RECENT DEVELOPMENTS IN ROLL STABILISATION OF FISHING VESSELS

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ABSTRACT

A survey is made of the principal methods being used for roll stabilisation of fishing vessels in Australia. The vessels surveyed are generally of fifteen to twenty-five metres in length. The methods are described, with attention being paid to practical details of the operation. Developments in the methods are described, showing that improvements in operation have been made, and that there is potential for further improvement.

1. INTRODUCTION

Various methods have been tried over the years for damping the rolling motion of commercial vessels including, of particular interest in this paper, fishing vessels. These methods have had varying degrees of success, sometimes dependent on the skill of the operators, sometimes on the design and research effort. Many large vessels consider some form of roll stabilisation in the design as a matter of course, but this is often considered as an afterthought for small vessels.

Several types of fishing vessels use some form of roll stabilisation, including trawlers, drop-liners and long-liners. There has been significant growth in the size of the trawl fleet over the last twenty years from, typically from eighteen metres to twenty-three metres, and from having a slightly raised forecastle deck to having a full-height forecastle deck extending over half the length of the vessel. With bigger capital investments in vessels, there is more pressure to work in worse weather and, hence, more interest from the master and crew in equipment which can help to make the work on deck easier, including roll stabilisation.

This paper surveys the principal methods which have been and are now being used for roll stabilisation of fishing vessels in Australia, including the recent application of passive fins. The method of operation is described, together with practical details for operational effectiveness and advantages and disadvantages of the methods.

Some of the devices are hydrodynamically inefficient, but there appears to be little incentive for improvement due to the low order of cost of fuel in the overall operating costs. Roll damping performance is of prime interest to the operators.

2. ROLL STABILISATION DEVICES

2.1 Viscous and Wave-generation Roll Damping

Viscous and wave-generation roll damping are the two oldest forms of roll stabilisation, simply because they are present on the bare hull of every vessel. The underwater hullform, in addition to providing a viscous (frictional) force which resists the ahead motion of the vessel, provides a viscous force in the girthwise direction which resists the rolling motion, together with a wave-generation or potential flow component (unless the vessel is of circular cross-section) which also resists the rolling motion.

Some attention has focussed on viscous and wave-generation roll damping recently, with tests being carried out to see how well the theory can predict the experimental values, Hughes (1997) and Davenport (1998). The interest here is for the effects of changes in hullform on roll damping to be incorporated at the design stage.

2.2 Bilge Keels

Bilge keels may well be the second-oldest device for reducing the roll motion of vessels, and need little by way of introduction to most designers, builders, or mariners. They have been described by many authors; see, for example, Lewis (1988) and Saunders (1957). Typically they take the form of a flat plate (or pair of flat plates having a triangular cross-section with a narrow base at the hull) extending normal (or nearly so) to the hull at the turn of the bilge and extending lengthwise over about the middle one-third to one-half of the vessel, as shown in Fig. 1.

Bilge keels have the advantage that they are always operating, do not have to be swung into position or retrieved, and require little more maintenance (if any) than that of the hull itself. However, in order to provide the minimum resistance, they need to be well aligned with the flow around the hull. This is possible on a round-bilge hull, although not always achieved on small vessels, but is almost impossible to achieve on a hard-chine hull, where they are usually fitted along (or close to) the line of the chine.

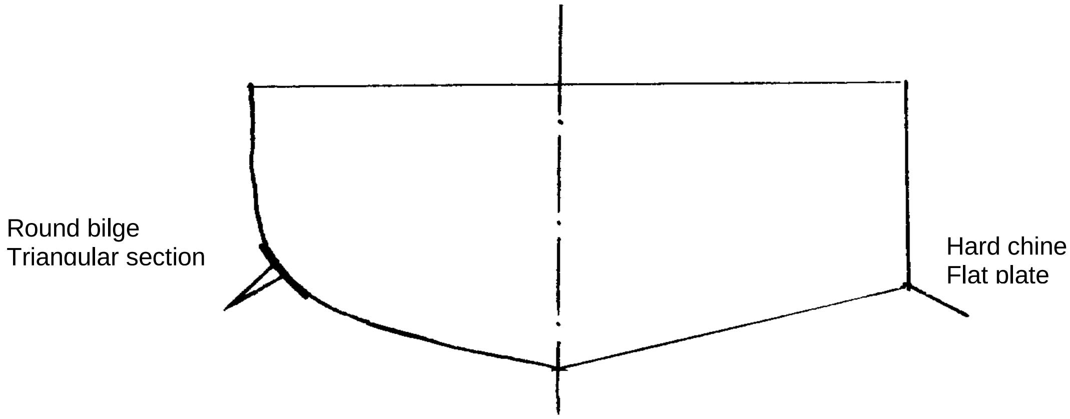

Figure 1 Bilge Keels

Bilge keels have recently been fitted to several 20–22 m vessels of both round-bilge and hard-chine hullforms, and have been of the order of 600 mm wide, which is about 50% wider than would usually be fitted to vessels of this size. The roll damping achieved is less than that by paravane stabilisers and, on the hard-chine vessels has been accompanied by an increase in fuel consumption of the order of 10–15%, and this option is not widely favoured.

2.3 Anti-roll Tanks

Anti-roll tanks use the motion of the fluid in a tank to damp the rolling motion of the vessel. The tank dimensions are designed to time the transfer of fluid to be equal to the natural roll period of the vessel, but ninety degrees out-of-phase with the motion. The fluid therefore provides a moment which opposes the rolling motion and decreases the amplitude of the roll.

These tanks come in various configurations, the most common being the free-surface (wing tanks connected by a narrow, full-depth channel) and U-tube (wing tanks connected by a narrow channel at the bottom (Goodrich 1969) as shown in Fig. 2. Design information is given, for example, in Cox and Lloyd (1977). The free-surface moment of the tank is significant, and the vessel must have sufficient intact stability to cater for the resultant loss of *GM.*

Free-surface tanks require tuning by adjusting the fluid level to provide maximum damping. Controlled-passive U-tube tanks usually have valving in the air path between the two tanks to control the air flow and, hence, the water flow between the tanks. Completely closing the valve effectively turns off the tank. Active U-tube tanks have sensors for the ship motion which provide feedback to a controllable-pitch propeller (located in the connecting duct) forcing fluid in the direction required to reduce the roll.

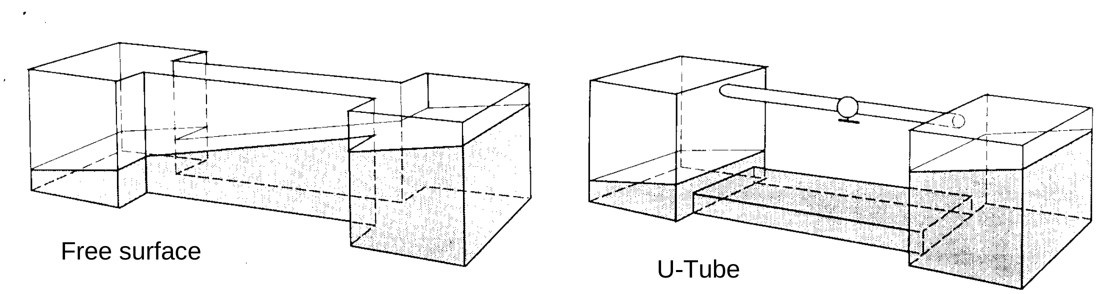

Figure 2 Anti-roll tanks

There have been many successful applications of anti-roll tanks to commercial vessels, a recent one reported by Dummett (1998) being the retro-fit of a passive tank on the deck of *Searoad Tamar,* a roll-on/roll-off vessel on the trans-Bass Strait service. Martin (1994) indicates that almost all fishing vessels over 45 m have passive tanks installed. However, applications to fishing vessels in Australia have been few. The two known to this author are:

Crystal Voyager was a 23 m trawler designed for the northern prawn fishery and built in 1975. The aft wing fuel tanks were designed with a large-diameter connecting pipe operating on a passive U-tube system. The vessel completed in Ballina close to the opening of the northern prawn season, and left on her first voyage north without having tested the anti-roll capabilities of the tanks. During the voyage, the engineer transferred fuel forward and then opened the cross-connection valve, and the roll motion almost disappeared. The master had a fright, and hurried to the engine room to find out what had happened! These tanks were highly successful, and the roll reduction was 60–70%, of the same order as measured by Bass and Friis (1997) in model and full-scale tests on two 19.8 m vessels.

Cape Grafton and *Cape Conway* were 19.8 m sister vessels also designed for the northern prawn fishery and built in 1978. They had a pair of high wing fuel tanks at about midships set up as a free-surface system, but using a novel set of removable dividers on the centreline for regulating the rate of flow of fuel. However, in their final configuration the vessels had insufficient stability for unlimited operation of the anti-roll tank, and the dump valves to the double-bottom tanks were left permanently open. This confirms comments made by Bass (1997) about stability being marginal with tanks in operation.

Anti-roll tanks take up space, and it is therefore preferable that they be integrated into the vessel at the design stage. The possibilities for retro-fit, especially to fishing vessels with premiums on hold space and deck working areas, are limited. However, given the success of this system in reducing roll amplitudes, it is surprising that there have been so few installations in small vessels.

2.4 Paravane Stabilisers

2.4.1 Flat Plate

Paravane stabilisers, commonly known as *flopper stoppers*, were originally used by US west-coast salmon fishermen (Hanson 1955, and Allan 1955). A conventional paravane is usually a delta-wing shaped flat plate with a vertical fin for tracking and a ballast bar, as shown in Fig. 3. A paravane is towed on a line (wire, rope or chain) from the end of a boom on each side of the vessel. When a boom end moves downward with the rolling motion of the vessel, the location of the ballast bar causes the paravane to dive, keeping tension on the line. When a boom end moves upward, the location of the towing point causes the paravane to take up a high angle of attack and provide a force resisting the rolling motion of the vessel. The paravanes on each side of the vessel alternately dive and provide a roll-damping force as the vessel rolls.

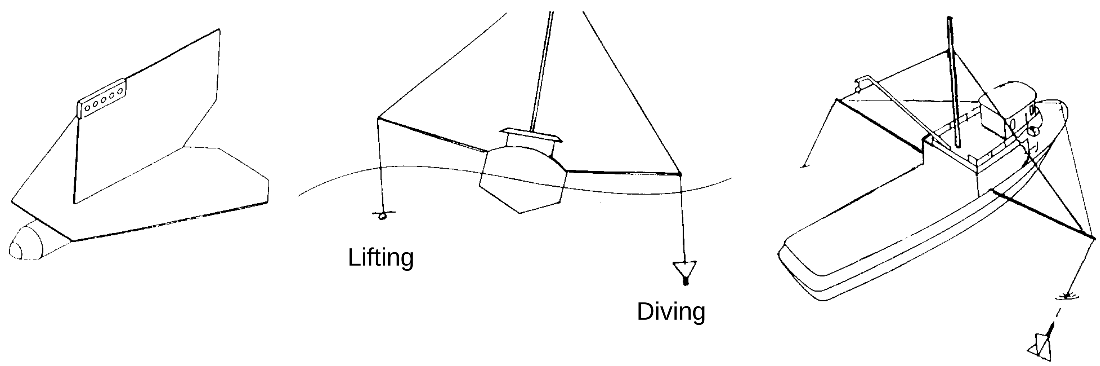

Figure 3 Paravane Stabilisers

Beebe (1975) gave an excellent introduction to stabilisation by paravanes, including design information for sizing and rigging, and his Chapter 6 is required reading for would-be paravane designers. Fuller *et al.* (1979) went a big step further and provided design data for sizing paravanes to give any required amount of roll damping.

Paravane stabilisers have a number of advantages. They are simple, reliable, of low cost, and can be retro-fitted almost as easily as they can be incorporated into an initial design. For these reasons they are in most common use. The cost factor is essential, since it is not uncommon to lose the occasional paravane by misadventure, such as hitting floating objects. It is also not uncommon to pick up long-lines, lobster-pot ropes and the like.

Paravanes are available commercially, *e.g.* from Higwood Anchors Pty Ltd, or may be built locally (either to a design, or not). One paravane had a ballast bar made of railway line cut off square at the ends! Even with faired ends on the ballast bar, the simplicity of construction and the high angle of attack when rising means that, in addition to the high damping of roll, there is also a high contribution to the resistance of the vessel.

The loss of a weather-side paravane was implicated in the loss of the Canadian fishing vessel *Straits Pride II* (TSB of Canada 1992, and Bass and Weng 1994) in heavy weather. However, Australian long-liners often work with only one paravane deployed when they are hauling gear, for fear of fouling the line with the paravane. Some Australian trawlers also deploy one only, as they like the flexibility in damping of being able to deploy none, or one, or two paravanes. The deciding factor is often crew comfort, because if the damping is too high then the crew working on deck get wet and complain!

In practice, it has been found that when first put into the water, paravanes rarely track perfectly and tend to steer either towards or away from the vessel. It has therefore been found necessary to use the aftmost 50 mm of the vertical plates as trim tabs to provide fine control of the tracking of the paravane. This is often done fairly basically, by using the largest available shifting spanner or belting with a pound board over a hatch coaming. On one vessel the port paravane required a 1 mm offset and the starboard paravane required a 6 mm offset for correct tracking.

Ideally, the attachment point for the towing line on the paravane should be changed when the vessel changes from trawling to steaming due to the different forward speeds changing the angle of attack. This requires the retrieval of the paravanes for adjustment at sea, and only keen masters do that. The high drag of a paravane set for trawling speed when used at free-running speed can be seen by the angle of the towing line as well as felt.

The length of the towing line is a matter of preference. It needs to be long enough for the paravane not to break the surface when the vessel is rolling, and Fuller *et al.* (1979) give guidance on this. One master in the south east trawl fishery likes to operate with the paravane about the length of the vessel below the boom block, *i.e.* on a much longer line than most others. This has the advantage that the paravane is much less subject to surface wave action and never breaks the surface.

A survey of paravane stabilisers fitted to ten vessels in the south-east trawl fishery showed that the area is given approximately by

$$A = 0.00089\ L^2$$

where A = flat-plate area (one side), m^2
L = measured length of vessel (length on deck), m

The distance of the attachment point from the centreline is given approximately by

$$d = 1.25\ B$$

where d = distance of attachment point from centreline, m
B = beam of vessel, m

The roll-damping moment for conventional paravanes is therefore proportional to

$$M_P \propto A.d = 0.00089\ L^2 \times 1.25\ B = 0.0011\ L^2B$$

This will be used for comparison purposes later.

2.4.2 Bi-directional

Conventional paravanes alternately dive and provide a roll-damping force as the vessel rolls, *i.e.* each paravane provides damping in one direction only. Some vessels, *e.g.* the 20 m long-line vessel *Kai Koura,* have recently tried modifying the method of attachment of the paravane to improve the damping capability. The towing line is replaced with a fixed bar linkage consisting of about 65 mm diameter pipe. The pipe is attached to the boom with a universal joint, and to the paravane with two bolts through the flattened pipe end, thus providing a nearly-constant angle of attack. The paravane thus provides roll damping whether the boom end is moving up or down, *i.e.* it operates bi-directionally and provides approximately twice the damping moment of conventional paravanes.

Thus far the bi-directional paravanes deployed have been the traditional flat-plate delta-wing types with the ballast bar still in place. There is scope here to delete the ballast bar as it is no longer required for the bi-directional operation.

There is a significant resistance provided by the pipe, and this increases the overall contribution to the vessel’s resistance. These have not found universal favour.

2.4.3 Foil

It was noted above that conventional paravanes provide a high contribution to the resistance of the vessel. This is relatively unimportant at trawling speeds, compared to the resistance of the trawl gear. However, vessels are tending to use paravanes at higher speeds, and use when free-running is not uncommon, and the resistance at these speeds can be significant. Beebe (1975) and Crosthwait (1980) indicate that up to thirty percent of engine power may be required to tow the paravanes through the water at free-running speeds. *Cape Kimberley*, a 20 m trawler in the northern prawn fishery, reported a loss of speed from 10 knots without paravanes when free-running to 9 knots with paravanes deployed. An analysis of the vessel’s resistance curve, propeller characteristics and engine output showed that the paravanes required 100 kW from a 350 kW engine (Riley 1985). Many vessels similarly report a loss of speed of 0.5–1.5 knots with paravanes deployed at free-running speeds (Krokowsi 1997).

Despite the wide use of paravanes, there is little in the literature to show that anything has been done to improve their hydrodynamic efficiency. The only known previous work is that of Crosthwait (1980) who used prismatic foil sections in a ladder arrangement but presented no data. The use of foil sections has been suggested for further work by Crosthwait, and by Riley and Helmore (1985).

In recent undergraduate project supervised by the author, Krokowski (1997) investigated the application of foil sections to conventional paravanes. A commercial set of paravanes on the 18.4 m trawler *Seaberu* were measured, and an equivalent set having the same plate areas but fitted with foil fairings was built. The vertical plate was fitted with a symmetrical NACA 0009 foil and the horizontal plate was fitted with NACA 2415 foil sections lifting downwards. Care was taken to provide the foil set with the same centre of gravity and centre of buoyancy as the commercial set. Instrumentation was provided and both sets were trialled at sea on the vessel. Results were not conclusive, but showed that the foil section paravanes gave the vessel a 2% increase in free-running speed at the same engine RPM.

These foil-section paravanes have since gone back to sea on the 20 m long-line vessel *Kai Koura*, where they have been connected on a bi-directional arm and are still in use. The master of the vessel has tried various settings and, with the paravanes attached by the forwardmost holes, reports that there is negligible loss of free-running speed with these paravanes deployed. The paravanes are from a smaller vessel, and provide less damping than the master would like, but he continues to use them for their low resistance.

There are clearly further changes which could be made to improve the hydrodynamic performance of conventional stabilisers. The main factor mitigating against this is cost, as the foil stabilisers are significantly more expensive to produce, at least as one-off items. The cost of fuel for a vessel in the south east trawl fishery is of the order of five percent of the annual operating cost and the potential for savings is therefore not large.

2.5 Passive Fins

Passive fins resemble high aspect-ratio bilge keels fixed normal to the hull at the turn of the bilge, like the well-known active fin stabilisers except that the only change of angle of attack is provided by the motion of the vessel. The fins themselves taper towards the tip and are of trapezoidal cross-section. The inboard ends are pivoted at the bilge, while the outboard ends are attached to fixed bar linkages, also of trapezoidal cross section. When stowed, the fins lie against the hull, inside the line of the sponsons so that they do not interfere with berthing, and the bars lie across the deck, as shown in Fig. 4. When the fins are lowered, the pins through the inboard ends of the bar linkages slot down into brackets mounted on the deck just inside the bulwarks, and rigging screws from the deck hold the pins down into the slots.

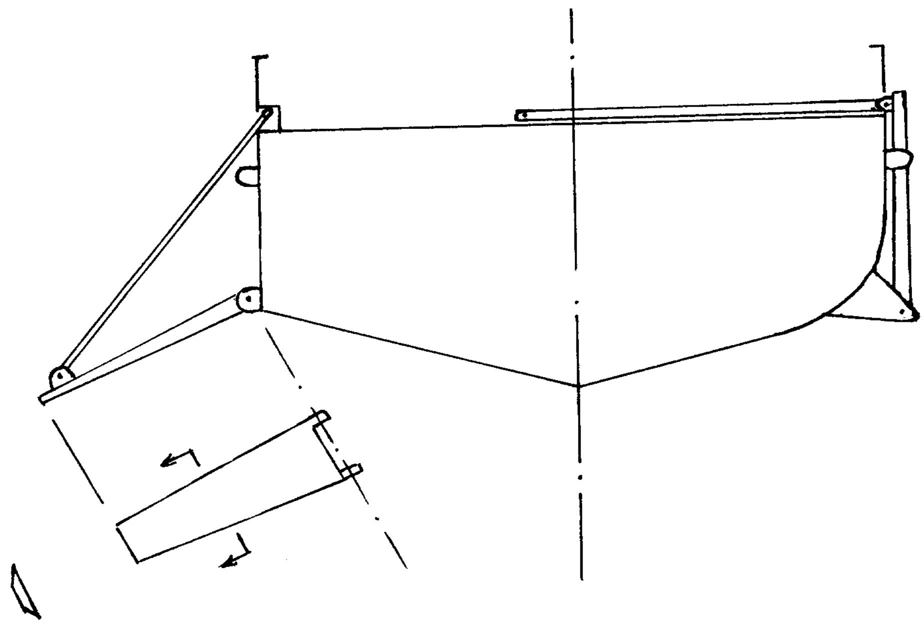

Figure 4 Passive Fin Stabilisers

Passive fins are not new (Goudey and Venugopal 1989), but they are enjoying a surge in popularity in Australia. The first vessel to fit these recently was the 23 m trawler *Tullaberga* in the south east trawl fishery, and these were highly successful in providing damping of roll with negligible loss of speed. She was followed by the 23 m trawler *Miss Francesca,* and about half a dozen more to date. Flexibility in operation is similar to that of paravanes; the vessel can be operated with fins stowed, one fin out or both fins out.

To see why these fins are so successful at roll damping, it is instructive to look at the damping moment provided. A survey of several of the fins which have been fitted showed that the area is given approximately by

$$A = 0.0034\, L^2$$

where A = flat-plate area (one side), m^2
L = measured length of vessel (length on deck), m

The distance of the centroid of area from the rollcentre is given approximately by

$$d = 0.625\, B$$

where d = distance of centroid of A from the rollcentre, m
B = beam of vessel, m

The roll-damping moment for passive fins is therefore proportional to

$$M_F \propto A.d = 2 \times 0.0034\, L^2 \times 0.625\, B = 0.0043\, L^2 B$$

where the factor of two accounts for the fact that two fins are acting at any time.

Taking the ratio of this moment to that determined previously for paravanes, we find

$$M_F / M_P = 0.0043\, L^2 B \,/\, 0.0011\, L^2 B = 3.9$$

It is acknowledged that there are a number of assumptions implicit in this ratio, principal among them being that the drag coefficient for a fin is the same as that for a paravane. However, since both resemble flat plates operating in clear water, this is reasonable for a first estimate. The result shows that passive fins provide nearly four times the damping moment of paravanes for typical sizes being fitted. Combine this with a lower loss of speed than paravanes, and the attraction is evident. There is opportunity for the hydrodynamic performance of the fin and bar linkages to be improved but, again, at a cost which would be difficult to justify to an owner.

3. CONCLUSIONS

The principal methods being used for roll stabilisation of fishing vessels of fifteen to twenty-five metres in length in Australia have been surveyed.

Viscous and wave generation roll damping are not set to become principal players, but the effects of changes in hullform can now be checked at the design stage. Bilge keels are a minor player and wide ones have been fitted recently, but at the price of an increase in fuel consumption for hard-chine vessels. Anti-roll tanks are one of the most effective forms of roll stabilisation, but have been tried in only a few instances on Australian vessels. Paravane stabilisers are by far the most common due to their simplicity, low cost and ease of fitting. Recent applications have shown that their effectiveness can be improved by bi-directioanl operation and by the application of foil section fairing. Passive fins are the new kid on the block, and are popular due to their operational effectiveness.

The paravanes and passive fins are not hydrodynamically efficient and could be improved. However there appears to be little incentive for improvement due to the low order of cost of fuel in the overall operating costs. Roll damping performance is of prime interest to the operators.

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