<u>An innovative windvane pendulum system for sailing boats with outboard rudders.</u>

Jan Alkema 26 sept. 2005

figure 8. The oar blade retracted

figure 7. The oar blade in the water

<u>Preface</u>

On boats with outboard rudders, it can be troublesome to install a pendulum windvane system. The pendulum has to be free of the rudder and should not limit the rudder movements from full port to full starboard. That means that the windvane system has to be mounted further aft of the boat on an extended support frame, which makes it more vulnerable in harbours and crowded marina's. It will also put extra weight on the transom.

A lot of sailing boats with an outboard rudder and wind vane system make use of a trim tab, directly mounted at the rudder. The trim tab works as a servo system to generate enough force to turn the rudder.
It is unquestionable that a trim tab with the right dimensions works, but on some points its performance is less than that of the pendulum system.

Pendulum or trim tab ?

Let's compare the characteristics of a trim tab and a pendulum system and focus on the following aspects :

- Steering torque
- Steering efficiency
- Yaw damping
- Support and vulnerability
- Obstructions in the cockpit

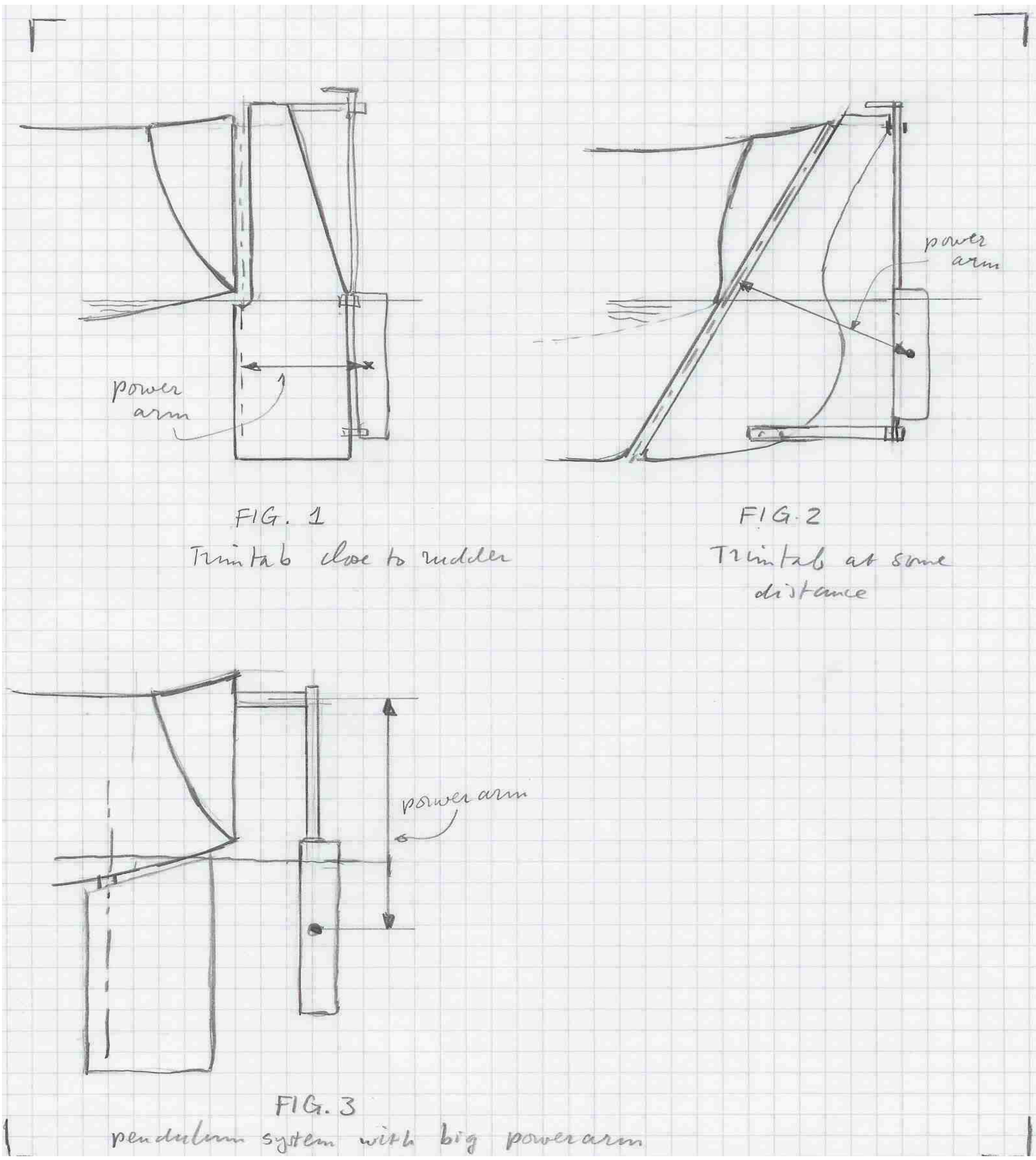

figure 1. Trimtab close to the rudder

figure 2. Trimtab at some distance behind the rudder

figure 3. Pendulum system with big power arm

Steering torque.
The trim tab can be situated just at the trailing edge of the rudder or at some distance of it. This choice is mostly depending on the shape of the rudder. In figure 1. the trim tab is directedly mounted after the trailing edge of the rudder. In figure 2. the trim tab is mounted at some distance behind the rudder.
In both cases the trim tab is working in the wake of the rudder. The solution of figure 2. has the advantage of giving a bigger torque, due to the increased distance between trim tab and rudder hinge.

The pendulum has normally a larger power arm as can be seen in figure 3. So the pendulum with the same dimensions of the underwater part as the trim tab, delivers more torque. This can be advantageous for heavy or unbalanced rudders. Pendulums can operate these rudders without problems, but trim tabs can be limited in their steering torque.

Steering efficiency.
A trim tab develops a force which direction is opposite to the rudder force. The trim tab is decreasing to some extend the effect of the rudder. With normal dimensions the loss of rudder force is approx. 10 %. So the trim tab makes the rudder less effective.
The pendulum force works in the same direction as the rudder, so it assists the rudder and increases the total rudder action and hence the steering efficiency.

Yaw damping.
Yaw damping is the ability to prevent or reduce oscillations in the course. Lack of this ability gives a zig-zag course, so it is an important characteristic of a course controller.
Yaw damping is not easy to explain, but the following example may help to get an idea of it. In this example we are only considering the influence on the rudder and we suppose that the vane is not turning during the yawing motion of the boat.

When wave and/or sail forces are turning the boat (yawing) , then there will be pressure on the rudder from the waterflow.
When the rudder is fixed a force is developed on the rudder which counteracts the yawing motion.
When the rudder is free, then it will line up with the water flow and does not give any counter force to the yawing motion.
A rudder with a trim tab is not fixed or free but controlled by the trim tab. When the boat yaws the water flow creates a force on the rudder+trimtab and initially the rudder tends to line up with the water flow and rotates a bit. But the trim tab gets a greater rotation (in the same direction) due to the linkage between trim tab and wind vane. The water flow on the deflected trim tab creates a force which prevents the rudder from lining up with the water flow. As a result of it the rudder gives some counter force, which damps the yawing motion.

This counter force and so the yaw damping, is however smaller compared with a rudder alone, that had been fixed.
A pendulum system, connected to the rudder can give more yaw damping and most when the pendulum is far aft of the rudder and out of its wake. When the boat yaws the rudder and the pendulum get a pressure from the incoming water flow. The pendulum wants to swing out and the rudder wants to line up with the waterflow. But because the pendulum is much more powerful than the rudder, it swings out and turns the rudder in the opposite direction. So instead of limiting the rudder angle from giving in (this is what the trimtab is doing), it increases the rudder angle to create an increased counter force. So the pendulum system gives a powerful and active yaw damping. The counter force and so the yaw damping of a rudder+pendulum system is bigger than for a rudder alone, that had been fixed.
This is true when the pendulum is out the wake of the rudder. When the pendulum is close to the rudder then the active yaw damping effect is less. But it is always more than from the trim tab, because when the pendulum swings out, it brings the blade far more out of the wake of the rudder compared with the trim tab.
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<u>Support and vulnerability</u>
An advantage of a trim tab system is that no heavy support is necessary. The trim tab is directly mounted at the rudder.
The trim tab is well sheltered by the rudder which is an advantage compared with a pendulum, which swings out and can pick up weed, ropes and floating debris
As already mentioned an extended support frame is inevitable for the normal pendulum system for an outboard rudder.

<u>Obstructions in the cockpit.</u>
The trim tab system has no steering lines and blocks to the tiller or wheel. The trim tab directly controls the rudder blade.
For normal pendulum systems steering lines with several guiding blocks are running through the cockpit to operate the helm or the steering wheel. This is mostly a nuisance in the cockpit.

<u>Combining the advantages.</u>
When I started to design a windvane system for my boat with an outboard rudder I wanted to have the best of both worlds. So the advantages of a pendulum system should preferably be combined with the advantages of a trim tab system. Would that be possible?
After many sketches and a lot of thinking I came up with a system which I later named the *Rudder Head Mounted* (RHM) pendulum or oar system. See the sketch in figure 4.

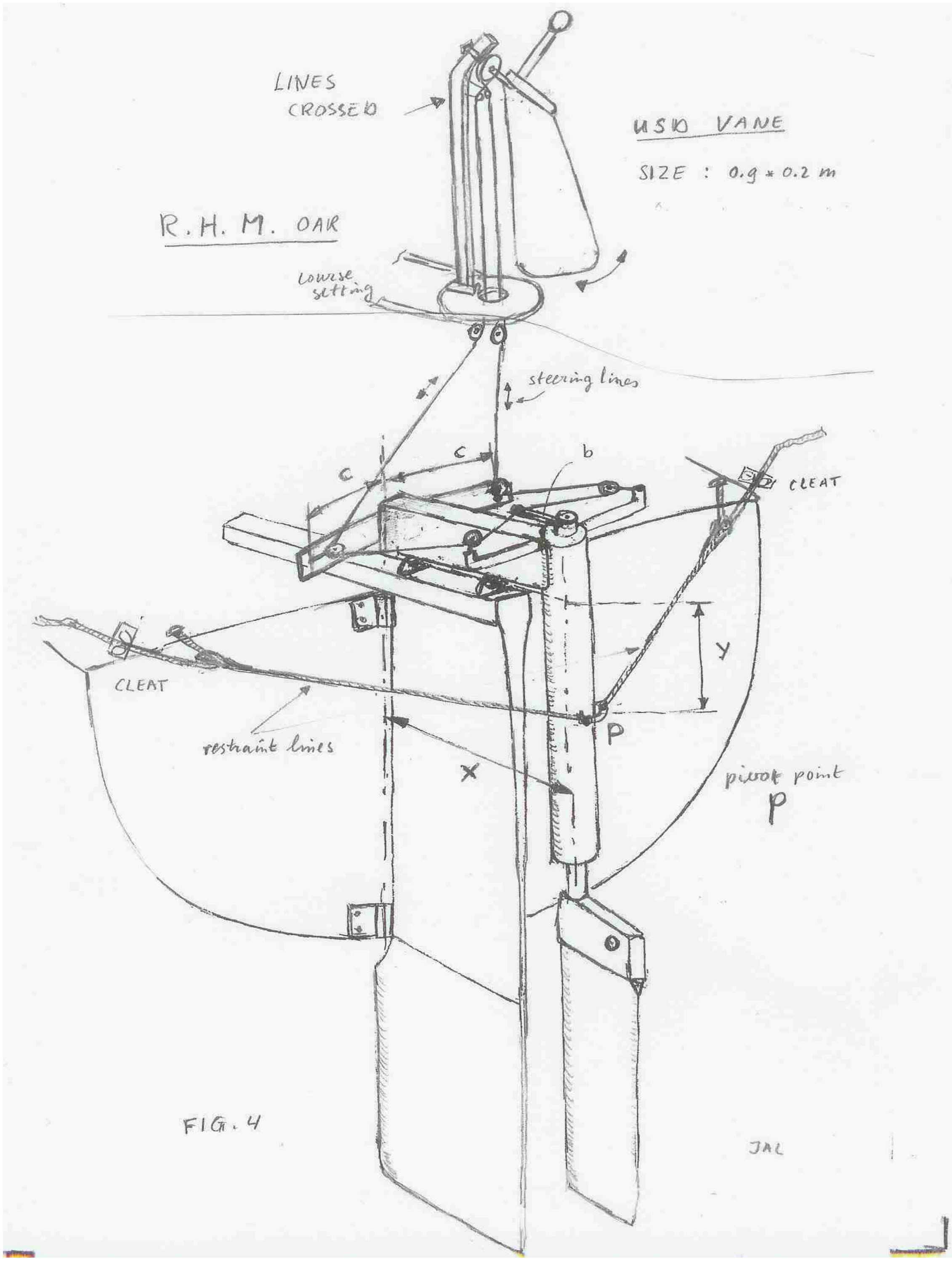

figure 4. The Rudder Head Mounted oar

The pendulum has the horizontal hinge mounted on the rudder head. Essential are the two restraint lines from the transom side to the oar carrier or pendulum tube. When these lines are loose, the pendulum can swing to each side, but it can not turn the rudder. The system is disconnected. When these restraint lines are tight, then they form a fixed point on the tube which will be a

pivot point. (point P) When the pendulum swings out then the rudder is forced to turn.
Figure 5 shows how the swing out movement of the pendulum gives a rudder movement, when the restraint lines are tight.

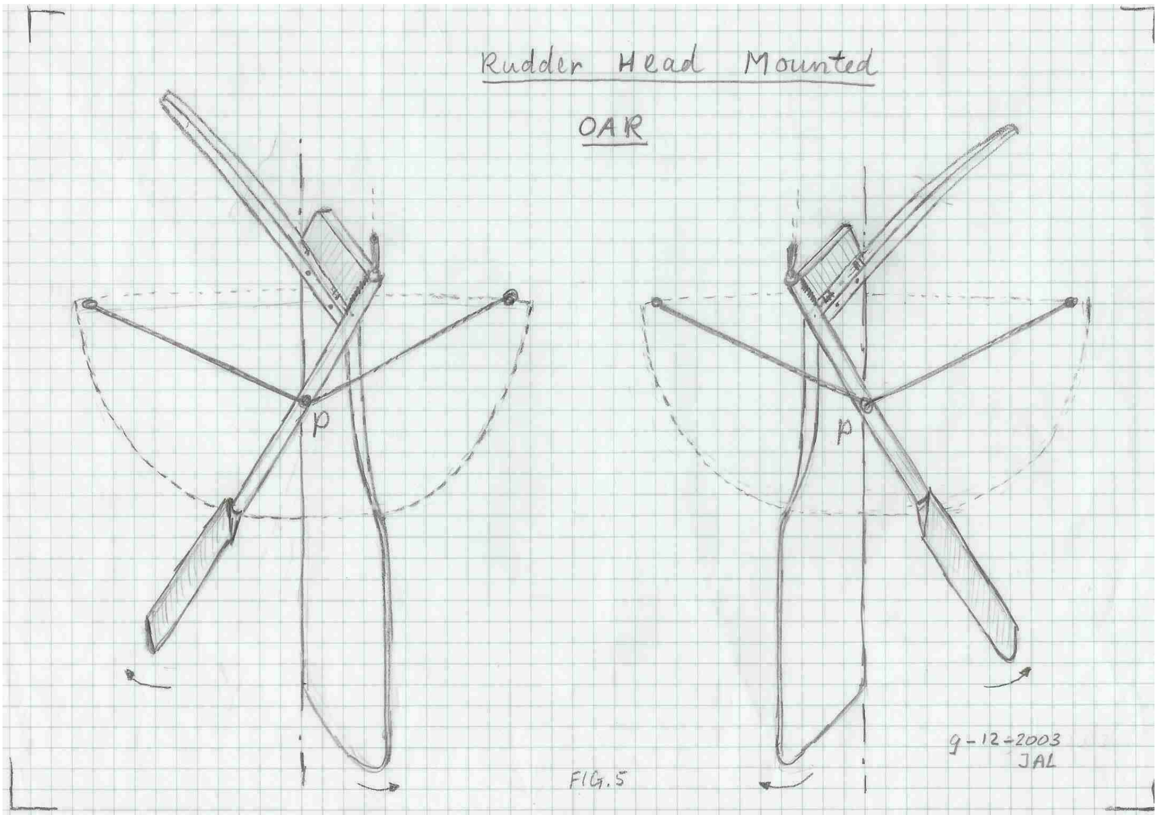

figure 5. How the oar turns the rudder

For stretching or adjusting the restraint lines I use clam cleats on the aft cockpit sole. To release the lines, simply pull them out of the cleats.

This Rudder Head Mounted (RHM) pendulum combines all the advantages of both the pendulum and trim tab :

- It is a true pendulum with the power of normal pendulums.
- It increases the rudder action.
- Yaw damping is better than with a trim tab
- No heavy support frame is necessary.
- There are no steering lines in the cockpit

One minus point of the pendulum remains. The pendulum is not so well sheltered after the rudder as the trim tab.

I made the prototype of the oar carrier and the oar from plywood. I used SS hinges which are normally used for the rudders of small dinghy's. The first sailing tests were carried out in 1981 and it worked from the start. Figure 6 shows the prototype of the oar carrier and oar, which fitted very well with the shape of the rudder.

figure 6. The prototype of oar and oar carrier made from plywood (5 years in use)

This RHM pendulum system is combined with a seperate wind vane which is mounted on the pushpit. Via thin stainless steel cables the rotation of the vane is transmitted to the little tiller on the oar.
Figure 4 shows how the cables are running from the windvane to the small tiller arm on the oar.

I used the prototype of the RHM pendulum for some 5 years. After that I have rebuilt the system, using stainless steel tubes. Ball bearings are used for the oar rotation and in all blocks to get as low friction as possible. I also made the blade retractable. It is still in use, after 20 years, with only small modifications up to now. Figure 7 and 8 (see at top of the article) show the pendulum system, including the wind vane. The windvane part will be discussed later.

<u>Position of the cleats for the restraint lines.</u>
The position of the cleats should be close to the sides, using the full width of the transom. The restraint lines have to remain reasonable tight without slack or overtension for rudder angles of +/- 20 degrees, which is the max. range for rudder corrections during sailing.

On my boat it appeared that the cleats should be positioned higher than the connection point P on the oar carrier or pendulum tube. On my system the vertical distance between P and the cleats is about 0.3 m.
In general it may need some trial and error to find the best positions of the cleats.

Well mannered behaviour.
On every pendulum system the oar needs feedback, otherwise the system will oversteer. When the oar is initially turned by the vane, it will swing out, but during that swing the oar is rotated back, to arrive at a certain swing angle and so at a certain rudder angle. The information of the swing angle is fed back in the turning of the oar through the linkage between vane and oar.
The RHM pendulum system needs more feedback than a normal pendulum, because the pendulum rotates together with the rudder, so that rotation must also be compensated as an extra.
The geometry of the cross beam and wires and blocks however ensures that there is more then enough feedback in the system, to get a well mannered behaviour of the pendulum without any sign of oversteering.
The system gives a good yaw damping in downwind and broad reaching courses on a lively boat like the Westerly Konsort. Note the straight track on figure 9 during a running course in force 5:

figure 9. Downwind course , straight track, no yawing

On windward courses the system works also very well.
Note the oar at work, most of the time out of the wake of the rudder in figure 10:

figure 10. The oar working out of the wake of the rudder

The windvane part.

Uptill now the windvane part has not been highlighted. The windvane part has been developed seperately from the pendulum.
Before starting with the RHM pendulum I used a big wind vane, directly coupled to the rudder. I had taken that windvane from my previous boat. It had an adjustable vane axis tilt angle. An article on that seperate wind vane has been published in the sailing magazine Practical Boat Owner nr. 170 Febr. 1981.
After building the RHM pendulum I combined it with the existing wind vane. The combination worked very well, although the vane was a bit oversized for operating the small oar.

Some 6 years ago I designed a new type of wind vane, the *Up Side Down* (USD) windvane, which could easily be connected to the existing RHM pendulum via the thin stainless steel wires.

figure 11

Figure 11: The USD windvane concept offers construction-inherent adaption to heel and needed steering force. V-shaped tabs at the trailing edge of the vane yield maximum output power.

The interesting feature of the USD vane is that the vane action increases when the boat heels. It automatically adapts its action in the right way to the sailing circumstances. Normal vanes don't do that. When heeled with some weatherhelm, the USD vane gives more action for a better accuracy. On a downwind course with no heel the USD vane action is less, which enhances course stability.

The USD windvane has been described in the article “ Which windvanes work best “ (Practical Boat Owner nr. 414 , June 2001) .

<u>How to operate the RHM /USD system.</u>

At the start the vane is locked is a vertical position and the restraint lines are slack, the blade is put into the water. With slack restraint lines no forces are excerted on the rudder. It appears that the oar is following the rudder without swinging out, also when the boat is steered manually.

When the restraint lines are tightened and the vane is set on the desired wind course and released, then the system is taking over and will steer the boat.

Normally I put the tiller in the upright position to get a free and uncluttered cockpit.

To disconnect the system I first lock the vane in a vertical position and then pull the restraint lines out of the cleats. Then the boat is ready for manual steering again.

<u>Conclusion.</u>

The described construction principle of the Rudder Head Mounted pendulum has been used for 25 years now. I made many sailing trips with the system to Denmark , UK and France. Uptill now I have not experienced any shortcomings in the system.

RHM and USD are working together perfectly, steering the boat accurately without yawing and making sailing trips even more enjoyable.

In my opinion it is a feasible and satisfying solution for boats with outboard rudders and a not too difficult do-it-yourself job to built.