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When, why and how to minimize drag from a fixed propeller.

FREEWHEEL OR LOCKED PROP?

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Should we freewheel?

This question often is asked, but I have yet to find the answer. I refer to the question of whether a propeller creates less drag if you allow it to revolve freely when sailing (with the engine off) or whether it is better to lock it.

Intuitively one feels that it ought to create less drag if allowed to rotate, hence the advertisements from a gearbox manufacturer saying: "so go ahead-freewheel! It will save fuel and decrease drag under sail..." Some makes of gearbox have limitations on how long you can "trail" the propeller when under sail or how fast the shaft may rotate without harming the gearbox through overheating or inadequate lubrication.

Such advertisements imply that is better to freewheel or trail, but is it really so?

Propellers have been tested in cavitation tunnels to discover their characteristics when reversing and when trailing. From these results I have worked out the drag of a typical yacht propeller 12 inches diameter with 8 inch pitch allowed to trail at various shaft speeds (in 3 knots of water with boat speed at 3 ½ to 5 knots) See figure 1. Zero rpm indicates the locked condition. When the prop is absolutely free to revolve (the shaft bearings are friction free) the rpm climbs to 376. Between the two extremes there is a varying degree of resistance to turning due to friction in the bearings. The interesting thing to note is that it only takes a bearing friction of about *1 pound foot to slow the shaft to the point were the prop gives as much drag as the locked case. Now 1 pound foot is a very small torque when it comes to conventional boat shafts.

*Unlike a foot pound, which is the straight line force needed to move one pound one foot, a pound foot (a rotational measurement) is the torque produced by a force of one pound acting one foot from the center of rotation.

I measured several shafts on yachts to see how much torque is necessary to slowly turn the shaft. Those with conventional shafts and stern tubes required torque loadings of 0.6 to 1.3 pound foot.

So on that basis and looking at Figure 1, ***the prop will create three times more drag when allowed to rotate than it will when locked.***

The maximum drag occurs when the prop is revolving slowly between 70 and 150 rpm and it is at just these speed that a friction torque of around 1 pound foot allows. At this point the prop, in effect, is working quite efficiently in the astern mode. ***It becomes an effective brake.***

This is the situation with that particular propeller. Let us look now at the effect of varying the particular conditions that I assumed in Figure 1. There are four factors that change the situation:

1. Speed of the water into the propeller.

2. The ratio of pitch to diameter.

3. The blade area.

4. Frictional shaft torque.

The yacht propeller example I took was typical one. The speed of water inflow was assumed to be 3 knots, which entails a boat speed of 4 or 5 knots if the propeller is sheltered behind the keel, or 3 ½ to 4 knots if the shaft is held off the hull by a shaft strut so that the propeller is in clear water.

As the speed of the water inflow increases, the drag increases as the square. In other words, at 6 knots (which is double the water flow speed of figure 1) the drag is quadrupled. But the shaft friction remains the same. Even so, it is still better to lock the shaft if the shaft friction is 1 pound-foot as shown in Figure 2.Six knots implies a boat speed of 7 to 8 knots - some sailing! I would think that inflow speed on small yachts are no more that 5 knots. In any case, it is when beating to windward that propeller drag becomes most noticeable and beating is not the fastest heading by any means.

The next factor in the four points is the ratio of the pitch to the diameter. Inevitably, boats that only do 4 to 6 knots under power have fine pitched props like our 12 x 8 the pitch is only two-thirds of the diameter. The tips of the blades of such props are almost square on the flow. They do not "windmill" very well. Coarse - pitched props have blades that more angled to the flow and consequently will "windmill" better. Nevertheless, ***a 12 x 12 propeller at 3 knots, for instance, will still give more drag revolving against a shaft torque of 1 pound foot than if it were locked.***

Blade area is important. The greater the number of blades and the wider each blade within a given diameter, the greater the locked drag as one would expect. But the revolving drag is not increased very much. Figures 1 and 2 assume a normal yacht's thin bladed, two or three blade propeller in fact one having a total blade area of only 35 percent of the "disc" area (i.e. the area swept by the propeller).

Last on the list is the frictional shaft torque. This will be worse with a hydraulic gearbox that with a mechanical type. Rubber bearings and large diameter shaft also will increase friction (and so too, of course, will shaft misalignment!).

Ordinary yacht propellers operate in a slow flow of water: they are fine pitched with little blade area while the shaft friction is high.***All these factors point to the conclusion that it is better to lock the shaft.***

Because it may help sailors understand the forces and the conditions, let's take a look at twin screw motor cruisers. Consider the case of a faiths twin screw ***motorboat.*** Suppose she is running at 12 knots on one engine. (her top speed on ***two engines*** may be 20 knots or so.) Her powerful engines will require a large blade area within the confines of the propeller diameter in order to absorb the power without cavitating. The blades will be wide. The pitch will be about as large as the diameter coarse pitched. The speed of flow into the propeller will be around 10 knots. The drag of such a propeller is shown in Figure 3 (15 x 15 propeller). Note that the actual drag involved in this case are hundreds of pounds. Also, a shaft friction of 1 pound - foot only slows the shaft minutely, so that ***in this case it is clearly better to allow the idle shaft to revolve.***

This type of propeller is more like an archimedian screw and naturally rotates very easily. In contrast, the skinny, narrow bladed prop with a fine pitch but without a fast flow of water does not freewheel easily.

There obviously is quite a science behind choosing a propeller for a sailing boat. On one hand there is the performance under power to consider; on the other, the drag while sailing. In the case of fixed blade propellers (which is what I have been talking of so far), it generally is best to have a locked two bladed prop with narrow blades having the minimum blade area. That minimum is about 5 square inches per engine horsepower (the area being measured over all the blades). That will ensure good propulsion under power but minimum drag while sailing. ***The two bladed prop should be locked in the vertical position, thus being shielded to some extent by the keel or shaft strut.***

Alternatives to the solid prop are those that fold, variable pitch propellers (which now appear to be going out of fashion) and the latest "small boat drives" literally outdrives for yachts. ***Outboards, outdrives*** and these fast catching on sailboat drives have very little shaft friction. One or two that I have measured have only 1/8 pound foot torque which puts a different complexion on Figures 1 and 2. Even with a fine-pitched, narrow bladed prop, this level of shaft friction is likely to ***give less drag freewheeling than locked***.

Whether or not to lock depends also on constraints other than propeller drag. There is the gearbox question for a start. But there is also the thought that the bearings and glands (and the oil seals in the case of the sailboat drives) are wearing away under the countless millions of shaft revolutions while under sail, let alone under power. Locking the shaft is easy with a mechanical box - you just put it in gear. But remember that with some engines this entails sliding the whole prop shaft. if the shaft must move forward to engage " ahead", the rearward drag on the propeller may make the clutch slip. To avoid the wear which that would involve, it would be far better to engage "astern".

This does not work with a hydraulic box, since oil pressure is only there when the engine is running. That leads you into the necessity of a shaft locking arrangement and then into the problem of how to ensure that you do not accidentally leave it engaged when you next start the engine.

THE END

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