The Use of Roll Stabiliser Fins at Zero Speed

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Abstract

To reduce the roll of an anchored ship passive anti-roll tanks have for years been the only viable option. Now however, a novel development makes it possible to use stabiliser fins for this purpose. This paper explains the principle behind the ZeroSpeed^{TM} system, compares it with the passive anti-roll tank and discusses results of model tests with the new system.

Introduction

For many years fin roll stabilisers have been used to reduce the roll of a ship in a seaway. Their use on motor yachts is more recent but today they have become standard issue in the mega-yacht sector.

A much-cited disadvantage of fin stabilisers was that they worked poorly at low speed and not at all when adrift or anchored. The simple reason for that was the basic principle of stabiliser fins which depends on the flow of the water past the fins. When the speed is low or zero then the stabilising lift force becomes very small and at zero speed vanishes altogether. This was a major drawback of fin roll stabilisers.

Recently a novel approach was developed allowing the use of fins when the ship is adrift or anchored. In this paper the new concept will be explained and its relative merits with respect to anti-roll tanks discussed. In conjunction with De Voogt Naval Architects and the MARIN ship research institute model tests were carried out to quantify the performance of the new system and compare the results with that of an anti-roll tank. The tests will be discussed and the results presented. Additional information on this subject can be found in [1}, [2] and [3].

Roll stabilisation at zero speed

Roll stabilisation capability at zero speed is a welcome asset for mega-yachts. These ships often spend days on end anchored in a more or less sheltered bay. When a swell enters this bay and has a period that is near the natural roll period of the moored vessel the ship can start to roll heavily, even at small wave heights. As large motor yachts have a roll period of somewhere between 6 and 11 s and swell can have a period of anywhere between 7 and 14 s this is a regularly occurring problem. The conventional fin roll stabiliser system fails to provide stabilisation under these zero speed conditions. So, over time several concepts were developed to provide that capability. Of these only the well-known anti-roll tanks proved viable. The main advantage of such a tank is that it works over the whole speed range of the ship, hence also at zero speed. Although there are both passive and active anti-roll tanks the passive one is by far the most common. However, a serious drawback is that either its roll damping capacity is limited or otherwise it has to be made quite large (up to 5 % of the ship's displacement). This increases the displacement and takes up much internal space. Therefore, in practice modern motor yachts with an anti-roll tank are also equipped with fin stabilisers to provide sufficient stabilisation capacity when underway. The tanks are then mainly intended for use when adrift or anchored. This approach has merit but means that there are two systems to design and maintain and there is still the space loss and increased displacement associated with anti-roll tanks. A compact integrated system for both underway and zero speed stabilisation is obviously preferable.

Using stabiliser fins at zero speed

In 1998 another zero speed stabilisation concept was introduced when the M.Y.

Figure 1 Standard (right) and zero speed (left) fin shapes.

Boadicea was equipped with a roll stabilisation system using the stabiliser fins to stabilise when adrift or anchored. This system used the fins in a different way when operating in zero speed mode. However, as the system can also be used in the conventional underway mode it meets the desirable requirement of a single integrated system for both underway and zero speed stabilisation. The results with this system were very promising and after a few years it was commercialised jointly by Quantum Controls of the Netherlands and Quantum Marine Engineering in Florida, USA. Going under the brand names OnAnchor™ and ZeroSpeed™ at present 18 ships have already been fitted or retrofitted with zero speed stabilisation. Users report very good performance and are extremely satisfied with it. So how does this wonder system work?

Operating principle

The operating principle is based on the "paddle principle" which can be illustrated as follows. Suppose somebody standing in a small rowing boat in calm water and having an oar over the side with the blade flat, immersed in the water and pivoting in the thole. If that person starts moving the blade up and down a force is exerted on the boat's gunwale that will cause the boat to roll. A number of observations can now be made.

- The faster the oar moves through the water the larger the drag force needed to move it. This increases quadratic with speed. So if the oar is moved slowly the force is small.
- When starting the motion or changing the oar's speed a certain mass of water is accelerated or decelerated which gives an additional mass force.
- If the person in the boat moves the oar in a regular way and starts slowly and then gradually faster then:
  - the boat will roll just a little when the oar is moved slowly because a relatively large force is needed to heel the boat but the force generated by the oar is small;
  - the boat will gradually start rolling more and more when the oar is moved faster and faster because the force generated by the oar is increasing;
  - at a certain point the boat will roll a lot with only a moderate amount of effort. The time for a full roll from one side to the other and back is at this point equal to the natural roll period of the boat;
  - if the oar is moved even faster and faster the boat will again start to roll less because the inertia force of the boat increases also very rapidly thereby cancelling the effect of the increasing oar force.

What the observations illustrate is that the boat rolls quite easily at its natural roll period and that the force on the oar has drag and inertia contributions.

If waves exert a force on the boat it is clear that the boat will also roll easily when the wave period is equal to the boat's natural roll period. If the person on board is now observing this roll motion and starts moving the oar in such a way that the force he/she generates opposes the wave-induced roll action he can reduce the roll dramatically with only moderate effort. If instead of sticking out in a transverse direction the oar was made to pivot on an outrigger on the boat and then turned 90 degrees so that it is parallel with the boat and the oar's blade is moved up and down again then the system works equally well. If as a next step this 90 degree rotated oar is replaced by a fin-sized contraption with a sufficiently large chord and a low balance then the principle is still valid.

The ZeroSpeed™ system employs this principle to reduce the roll motion. Here the oar is replaced by the fin. This fin does not have the normal plan form and balance. Instead the fin has less balance than a normal fin and also the chord is increased to have maximum sweep area (see figure 1). Having this plan form gives high speeds (and hence drag forces) near the trailing fin edge and a large catchment area where water is trapped and accelerated or decelerated. Moreover, there is minimal cancelling effect which happens with a more balanced fin where large amounts of water are moved in opposite directions meaning that the forces needed for that partially cancel each other. All the observations about the boat-oar system also apply to the ZeroSpeed™ system.

In practice the fin motion is controlled by a controller. A roll sensor continuously measures the roll of the ship and sends this information to the controller which controls the fin rotation. Initially the fin is waiting at a certain start angle of around 30 degrees with respect to the centre position. At the right moment the fin starts rotating, accelerating until a certain rotational speed is achieved. When approaching an angle of 30 degrees in the opposite direction the fin decelerates to stop at this position. There it waits again until in the next half-roll it moves in the same

	ZeroSpeedTM		Anti-roll tank (passive)
+	- Works underway and at anchor	+	- Works underway and at anchor
+	- No extra internal space required beyond that used by ordinary stabilisers	--	- Takes up valuable space (1.5 to 4 % of displacement filled with water plus extra air space, ducts etcetera)
+	- Can be easily retro-fitted	--	- Very difficult to retro-fit
+	- Equal or better performance than anti-roll tank in typical conditions	--	- Insufficient capacity for good underway performance, most of the time augmented by fin stabilisers.
+	- Only one system to install and maintain	--	- Two systems to care for when additional fin stabilisers are fitted.
+	- No extra displacement	--	- Displacement increases
+	- Better behaviour in quartering following seas when underway	--	- Can show undesirable behaviour in stern quartering and following seas
		--	- Reduces static stability of ship
+	- Suitable for later improvements in control algorithms	--	- Hard to modify or update
		+	- Proven solution
--	- Some extra drag	+	- No drag due to fins (if no extra fins are fitted)
--	- Requires ship power	+	- No electrical/hydraulic power required (for passive anti-roll tank)
--	- More wear and tear on fin hull units		
--	- Potential for noise problems	--	- There are reports about noise caused by anti-roll tanks
		--	- Must be re-tuned when ship conditions change.

Table 1. Advantages and disadvantages of ZeroSpeed™ and passive anti-roll tanks.

way back to the initial position.

During the three stages of the motion, accelerating - high speed - decelerating different forces are generated. If the start moment is precisely timed with the roll motion then these forces can be made to oppose the roll motion and thereby reduce it. The start moment with respect to the ship's roll, the initial fin start angle, acceleration, maximum speed and deceleration are important parameters that must be carefully tuned to deliver maximum performance.

Pros and Cons

The only practical alternative to the ZeroSpeed^{TM} system is the use of anti-rolling tanks. To assess their relative merits table 1 lists their relative strengths and weaknesses. However, although the main advantages are clear there are three secondary points which are often brought up in discussions with prospective customers. These points are:

- power consumption
- wear and tear
- potential noise problems.

Power consumption. Unlike an anti-roll tank the ZeroSpeed^{TM} system needs power to operate. Using good load management techniques in the hydraulic power pack this has proven to be no insurmountable problem so far. However, it is possible that in a retrofit situation on board of an older ship generator capacity must be increased.
Wear and tear. The ZeroSpeed^{TM} system is clearly racking up more operating hours than a stabiliser system solely used underway. Hence yes, wear and tear increases. However, loads on the hull units at zero speed are not larger than underway and a well-designed hull unit is designed for continuous use. So, this point has not been

Decay tests				
Test#	**Fins**	**Anti-roll tank**		
1	Centred	Not operating		*Test conditions*
2	Operating	Not operating		*- calm water*
3	Centred	Operating		*- ship initially heeled and then released.*
Seakeeping tests				
Test#	**Wave height (m)**	**Fins**	**Anti-roll tank**	
4	0.5	Not operating	Not operating	*Test conditions*
5	1	Not operating	Not operating	*- irregular seas, wave direction 120 (stern quartering)*
6	2	Not operating	Not operating	*- wave spectrum used, JONSWAP, long-crested*
				- model restrained in horizontal plane by weak springs.
7	0.5	Operating	Not operating	*- runs 3, 10, 11 and 12 not reported here*
8	1	Operating	Not operating	*- fin timing at optimum setting*
9	2	Operating	Not operating	
10	0.5	Not operating	Operating	
11	1	Not operating	Operating	
12	2	Not operating	Operating	

Table 2. Test programme with model of 55 m motor yacht. All tests carried out at zero speed.

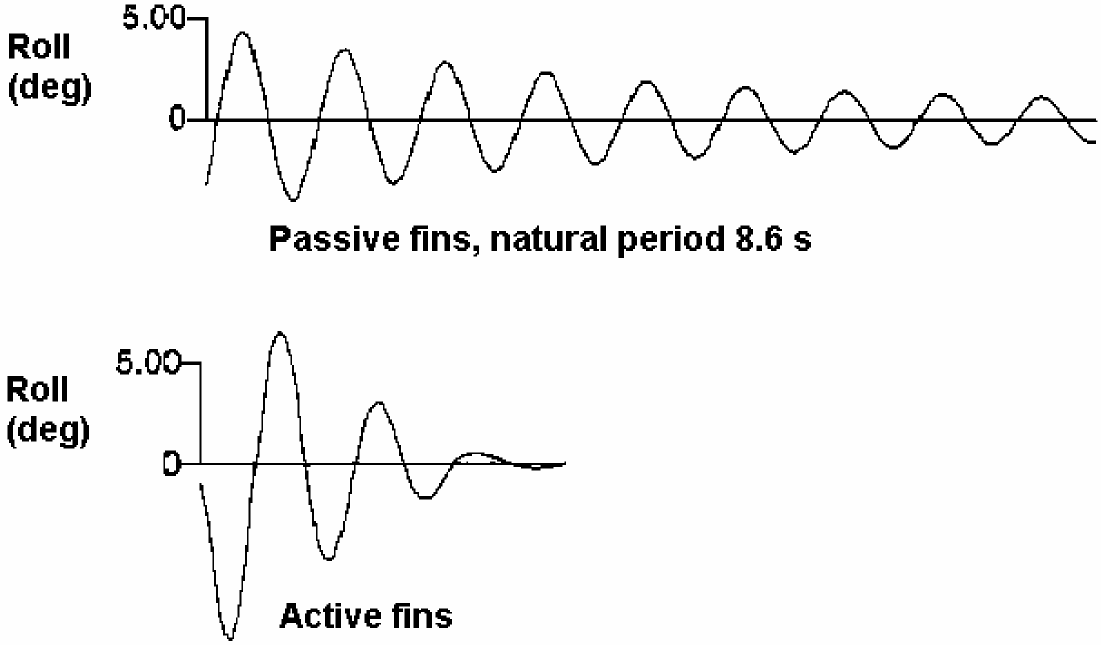

Figure 2 Results of a roll decay test without and with fins active.

an issue so far.

Noise problems. When the main engines are switched off, other noise sources become more dominant. Possible sources of noise in the ZeroSpeed^{TM} system are: the hydraulic power-pack; hydraulic lines and/or servo valves; and water noise. The preferred power-packs (Quantum Marine Engineering's QIS series) where designed with low noise in mind. Moreover, being placed inside the engine room adds another layer of isolation. Because fin units and hydraulic control valves are often placed inside the engine room what little noise they make is also well suppressed. In those cases where hull units were placed in or near staterooms local isolation eliminated possible problems. The water moved by the fins was reported by some customers who slept near the fins to be just audible but of an (quote!) "insomnia-curing quality". So far, no noise-related problems have been reported.

Model tests

Many people wonder about the performance of the ZeroSpeed^{TM} system. After all, it was foisted upon a system that was never intended for such an application. So, can the performance be on a par with established systems tailor-made for the purpose? A telling sign that it can is that throughout the history of the ZeroSpeed^{TM} system feedback from customers about the performance of the system has been very positive. These are qualitative assessments which are extremely important because they also include the perception of the customers. However, there is also a need for quantitative data, preferably obtained under controlled conditions which can only be achieved with model tests. Therefore a series of tests was planned and executed in May 2002 at MARIN. These were carried out using the model of a 55 m motor yacht with a natural roll period of 8.6 s and equipped with both an anti-roll tank and two fins of 3.8 m^2 each. The model was tested in an irregular long-crested stern quartering sea and zero ship speed. JONSWAP type wave height spectra were used with a (narrow) spectral peak at 8.6 s and significant wave heights of 0.5, 1.0 and 2 m. These conditions represented a worst-case roll

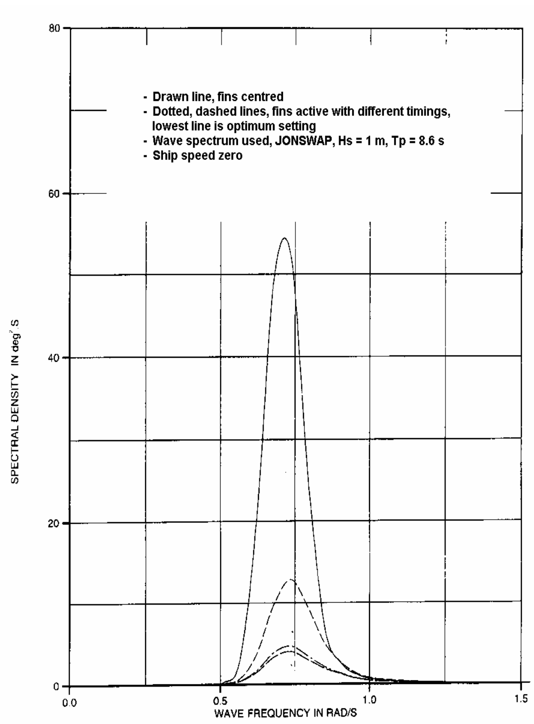

Figure 3 Roll spectrum with passive and active fins. Results of active fins shown for different timing settings.

scenario. The tests were carried out with fins centred, fins operating and with fins centred and anti-roll tank operating. Prior to these main tests some roll decay tests were carried out in calm water to establish the roll damping with centred and operating stabiliser fins and with centred fins and

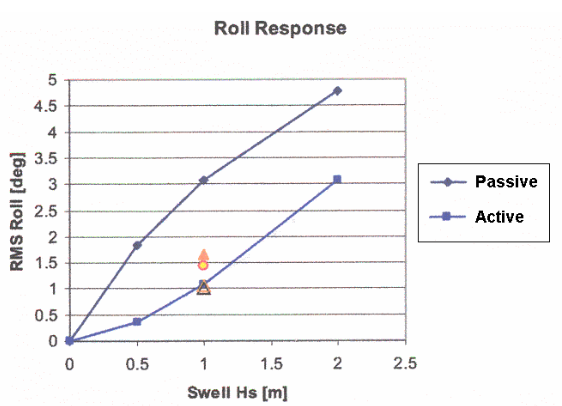

Figure 4 Roll angle with passive and active fins as a function of wave height.

operating anti-roll tank.

Table 2 gives an overview of the test programme. Unfortunately space does not permit a full discussion of the results. Figure 2 shows the roll decay of the ship with centred fins and with fins operating. In the latter case the damping has increased considerably which in practical conditions means less rolling. This was also proven in an irregular sea with a significant wave height of 1 m. Figure 3 shows the roll spectrum with the fins centred and operating with different settings of the fin timing. This figure shows two things, namely the:

- large influence of the fins
- importance of optimal fin timing.

Finally, figure 4 shows the significant roll angle as a function of the significant wave height and with the fins centred and operating. The reduction is very large, varying from 80 % at 0.5 m wave height to 40 % at 2 m wave height. The reduction of the performance at high wave heights is due to the system's limited capacity which at some point can no longer completely compensate the wave forces. However, at the much more typical 0.5 to 1m swell the performance of the system is very good indeed.

Final remarks

This paper attempted to: explain the principle of the ZeroSpeed™ system; the practical issues of implementing it on board of a ship; and its performance. It showed that the results are excellent. The technology used has proven itself repeatedly on board ships. This does not mean that there will be no further developments. Being a relatively new technology means that there is still room for improvement. At present Quantum Controls BV is working on:

- better fin performance prediction at zero speed conditions
- an even more optimised fin shape
- improved control algorithms.

Doing so will broaden the range of ships where this system is feasible and further increase its performance.

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