STABILITY SOLUTIONS

Looking At Why Boats Roll—A Noted Naval Architect Reviews Alternatives To Reducing Roll And Improving Stability
by Charles W. Neville

The basic premise is that a yacht is supposed to travel through the water with the top side up and the bottom side down. Almost all the calculations that the designer or naval architect does are predicated on this simple principle. If, instead, the vessel of your dreams (or the one defined by your pocket book) rolls and wallows around as you struggle to get from point “A” to point “B”, then there are two things you can count on. One, the performance characteristics of your vessel will be significantly reduced—as hull resistance and an inability to maintain momentum significantly degrade your overall speed potential. The second is that you and your crew will be in for a really foul time afloat.

However, there is more at stake than simply the inconvenience of a slow passage. There is the question of safety. In vessels rolling uncontrollably, the potential for gear and equipment failure escalates. To that add increasingly short tempers, bad or sluggish judgment, and minor mishaps caused by sheer fatigue. Any or all of these can start a chain of events that leads to otherwise excellent vessel and competent crew toward serious jeopardy.

Hull Design Isn’t Enough
The question of roll goes deeper than good hull design. In relatively small vessels there is no combination of length, beam, and draft that can overcome the uncomfortable ride that a treacherous, angry sea can dish out. Good hull form can improve a vessel’s motion in terms of roll period and such, but only up to a point. (In a future article we will examine the theoretical stuff; why one hull rolls more than another and how the general geometry of the design can affect your comfort.) Hull form is not the whole answer. For extensive time spent offshore, some form of roll control is essential. Here are some suggestions and options available to improve motion afloat:

Hull influenced changes
- Shifting weight or changing ballast
- Modifying the hull in some way such as adding sponsons or some other major face lift
- Attaching bilge keels
Other additions or alterations
- Fitting steadying sail or sails
- Adding a paravane system (Also known as a “flopperstopper rig”)
- Fin stabilizers—controlling roll with horsepower
- The exotics—from anti-rolling tanks, or a Flume™ Stabilization System.

No Simple Answer
Whether you are building a new vessel, or considering modifying an existing one, it is important to realize that none of these options are really sim-
ple. Each carries with it a cost, in most cases a significant cost.

Like most of us, you probably want your efforts (and expense) rewarded by a significant improvement in vessel comfort. It is a sad fact, however, that you can spend a ton of money achieving singularly unimpressive results. So tread slowly.

**Hull Shape**

Let's look at hull shape. Some designers and many salesmen may disagree, but after drawing boats for almost twenty years it has become painstakingly clear to me that there is no perfect hull shape. This is true when considering most characteristics, including roll. Why do I think this?

Well, the question of roll and comfort is surprisingly subjective. What one owner may call a “comfortable languishing roll” may by another be conservatively labeled a “roller coaster ride from hell.” Since it is very hard (and expensive) to make significant hull changes after the boat is already built, let’s look at a few basics.

Typically the slacker the bilges (the more barrel shaped the underwater hull looks viewed head on) the less outside force it takes to make the vessel roll. This shape, combined with the location of the vertical center of gravity (VCG), have the biggest influence on roll. VCG is simply the theoretical center of the weights of all parts and pieces of the boat, its stores, and equipment.) Above water components (like a high deck house) also have an effect, but generally in the form of raising the VCG or adding exposed windage.

Making changes at the hull level can involve either trying to modify the underwater shape in some way, or trying to shift the VCG to a position that is perceived to be more desirable.

**Changing The Hull**

Attempts made to “significantly” modify the hull shape itself usually involve some form of major surgery. For example, sponsons (pods located outboard near the waterline), or some other structure could be added in the hope of minimizing an undesirable roll.

Occasionally, attempts are made to modify some offensive characteristic by either filling in or cutting away some part of the hull. Be extremely careful with such drastic changes. If you plaster additional stuff on the bow or along the bilge in an attempt to change some negative characteristic, it can be extremely difficult to predict whether the net change will really be an improvement or a complete disaster.

We are sometimes asked to add a stern extension to improve a boat’s performance. On the surface the plan sounds reasonable enough. But after closer examination, it often becomes clear that the additional weight being added to the hull totally negates any performance improvement. A lot of work and expense to reap minimal gain.

So such is the danger of any hull change.

**Changing Ballast**

Many slower speed vessels carry ballast in one form or another. Manipulating this ballast can change the vessel’s VCG. In the best cases, modifying ballast (amount and location) is used to fine tune performance, including the rolling characteristics of a boat.

Some of us even like to add a modest amount (say between 5% and 10%) for the sheer heft feeling it adds to the mass of a small vessel.

Often ballast is lead, iron, or concrete, but liquids can also be used as a form of ballast. Sometimes ballast is transferable, intended as a way of offsetting the weight of depleted fuel.

If liquid ballast is carried, it should be carried in tanks designed and built for that purpose. These ballast tanks should be kept fully filled. The liquid inside should not be allowed to roll around freely. If the water is allowed to shift under way it can create what’s called a “free surface effect.” The moving liquid can aggravate the existing roll, reducing stability even further instead of improving it.

Particularly ex-sailboaters must be cautioned that when it comes to weight or ballast, lower is not necessarily better in displacement motor yachts. Too much ballast down low results in a very stiff boat with a very low VCG, which can be as bad as a boat that rolls too much. A very low VCG can develop a violent motion that politely reminds you why you don’t want to drive the average sport fisherman to Europe!

To increase the roll period of a vessel you could shift or add weight up high or outboard. To reduce the roll period you could add or shift weights lower down in the hull.

I was recently back aboard one of our boats that highlights my point perfectly. At the 1979 launch of Namaste, a 48 foot Durbeck built, Steve Seaton design that I worked on, we determined that the initial roll period of the vessel was shorter than the owner wanted (around 3.5 seconds)—he found the motion quite uncomfortable. So we decided to add about two thousand pounds of ballast up under the fly bridge some distance above the water. That additional weight increased the roll period to a much more desirable 4.5 seconds, and the owner was quite satisfied with the changes.

In modest amounts such alterations are not likely to control whether a boat does or does not roll in a serious seaway, but more likely to adjust the quality of that roll. It’s a matter of comfort.

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this until you talk to your trained professional." Even so, I must warn that you shouldn't make changes like this without being able to mathematically predict what those changes are likely to do. You may improve a vessel with good ultimate stability, but you could just as easily put in jeopardy a vessel with marginal stability. It is best to consult (grudgingly) "your trained professional."

Bilge Keels

The third hull shape option we have noted is really an appendage—bilge keels. Bilge keels are a common addition to large ships to help passively control rolling. They are also one of the simplest and oldest anti-rolling devices.

Bilge keels are projections that are attached to the hull at approximately the turn of the bilge and at approximately right angles to the hull itself. Bilge keels typically extend between one-half and two-thirds the length of the boat.

Most often one long bilge keel is fitted to each side, although sometimes two or more small ones are used. To minimize resistance, bilge keels should be positioned along the streamline, which is the course the water takes as it flows along the vessel. Unfortunately that is a difficult location to find without the help of model test information.

Bilge keels work in two ways. As the vessel rolls, the keels' primary contribution is to throw off additional turbulence into the water that surrounds them. As they do so, there is increased resistance produced, which reduces roll.

A smaller secondary component of their effectiveness is that the bilge keels "entrain" the water that surrounds them as the boat rolls. That means the boat acts as though its mass has increased because of the water that is moving along with it. This additional mass (of water) results in a small increase in the roll period of the vessel itself.

It should be noted that bilge keels are much more effective when the vessel is moving than when it is at rest—implying that there is also a hydrodynamic component to their effectiveness. Bilge keels can only be considered a method of reducing roll, as they will never completely eliminate that roll. And a roll must exist for them to have any effect at all.

There is little question that bilge keels work. Throughout the world's large ship fleets, bilge keels are used on almost every type of ship regardless of its size or service. They are also popular on large commercial fishing vessels. They remain a popular choice because of their simplicity, economy, and effectiveness. This is particularly true when they are added to a new vessel.

Unfortunately on smaller vessels the net gain in comfort that they offer is not extraordinary. Bilge keels can produce reduction in roll magnitude on the order of 10 percent in ships, some say as low
as 5 percent in smaller vessels. If a vessel is rolling 10 degrees and you decrease that roll by 5 percent, it is still rolling 9-1/2 degrees. If it was rolling 20 degrees, it would still be rolling 19 degrees. It is a reduction, but certainly not significant.

**Steadying Sails**

Steadying sails are the first item in our category of “additions and alterations.” In a sense they serve a function similar to bilge keels, only using air as their medium instead of water. The problem with steadying sails is also a question of effectiveness. Do steadying sails work?

Yes, but unless you are talking “motsailer” proportions, most rigs aren’t tall enough, nor sails big enough, to markedly affect a vessel’s performance in a seaway. They have an effect to be sure. They look shippy. They add character. They are better than nothing (if no other choices are available). But the typical postasage stamp sized steadying sails are not likely to make a major change to the comfort of the vessel.

There is an additional complication with steadying sails. If you do fit sails large enough (or effective enough) to make a difference, the whole system better be stout. With a large rig, the mast and other components can take an enormous load as the sails try to level out roll. The size of equipment, and the reinforcement at the mast step, chain plate, and stay attachments should be carefully considered.

**Let’s Get Serious**

The problem with all of the systems we have considered so far is that they only have a modest effect on the roll of the vessel. If you are looking for more dramatic effects, however, there are still other systems you should consider. Without question the most effective of the so-called “passive stabilizer systems” is a paravane system, commonly known as a “flopenderstopper rig.” And they work.

**Paravanes**

The flopenderstopper rig is a system of mast, booms, and rigging all designed for the express purpose of towing a small delta-shaped device called a “paravane” or “fish” off the side of the vessel below the water’s surface. The system grew out of the commercial fishing industry where the boats were already rigged with mass and outriggers used for setting and retrieving nets. If you have seen commercial fishermen with long booms hanging out to port and starboard you have seen the essence of the flopenderstopper rig. The good news is that yacht systems can be made much more attractive and less complicated.

The mast and boom part of the system should be ideally located between 25%–30% of the vessel’s waterline length measured from the stern.
These spars must be very rugged. When the system is working it will transmit enormous loads back to the hull. Where each of the elements of the system are attached to the hull or deckhouse, the whole structure must be seriously reinforced. The mast and booms should be located adjacent to a bulkhead or other major load-bearing structure. If this is not possible the structural system gets even more complicated. Then you have to structurally bridge windows or other areas that can not safely transmit such massive loads.

The stresses involved are among the major problems with installing a flopperstopper rig. The rigs are difficult to properly retrofit because it is important to adequately reinforce many different parts of the vessel. In addition, most often these are regions of the boat that are hard (and often impossible) to reach, making it even more difficult to properly and effectively stiffen the proper areas.

The visible parts of the system are the mast and rigging. However, the parts that make the system do its job are towed well below the water’s surface. These are the paravanes, the “fish” part of the system.

How Paravanes Work

The basics of the operation are as follows. The paravane looks like a small delta-shaped airplane with a large weight attached to its nose. For a 50 foot vessel, each fish would weigh about 45 pounds with about 300 square inches of surface area. Located at the top of the paravane is a series of holes for attaching the tow line. That series of holes allow for adjustment of the fish at different speeds.

When deployed, the fish hangs from a stainless steel tow cable. Alternately a length of high test chain can be fitted. This cable or chain is then usually attached to a length of nylon line which acts as a shock absorber—reducing the strains imposed on the rig and on the owner’s nerves. This entire tow rig is then attached to the end of long booms which project outboard from the sides of the vessel.

Two paravanes are used, one to port and one to starboard. The length of the tow line is usually fixed but can be made adjustable. When fixed, the length is designed to allow the fish to be towed at a constant depth with some adjustment of boom angle. As the vessel moves forward the paravane “flies” below the water’s surface. As the boat rolls, however, it begins to do its real job.

For example, when the vessel rolls toward the starboard paravane, the weight at the forward end causes the fish to dive deeper into the water. At the end of that roll, the vessel begins to roll back to port. As it does so, the paravane flattens out (because of the location of the attachment point). As the roll back continues, the vessel tries to pull the flat shape of the fish up through the water. (Imagine pulling any large flat object through the water when its surface is perpendicular to the pull. This creates a tremendous amount of resistance based largely upon the surface area of the object.)

As the vessel begins its roll back towards the starboard paravane, the procedure is repeated with the port paravane, causing even more resistance. With each oscillation, the roll decreases until the entire motion of vessel moderates.

Flopperstopper systems do work, and they do work well. So why aren’t flopperstoppers more prevalent? It is a question of their effectiveness. A properly-sized rig can reduce the roll in a seaway by two-thirds. Special pan-shaped devices can replace the fish and make the system even effective at anchor.

The answer to that question is a function of several things—cost, ease of installation, simplicity of operation and, quite frankly, looks.

First of all, if properly designed and installed, flopperstoppers are not cheap. There are masts, booms, running and standing rigging, the paravanes themselves and all manner of other small parts and pieces. All of this gear is required in fairly massive dimensions, making quality equipment pricey. And as we have said, in new construction or as a retrofit, there may be many structural modifications necessary even if the hull is basically suitable.

Second, flopperstoppers take some effort (sometimes quite a lot of effort) to use. You are working on deck, usually in nasty, dangerous weather conditions. While you are getting ready to first deploy the system, there is no roll control available, and the vessel’s motions may well be at its most severe point. Launching the vanes is not difficult. It is generally a matter of pitching them overboard well away from the hull sides. The difficult part is that the boat is rolling wildly, you are struggling to hold on, and the booms and rigging are now loose from their stowed positions, swinging around dangerously.

Under way the system is relatively benign. Here the concern is being comfortable with the strength of the system—that everything will stay together as it should. A proper installation should be bulletproof.

There is also some concern about using the system in shallow water. If you are towing the fish at 15 feet below the surface, you had better have a good depth of water under the keel for safety. This can be a problem, since very often roll control is out of the question when you need it most—coming through a shallow inlet or other shoaling area, the water depth may not allow you to use your stabilizers.

Under way paravanes are also noisy. They transmit a whine through the wire that can take some
getting used to. Other parts of the rig can similarly create weird and wondrous noises plus significant vibrations. Be warned.

The most troublesome aspect to using a flopperstopper system, however, is retrieving the fish. Here again you are often in the nastiest of conditions, leaning over the side, trying to retrieve 45 pounds of steel from a rolling heaving platform. It is easy to picture many unpleasant scenarios.

Various systems and methods have been tried to simplify this procedure. But any way you look at it, retrieving the vanes is a time when safety becomes a real concern. A moment’s inattention or something unexpected can present real problems.

The third reason is more personal. To some owners, flopperstoppers look salty and traditional. To others, they just look plain ugly. This is compounded by the fact that visually they don’t look right on some boat designs.

But here’s a generality for you. Ex-sailboaters seem more likely to take on the “flopperstopper” challenge. They are used to seeing a lot of stuff dangling from poles about their boats. They are also more likely to accept the task of having to pull and tug on ropes and things from time to time.

**Active Fin Systems**

Don’t you just wish you could throw a switch and make it all go away? Enter the discussion of fin stabilizers. Fin stabilizers are the first active system of stabilization that we have discussed.

By “active” I mean that the system employs some mechanical means of initiating a force to counteract the roll. The basic methodology of fin stabilization dates back to 1889 when Sir John I. Thornycroft secured a patent on such a device. Its use in small vessels, however, is much more recent, probably not coming into prominence until after World War II.

Fin stabilizers create their own force, designed to provide an equal but opposite reaction to the force of the waves causing the vessel to roll in the first place. One or more sets of fins are generally located below the turn of the bilge within the middle third of the vessel’s length.

These fins, which look much like spade rudders on a sailboat, are energized by hydraulic or pneumatic rams. On command these actuators cause the fins to quickly rotate a fixed amount, flipping in opposite directions. The fin on the high side of the rolling vessel swings its leading edge downward. The other swings its leading edge upward. Together they create a counteracting roll.

If you have ever used an oar or rudder to scull a small sailboat or dinghy, you will easily understand how such a force can be used to generate an equal but opposite roll tendency. As a roll begins, the brain of the system tells the fins to swing opposite the roll. If the vessel is about to roll to port, the fins produce a counteracting force to starboard.

If well managed and effective, the roll force from the seaway and the counteracting force created by the fins will offset each other and the vessel won’t roll at all (or at least not very much).

The control system is generally an electronic or hydraulic gyroscope (gyro) or some sort of gravity-dependent device. This is the portion of the system that senses the oncoming roll and then sends instruction to the operational machinery required to make the fins move.

How well the system works is generally a function of the size, location, and lift characteristics of the fins themselves, combined with the quality and sophistication of the gyroscope or sensing device. The whole system needs to be able to produce just the amount of force required without inserting a tendency to either over or under correct the roll. Besides their overall effectiveness, another

Namaste used a F/S system for 20 years, but was in Washburn’s Boat Yard last fall having an active fin system installed. Her skipper tired of the vane-handling effort, wanting instead the convenience of a modern fin system (top). Detail of fin and actuator (below).
advantage of fin stabilization is the relative ease of installation. The most critical thing is having a clear spot (on both port and starboard) to mount the fin equipment and their actuators. That spot should be located within the middle third of the vessel’s length, and allow reasonable access for both installation and routine maintenance service.

The tip of the fins should be located well inboard of the maximum beam of the vessel to protect the fins when docking or when working close to other vessels. Because the loads produced by the fins are quite large, some analysis should be done to assure that the area of the hull chosen is of adequate thickness. The addition of stiffeners or other reinforcements is not uncommon to assure the required strength.

What about speed? Fin stabilizers are most effective at speeds between seven and eighteen knots. Under seven knots (or at rest) there is simply not enough water flowing over the fins to make them work properly. Above eighteen knots they should not be needed. The dynamics of the vessel operating at higher speed tend to reduce roll. Also, if you do fit fins to high speed vessels, they must be quite small to keep from producing violent rolls at those higher speeds. If the vessel then slows down to handle heavy weather and seas, those same smaller fins are too small to work well.

For vessels that normally operate at higher speeds, there are systems which lock the fins in a neutral position, so the fins won’t create additional negative drag. Fins are also available that retract back into the hull when not needed.

The presence of fin stabilizers does create some drag, which can affect the speed and performance of a vessel. At displacement speeds this extra drag is probably minimal. But this drag becomes more significant in vessels operating at semi-displacement speeds or climbing the hump into the planning region.

However, even with additional drag from operating fins, it is still possible to see a net fuel savings of around seven or eight percent in seaway conditions. This happens because, from a practical point of view, roll reduction allows the vessel to operate much more efficiently. A vessel tracking a course on an even keel with good flow to the propeller is operating at a much greater efficiency. So the added drag can be offset by fuel savings.

Unfortunately, in flat calm conditions, fins are just another appendage with unnecessary drag. The most serious negative to fin stabilization seems to be cost. The systems are not cheap. Adding stabilizers to a 48-foot boat can cost about $30,000.

Despite the initial high cost, they are simple and reliable. Modern fin systems are the most likely choice to give you the payoff you expect in serious roll reduction.

Most cruise ships are fin stabilized. These systems routinely reduce the amount of roll experienced by the cruise lines by 75% or more. In some conditions they are as much as 90% effective.

Water Ballast

Whenever I get into a lengthy discussion on the subject of roll stabilization systems, eventually someone will say, “why couldn’t you just have some kind of tanks connected together and let the stuff moving back and forth inside the tanks somehow reduce the roll...” The simplest answer is, you can. Particularly in the big ship fleets, many types of internal tank systems have been designed over the years to help counteract rolling. The ship’s operators have had varying degrees of success. Although we once got a quote to install such a system in a 70-foot motor yacht design, I must admit that I have seen little evidence of the acceptance of this technology in small to moderate sized motor yachts.

Such systems can be active or passive in their operation depending upon the specifics of what makes them work. Generally these systems use gravity in one way or another to move water. This is probably because the thought of pumping high speed streams of water back and forth is even more scary than the thought of the more tranquil fluid rolling around inside your boat.

Active Fram Tank System

A fram anti-rolling tank system is an example of an active system. A fram anti-rolling tank consists of U-shaped tank assembly. Larger tanks are located to port and starboard often fairly high up in the hull. They are interconnected by a smaller horizontal section. The taller side tanks are also connected across the top by an air line equipped with valves. The mechanical manipulation of these valves controls both the amount of water, and the delivery time relationship between the roll of the ship and the transfer of water between the port and starboard tanks. The valves are adjusted so that water is always running downhill to the tank on the lower side. This transfer creates a restoring moment which attempts to counteract the ship’s natural roll.

These systems are normally designed to be effective over a very narrow range of sea conditions. Unfortunately, when compared to a large ship, a trawler sees a wide range of sea conditions relative to her small size. As such I doubt the practicality of such a system in a small motor yacht.

Passive Flume™ Stabilization

A Flume™ Stabilization System is a passive type of system developed by a company called, understandably, Flume Stabilization Systems. Their market is mostly larger ships. A Flume system makes use of two or three transverse tanks formed by dividing a single larger tank. These inner tanks are
interconnected with a system of nozzle structures. These nozzle structures are used to control the movement of water within the system in such a way that a roll damping effect is generated independently of the vessel's speed. The system is tuned to a very narrow range of sea conditions. Adjustment of the liquid level within the system changes the system's response as the seaway changes. Such changes are small, and don't happen quickly.

Again, I have seen little evidence that these types of systems have been used much, if ever, in small motor yachts. In addition to questionable effectiveness and practicality, there are other significant negatives. The tanks and connecting structures take quite a bit of space away from accommodations. The vessel must also be able to carry the additional weight of water that is being used for stabilization. I expect the cost in new construction would also be high, and the possibility of retrofitting a system almost nonexistent. All in all, these methods of stabilization are probably far from the best choice for your trawler.

If any readers do have any additional information on water systems in small vessels, I'd love to review or reconsider it.

To Sum It Up

If you are serious about cruising for long periods of time with the potential of being caught offshore in the bad stuff, some form of stabilization should be a primary concern. Look at the different types of systems or structures that are available, and determine what makes sense for you.

And whichever method you choose, make sure that the money you spend is equivalent to the amount of relief you'll receive from your vessel's rock and roll.

For More Information:

**Active Fin Stabilizer Systems**

Naiad Marine Systems, 50 Parrot Drive, Shelton, CT 06484

800.760.NAIAD, 203.929.6355

Seabreeze Stabilizers/Barrett Marine, 106 Mill Plain Road,

Darien, CT 06820, 800.999.4074

Wesmar Stabilizers, 14120 NE 200th Street, PO Box 7201,

Woodinville, WA 98072-7201, 206.481.2296

**Other Suppliers**

Kolstrand Marine Supply (Paravane Equipment)

4739 Ballard Ave NW, Seattle, WA 98107, 206.784.2500

**Selected Reading (availability of last three unknown, but worth a search)**


revised by James F. Leishman: Published 1994 by

International Marine, Camden, ME.

*Principles of Naval Architecture, Volume 1: Stability and

Strength*, edited by Edward Lewis: Published 1988 by the

Society of Naval Architects and Marine Engineers

*Introduction to Naval Architecture*, by Thomas C. Gillmer

and Bruce Johnson: Published 1987 by Naval Institute Press,

Annapolis, MD.

*Fishing Boats Of The World I*, Edited by Jan-Olof Traung,

5th reprint 1978: Published by the Food and Agriculture


*Design of Small Fishing Vessels*, Edited by John Fyson:

Published 1985 by the F.A.O. of the United Nations.

*Motor Yacht And Boat Design*, by Douglas Phillips-Birt,


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