Should you anchor from the stern in a storm?

Donald J. Jordan

The boat will lie quietly and align itself with changes in wind direction

In the fall of 2004 four hurricanes devastated southern Florida. Science News, April 2005: "Hurricane Ivan struck the Gulf Coast causing extensive damage. Insured U.S. losses exceeded $7 billion." The media showed scenes of marinas in shambles; damaged boats from moorings and anchorages littered the shore.

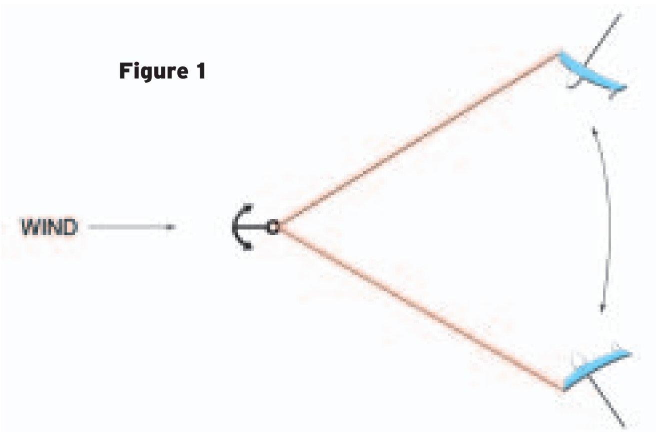

Figure 1

Yachting World, November 1996, Hurricane Bertha, British Virgin Islands: "Moorings are vulnerable in the wind. It is particularly unnerving to watch the yachts tacking back and forth and blowing flat at the end of each tack. Chafing is one the biggest enemies of hurricane survival" (see Figure 1).

The research that led to the design of the series drogue — and even more important, the actual experience at sea with a variety of yacht designs and with storm encounters up to hurricane strength — can provide another benefit to the yachting community. These engineering data clearly show that, in storm conditions, a sailing yacht should be moored or anchored from the stern with a bridle, not from the bow. If moored from the stern, the boat will lie quietly and will weathercock with changes in the wind direction.

The design loads for the mooring or anchor can then be estimated with sufficient accuracy to permit the design of a reliable mooring system for hurricane winds. There is no technical reason a sailing yacht need break away from a mooring.

The wild and destructive motion shown in Figure 1 is caused by a form of dynamic instability that is now well understood. Similar unfortunate behavior was experienced on early aircraft designed to fly at high speed. Now known as flutter, the wing would twist and oscillate up and down with increasing amplitude until failure occurred. A similar but more widely publicized event was the failure of "Galloping Gerty," the Tacoma Narrows suspension bridge that undulated in the wind until one day, in a heavy gale, the vibrations grew so severe that the bridge broke into pieces.

Not all boats become dynamically unstable when tethered from the bow in a strong wind. However, modern sloop-rigged sailboats with a cutaway forefoot, short keel and spade rudder are particularly vulnerable, and such designs make up a large share of the sailing community. A schooner-rigged yacht with a long, straight keel is better, and most of the old gaff-rigged schooners would ride fairly well. Powerboats often fare better than sailing yachts. However, boats with a high bow and a large structure forward can do poorly. All designs would be more secure anchored from the stern.

Fifteen years at sea with the series drogue has demonstrated that a yacht will not be "pooped," and the rudder and companionway doors will not be damaged by mooring from the stern. The cockpit may occasionally fill from waves slopping aboard.

Stability of anchored or moored sailing yachts

If an anchored sailing yacht is stable it will lie quietly; if it is unstable it will develop a violent motion under high wind conditions. An object is said to be stable if, when a force is applied to deflect the object, an opposing force is generated to

Where do you stand?

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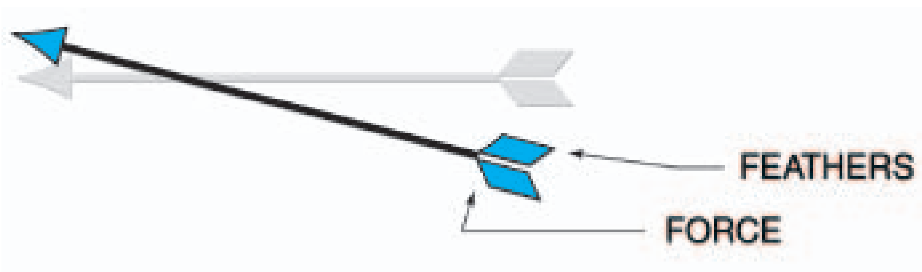
return the object to the original course. All moving vehicles — boats, cars, bicycles, airplanes — are designed to be stable when moving forward, otherwise it would not be possible to steer them in a straight line. If a vehicle is stable moving forward, it will be unstable moving backward.

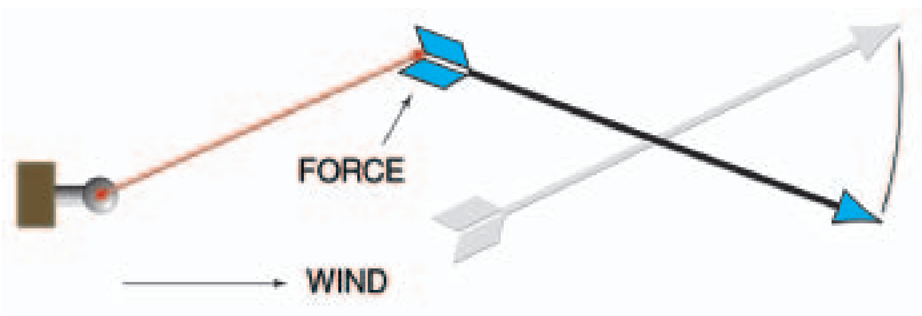
The most familiar example of an object with positive directional stability is an arrow.

An arrow is highly stable moving forward. If deflected from its course (see below), the feathers act to bring it back.

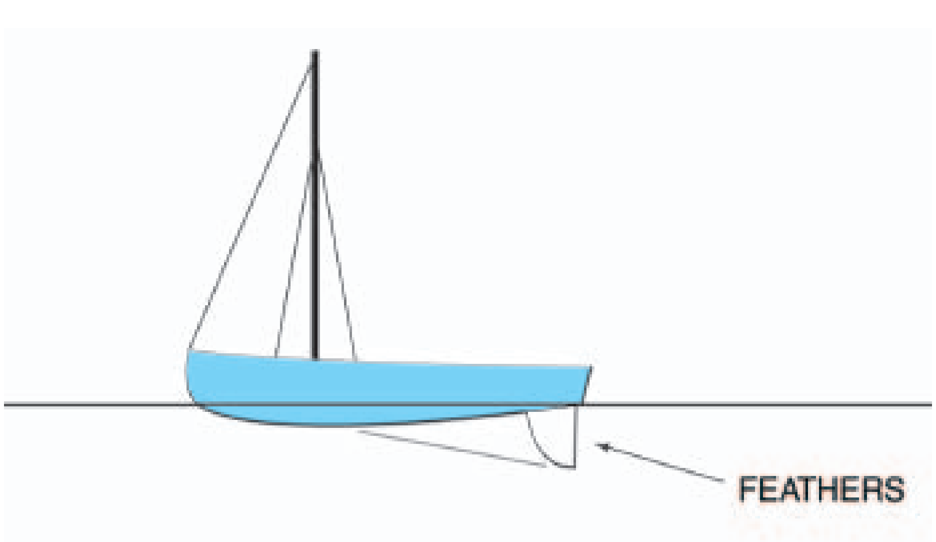


If an arrow is tethered at the arrowhead end and exposed to a strong wind it will be stable and will lie quietly, aligned to the wind.

If the arrow is tethered at the feather end, it will be unstable and will flail around wildly.

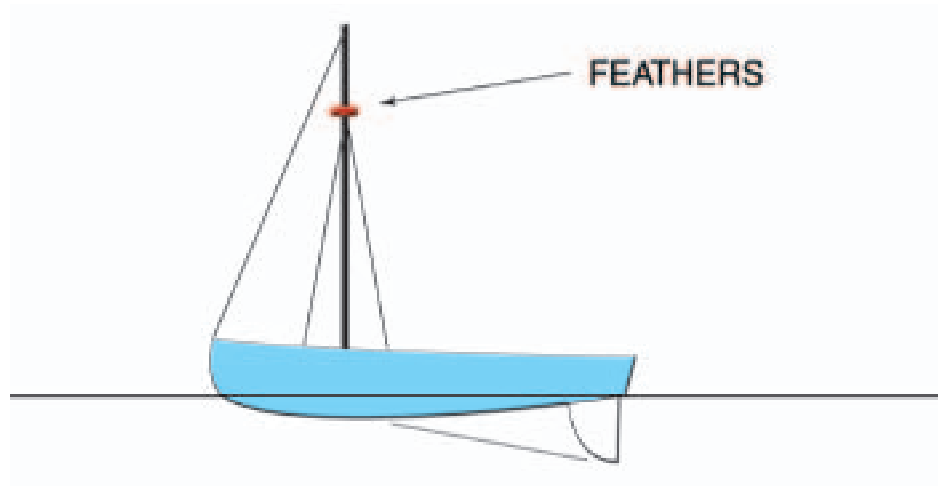


The motion of an arrow is influenced only by air forces. However, the motion of a sailing yacht is influenced by both air and water forces. All sailing yachts are designed to be stable when moving forward through the water. Therefore, they automatically will be unstable when moving astern through the water, as any skipper who attempts to steer the boat backward will attest. The boat will yaw.



Water forces

When sailing forward, the keel and the rudder act as the feathers on the arrow (see above). When under sail, the air forces on the sails and rigging are balanced so that the loads on the tiller are minimized, and the air forces do not have an important effect on the directional stability. The boat will hold the desired course with little control from the skipper.



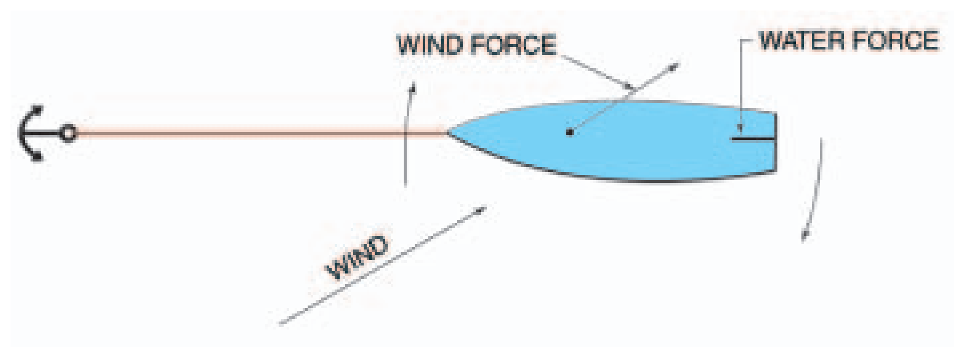
Air forces

However — and this is a critical point — when the boat is at anchor and the sails are down, the mast and rigging act as the feathers on the arrow (see above). Since the mast and rigging are at the forward part of the boat, ahead of its center of gravity, the boat will be unstable and will develop a violent motion in strong winds, such as those with a hurricane. The force on the mast and rigging of a conventional 40-foot sloop will be about 800 pounds in a 75-mph wind. When anchored from the bow in a hurricane the boat is, in effect, moving forward through the air at a speed of 75 mph, a situation similar to a boat on a trailer being towed at 75 mph.

An unstable system

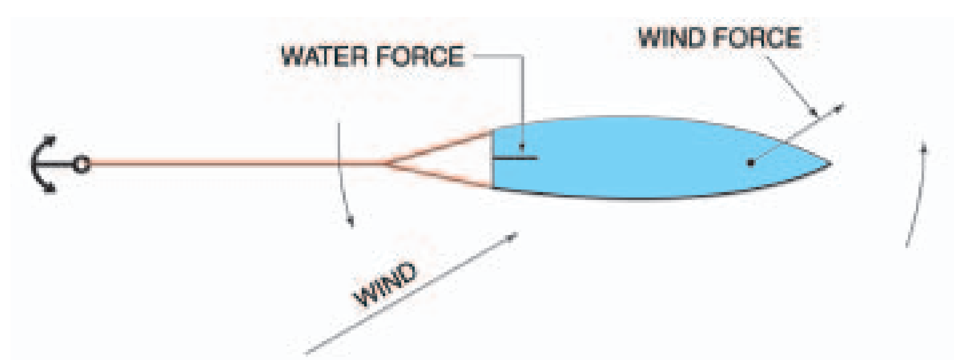
A tethered boat will be unstable if, when the boat yaws due to a wave strike or change in wind direction, forces will be created that act to yaw the boat further. The boat will continue to yaw until fetched up and brought about by the load from the tether.

The sketch below shows a boat tethered from the bow. A wind shift of 30 degrees strikes the boat. The boat starts to move sideways. The air force on the mast and rigging tends to move the bow farther away from the wind. The sideways motion also causes water loads on the keel and rudder, which move the stern upwind, thus further increasing the yaw.



A stable system

A tethered boat will be stable if, when the boat yaws, forces will be created that act to reduce the yaw and return the boat to its original course — or in this case, turn the boat into the new wind direction. This sketch, below, shows the boat tethered from the stern. The air force on the mast and rigging now acts as the feathers on the arrow and aligns the boat with the new wind. Also, the water forces on the keel and rudder now act to align the boat with the wind. The higher the wind and water forces, the more firmly the boat will be aligned. Many skippers have commented on how aggressively the series drogue holds the stern into the wind and waves in a storm at sea.



An engineered design for moorings

To design a dependable mooring system it is necessary to establish a reasonable maximum load, which will cover all anticipated storm conditions. To my knowledge, this has never been done. Moorings have evolved empirically over the years. If moored yachts are unstable and sail back and forth, it is difficult to establish the

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peak loads. The maximum load will occur when the yacht reaches the end of the excursion and is blown flat. This load can obviously be relatively high. The air loads can be high since the boat can be broadside to the wind. In addition, the air loads can be greatly augmented by dynamic or inertia loads as the boat is yanked to a stop, blown flat, pivoted 180 degrees, then accelerated in the opposite direction.

The most common form of failure is chafing of the tether as the load goes from zero to maximum in one direction, then from zero to maximum in the other direction. The transient loads continue for hours during the course of a hurricane.

If the tethered boat has adequate directional stability and weathercocks into the transient wind shifts, the maximum load on the mooring can readily be predicted with acceptable accuracy for design purposes. There will be no significant dynamic forces. The forces from the 4- to 6-foot waves formed in the harbor by hurricane winds will generate very low loads.

The primary loads will come from the air loads on the hull and rigging caused by the hurricane-force winds. Fortunately, very complete data on the aerodynamic drag of all reasonable objects are available from testing in wind tunnels and other facilities.

If we consider a typical modern 40-foot sloop-rigged yacht in a hurricane rated at 100 mph, we know from boundary layer measurements that the velocity near the surface will be less than that of the main stream because of friction with the water surface. The velocity near the water surface will be about 60 mph, at the mast 75 mph. Under these conditions, the drag of the hull, facing stern to the wind, will be about 300 to 400 pounds, and the drag of the mast and rigging will be 700 to 800 pounds. We might use a conservative estimate of 2,000 pounds for design purposes. The breaking strength of a 3/4-inch nylon mooring line is 16,000 pounds.

Chafing should be avoided easily when the load is relatively steady in magnitude and direction. There is no technical reason that a mooring should fail in a hurricane. In fact, a properly designed mooring may well be the safest haven for a sailing yacht in a hurricane, far safer than a crowded marina or a quickly chosen hurricane hole.

To conclude this discussion we might ask why, over thousands of years of sailing experience, did sailors not realize that a sailing yacht should be moored from the stern, not the bow. The answer lies in the difference between the design of traditional vessels from the age of sail and the design of modern sailing yachts. Traditional vessels had long, straight keels running all the way to the stern. The rudder was small and did not extend below the keel. They were mostly schooner- or square-rigged, and they were heavy and deep in the water. The resultant wind force on the masts and rigging was abaft the center of the boat. As a result, they came about slowly and often with some difficulty.

Conversely, modern sailing yachts have short, deep keels and a cutaway forefoot. They also have powerful rudders and are lightweight. The single mast is tall and located forward of the center of the boat. These features are necessary to obtain good upwind performance and agility when coming about. However, they make the boat highly unstable when tethered from the bow in a strong wind. Fortunately, the more unstable a boat is when tethered from the bow, the more stable it will be when tethered from the stern.

Fifteen years of experience with the series drogue tethered at the stern has demonstrated that, with hurricane-force winds and even when buffeted by large, breaking storm waves, the boat will ride quietly and will quickly adjust to wind shifts and random wave strikes.

There can be little doubt that a proper stern mooring would have saved many of the moored boats that were destroyed in the four hurricanes that struck Florida in 2004. ■

Donald J. Jordan, developer of the series drogue, is a retired engineer and longtime sailor from Glastonbury, Conn.