is almost always possible to sail to a safer place where less costly help is needed to fix the problem.

For the Club members own accounts of their drivetrain adventures, see George Stonecliffe's account in the October and November SIYC Newsletters, and Rob Martin and Sarah Laidlaw's excellent blog, Little Leaky Boat.

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