The Reduction of Roll in Ships*

Commander P. Du CANE., C.B.E., R.N. (Member)†

INTRODUCTION

Since water transport began it is suspected that fairly continuous efforts have been aimed at the reduction of the unpleasant and unnecessary part of the motion of a ship at sea in waves. Obviously of all the possible motions that of progression in a general direction along the fore and aft axis of the craft is well desired, whereas generally speaking with only slight qualification, which will be dealt with later, all other motions such as pitching, heaving, turning, drift, sway, surge, yaw and roll are undesirable. With the exception of turning, which is really a motion in the yawing axis, the only motion which has so far been successfully reduced or controlled to a practical extent by mechanical or artificially assisted means is rolling. The remaining motions are in some cases, especially that of pitch, very uncomfortable to humans, but not much has been achieved up to date other than by passive means, i.e. by designing the shape to help in this.

2) "Slosh" or "Passive" tanks to use modern terminology (mass and moment adjustment).

There are, of course, quite a number of passive means, the best known being the bilge keel, as well as simply designing the ship to possess suitable characteristics (spring constant (*GM*) and damping to use the mechanical analogy).

In the days of sail this problem was not nearly so important while the wind was blowing, as the sails provided excellent damping. It was only in the doldrums and near broaching that heavy rolling occurred.

There were other arrangements, none, so far as is known, leading to lasting success, but one example of which was the stabilized compartment invented by Bessemer. Here the ship is allowed to roll but a living compartment so to speak "on gimbals" was controlled by gyros or other suitable means to maintain an attitude similar to that which would be achieved on land, i.e. the force of gravity would act through the floor

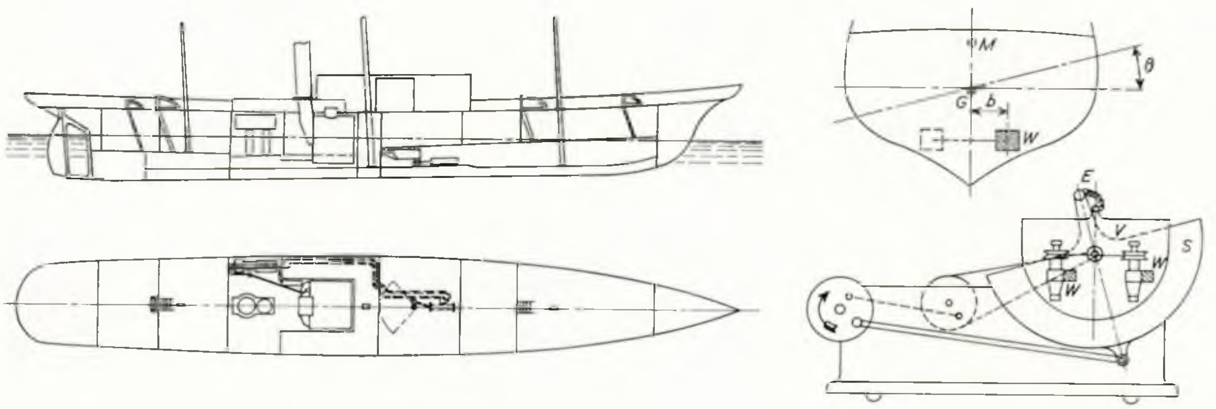

FIG. 1—S.Y. Cecile *fitted with steadying apparatus*

THE PROBLEM

It is rolling that we will discuss here. Rolling is certainly one of the more upleasant motions and in the presence of suitable conditions can become very violent given the circumstances that synchronism is attained between the frequency of the wave impulses and the natural (pendulum) frequency of the ship. As a corollary, as the energy required to roll a ship around its fore and aft axis is relatively low, so it becomes consequently easy to provide sufficient energy to damp or reduce rolling.

Probably it is correct to reduce the effective methods of roll reduction still in use today to two basic methods:

1) Activated fins (mostly acting as dampers).

at right angles though it would not, unfortunately, remain at unity—due to pitching and heaving—perhaps particularly the latter. It was, therefore, no cure for seasickness, which seems to be due to accelerations which persist beyond a threshold which is not exceeded in the case of speed boats for instance.

The well known Hiram Maxim of machine gun fame had a patent quite early in 1870. However, Sir John Thornycroft in 1892, produced a very ingenious and very nearly practical answer to the problem by what was essentially a moving weight installation. His arrangement can be seen in Fig. 1. There is little doubt that this could have been most successful if modern servo and hydraulic techniques had been developed at that date. As it was the control mechanism represents one of very few systems which could be said to anticipate the ship movements. This was achieved by a short and long pendulum working in combination. The short pendulum measures the

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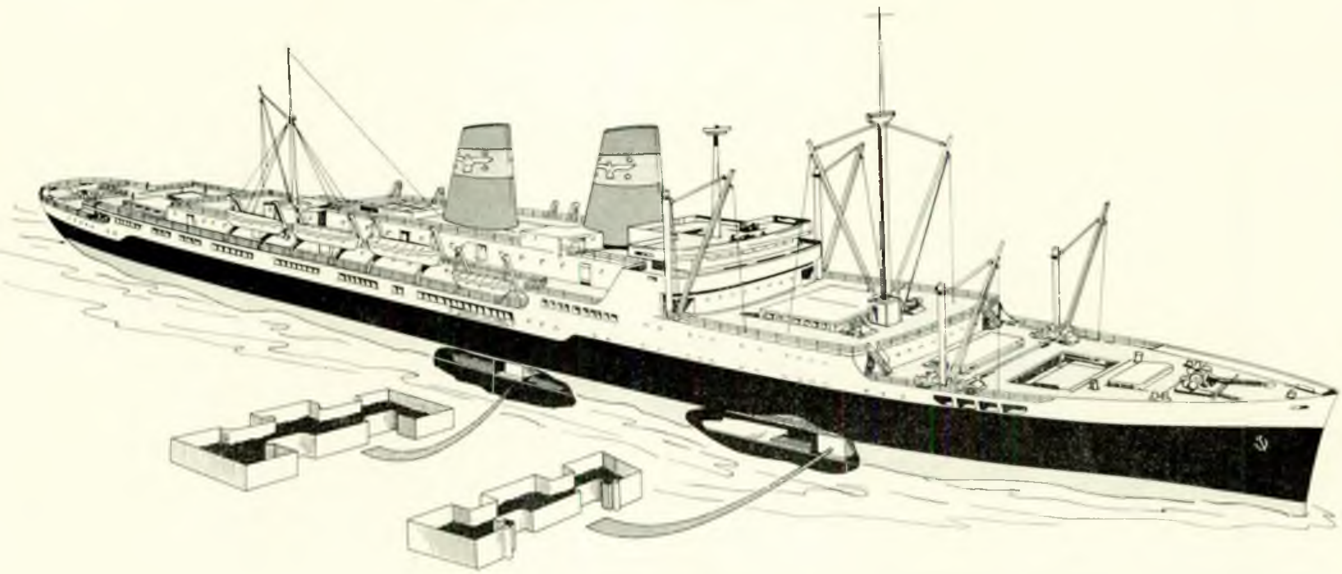
† Deputy Chairman and Research Director, Vosper Ltd.



With acknowledgements to John J. McMullen Associates, Naval and Marine Architects.

FIG. 2—*Flume stabilization system in t.s.s.* Olympia

effective wave slope which is a measure of the disturbing moment and the long pendulum measures the angle to the true vertical.

One other type which so far has not been mentioned is the stabilizing gyro. This is a case where the mass of the revolving wheel is sufficient to produce a worthwhile moment on the ship when the gyro axis is subjected to angular velocity in the roll axis. This method is not much used today excepting, it is believed, in the Polaris submarines as an aid to providing the necessary vertical reference axis for firing the missile.

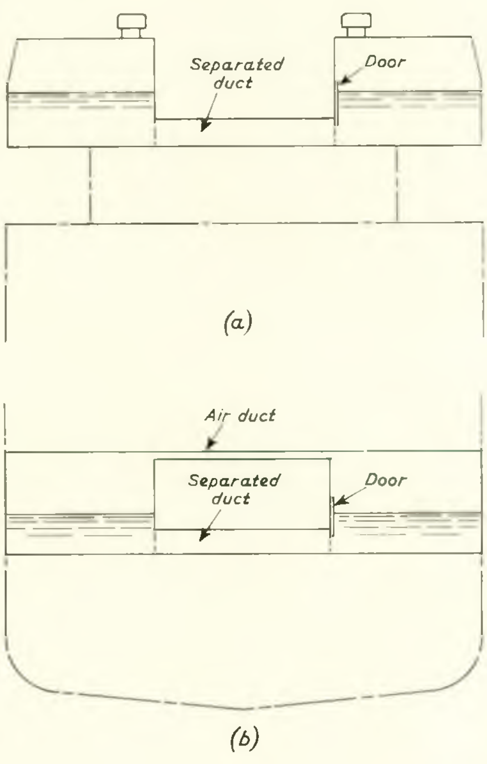


FIG. 3—*Motora passive tank arrangement*

This still leaves us with tanks and activated fins. Figs. 2 and 3 show typical installations.

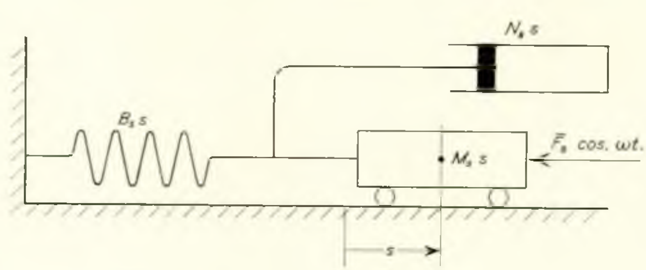
So far as tanks are concerned the technique consists in providing a mass of water with free surfaces suitably located so that they can provide a 90 deg. out of phase moment counteracting the roll. Much the same thing could be achieved by having a truck full of lead running freely up and down a transversely laid railway. To adjust the natural frequency of this assembly various measures can be adopted such as varying the amount of frictional damping in the wheels or slides. This is accomplished in the passive tank by nozzles, flumes or valves.

The mechanical analogy of the passive tank system is that of the double pendulum, the characteristics of which are studied at some length in the appendix to Vasta's S.N.A.M.E. paper (1962)[1].

THE NATURE OF THE PROBLEM

Whilst, correctly speaking, the profile of a wave is usually represented by a somewhat complicated mathematical expression it can be approximated so far as its effect on the ship is concerned by an equivalent wave slope usually known as the "effective wave slope".

The situation which arises as a wave passes transversely



Motion of a mass under the influence of damping, a spring and an external force

$$M_s s + N_s s + B_s s = \bar{F}_s \cos. \omega t$$

$$\omega = \sqrt{\frac{B_s}{M_s}} = \omega_s$$

$$T_s = \frac{2\pi}{\omega_s}$$

FIG. 4—*Mechanical analogy for a rolling ship*

by a ship can be understood as follows. It can be seen that, due to the alteration in the centre of buoyancy, a moment in the roll axis is applied to the ship proportional to the magnitude of the wave slope. In a system of waves it is usually assumed that this disturbing moment is sinusoidal in character with the frequency of the wave encounter. When this frequency of encounter synchronizes with the natural (or pendulum) frequency of the ship a very considerable build-up of angle of roll will result.

The mechanical analogy here is the spring system with mass and dashpot (see Fig. 4). The equation governing the dynamic behaviour of the above system is represented by that applicable to a weighted pendulum with damping.

$$T = J_s \frac{d^2\theta}{dt^2} + B_s \frac{d\theta}{dt} + K_s\theta \qquad (1)$$

where T = applied torque
J_s = moment of inertia of ship
B_s = natural damping
K_s = effective spring constant ($WGM\ \theta$)
θ = angle of roll

where active fins are fitted this equation becomes

$$T_N = J_s \frac{d^2\theta}{dt^2} + B_s \frac{d\theta}{dt} + K_s\theta \qquad (2)$$

where T_N = net torque applied by wave
and T_F = torque applied by fins

As mentioned earlier T varies sinusoidably in the frequency of wave encounter so the equation becomes

$$T_N = WGM\phi + B_s \frac{d\phi}{dt} - T_F \qquad (3)$$

Where ϕ = effective wave slope,

the equation then becomes

$$J_s \frac{d^2\theta}{dt^2} + B_s \frac{d\theta}{dt} + K_s\theta = WGM\phi + B_s \frac{d\phi}{dt} - T_F \qquad (4)$$

This neglects cross-coupling effects due to drift and sway, but is a fair assumption at least to first order. It also neglects lag in fin operation which can be quite important.

We are now in a position to study the effect on the ship with its known characteristics, i.e. spring constant (GM), moment of inertia (J) and damping (B_s) of the wave disturbing moments at various applied frequencies due to wave characteristics.

The mathematical method of effecting this is that of the transfer function, which, so far as the author is aware, came from the electrical engineering world where it is used to predict the effect at the output terminals of various applied voltages on a network with known characteristics.

The response characteristics for any given inertia, spring and damping system are shown in Fig. 5. The result in this case which represents a typical dynamic system is expressed in terms of "loop ratio" or "gain" on to a base of frequency—in this case period of roll.

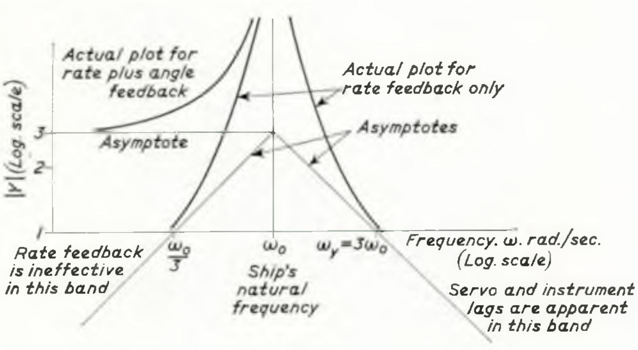


FIG. 5—*Plot of Y versus frequency where Y represents loop ratio (gain) and ω = circular frequency*

FIG. 6—*Typical control panel for roll damping fin installation allowing complete remote control of equipment*

This can then be processed to another useful and perhaps more immediately understandable curve of $\frac{\theta}{\theta \text{ fins off}}$ against frequency (roll period). Here the result is given in terms of a fraction of the roll amplitude, with fins on, against that with fins off.

Somewhat naturally as the frequency of wave encounter approaches the natural period of the ship the effectiveness is a maximum while gradually as the wave encounter frequency increases the effect on the ship is much reduced in terms of roll and so also is the damping ratio.

The characteristic described here is general in the study of roll damping systems. Though there is much sales talk, all systems in fact are fairly sharply tuned around the natural frequency and are much less effective well away from natural frequency. However, this is not important for the simple reason that but little motion in the roll axis results anyway from the frequencies well away from synchronism. The importance of this applies to the realistic irregular sea.

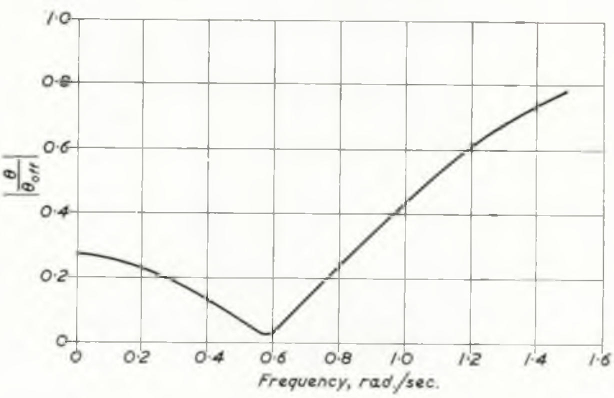


FIG. 7—*Magnitude of $\frac{\theta}{\theta_{off}}$ versus frequency*

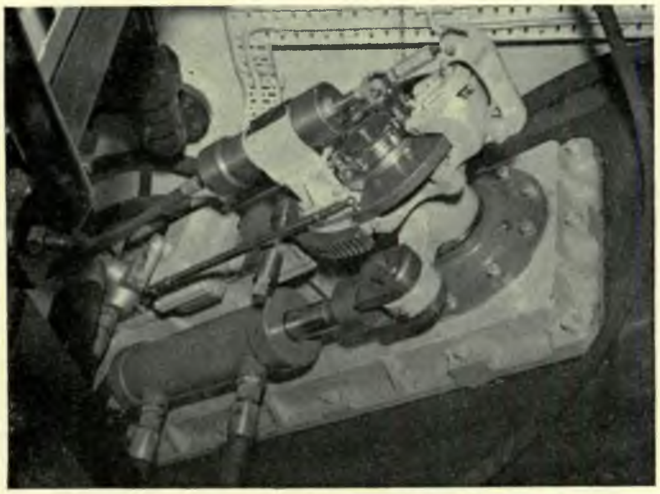


FIG. 8—*Typical fin actuating assembly for roll damping installation*

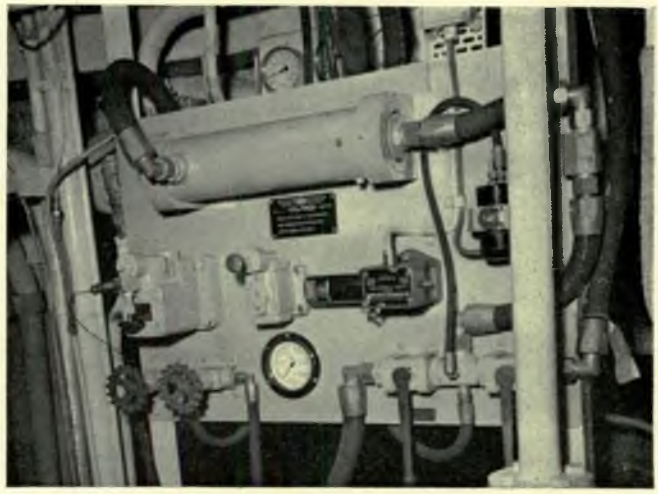


FIG. 9—*Typical panel containing hydraulic components*

Much here will depend on the magnitude and timing of the fin application so that we will now study briefly the characteristics of the various fins, and what is almost equally or perhaps more important, the means of controlling their motions.

FIN CHARACTERISTICS

As will be appreciated the energy required to damp the rolling motion of the ship is supplied from the main propulsive machinery of the ship. By virtue of its velocity through the water a fin presented at an angle of attack to the local flow will develop lift and consequently a moment around the roll axis. A certain relatively very small power is required for activating the fins.

Various configurations of fins can be fitted but basically they are usually of high aspect ratio which involves retraction and with trailing edge flap, which is the type usually associated with Denny-Brown or Sperry, or the low aspect ratio fin non-retractable type associated with Vosper.

The characteristics are somewhat different, but whereas the high aspect ratio fin with trailing edge flap will develop more lift per unit area up till the stall, the low aspect ratio fin has delayed stalling characteristics and by using more angle of incidence can usually develop much the same or even more total lift per unit area, especially if a blunt trailing edge is used.

However, though what has just been said is applicable to static conditions, this is not by any means representative of the real state of affairs when considering moving fins operating on a ship moving in a seaway. Here the transient lift is what matters and quite different laws apply. Few reliable data are available on this subject (see DTMB report 1647) but Vosper have carried out some experiments at model scale in their cavitation tunnel. The fins in m.y. *Sea Victory* have also been

FIG. 10—*S.A.S.* Oosterland *undergoing trials of her Vosper roll damping fins. This little ship has since made voyages to the Antarctic and Tristan du Cunha which would not have been considered feasible until the roll damping fins were fitted*

strain-gauged to produce a plot of fin lift against time and fin angle. There is undoubtedly a lift increment from this source and the reduced frequency expressed by $K = \frac{C/2}{V \Delta t}$ is an important parameter, where $C/2$ = half chord.

It is not quite clear why the blunt trailing edge gives such favourable results expressed in terms of percentage roll reduction fins "on" against fins "off", but it is probably to some extent a transient effect due to, and dependent on, the rotational velocity of fin movement. The effect of drag is not discussed here as it is not really important in a practical sense in a seaway.

CONTROL

As seen in equation (1) the damping term B_s relates to roll velocity so if we assume the function of the fins to generate a force and moment in the direction for damping or quenching the roll the fins must be actuated so as to develop their lift proportionately to rate of roll $\frac{d\theta}{dt}$ or $\dot{\theta}$.

In the simplest case, therefore, we must provide a signal to the hydraulic cylinders such that the incidence is a maximum when roll rate is at maximum. In other words fin incidence should be proportional to roll rate. This can be effected by use of a rate gyro placed with its axis athwartships. The measure of the precession is representative of the rate of roll. As the force available from the precession of the gyro is very small it becomes necessary to amplify this force hydraulically or electrically in order to operate a spool valve controlling flow to the cylinders.

It will be realized that to move the fins in this way proportional to rate of roll will inevitably involve some lag in time before the fin can be in the correct position to damp the motion. It will, therefore, be advantageous if some element of anticipation can be fed into the system. This can be done electronically or mechanically. Also, though the control proportional to rate is ideal for the synchronous case, this is not always the prevailing situation. When, for instance, the wave effective period of encounter is much greater than the natural rolling period (following sea) it can pay to feed in an element of signal proportional to roll angle. Similarly, if the wave frequency of encounter is much greater, which means the period is much shorter, then a term proportional to acceleration can pay. This is perhaps not so important as the long period case because it usually is likely to involve waves on the bow which will be effectively smaller and certainly will have little effect on the ship. However, in the case of large installations where considerable lag in operation can be expected an acceleration term can get things moving earlier and is used.

The order of advantage from this mixing of the signals is not believed to be very great and certainly the rate signal is much the most important. The most difficult condition to deal with is the quartering sea when the period of encounter approaches zero. For this case, of course, rolling velocity will approach zero so there would be no signal from a rate gyro. This can be very embarrassing in the yaw-heel case which arises in a following sea, when for quite a time a yaw will develop with a tendency to heel outwards at constant or slowly increasing angle. This can only be corrected by a signal to the fins proportionate to angle possibly from a damped pendulum though the exact order of advantage is not clear.

Roll damping in the case of fast ships is not easy, as to start with they do not roll much at speed. The natural damping of a fast ship is considerably increased. Also, with a wave formation coming from a predominant bearing relative the ship's course there is only a very small sector in which synchronism can be achieved—probably only over a sector of not more than 5 deg. bearing. What, therefore, really happens is that the gear does what is asked of it so far as roll reduction is concerned, but the other motions such as pitching, yaw, surge, etc. are now relatively much more important and noticeable. These, in the general unpleasantness aboard, are apt to be confused or not differentiated from roll so the fins get blamed quite unfairly. It is surprising how often the layman confuses roll and pitch.

The quartering sea is always important and a study of Bell's[2] literature will show how the technique of mixing the rate and roll angle signals can help for this case, which is an important one. So important is the matter of approaching the synchronous condition in fact, that in the case of the *Queens* the author is informed that they very rarely have their fins out on the passage West to U.S.A. when they may find a beam sea. The period of encounter for this case is likely to be considerably shorter than the natural rolling period which can be up to 20 sec. On the way East, however, it is quite likely that a big quartering sea will be encountered which produces a condition approaching synchronism and therefore gives the fins plenty to do.

FINS ADVANTAGES AND LIMITATIONS

One drawback to the use of fins is the fact that in dealing with ships with a large speed range it is not possible to design the fins to suit more than an unique set of conditions so that some compromise has to be made. As the lift provided by the fins is proportional to V^2 some operating speed must be decided upon and the hydraulics designed to be sufficiently powerful to meet these conditions. Above this speed the gear can saturate and the fin incidence will be limited by the force which can be applied.

Below this speed the fins tend to become less effective subject only to reduced frequency effects previously referred to but certainly at very low speed or at rest they will be ineffective. It will be understood the fin stock must be designed to withstand the bending moments and torque set up during full speed operation even though the hydraulics cannot supply enough torque to provide full incidence.

As a practical safety measure it is necessary to be able to lock the gear in the event of hydraulic failure and to return it to the mid-position where it can be locked by a pin. The return to mid-position can be carried out by a worm and worm-wheel or by a small auxiliary hand pump.

To arrive at the size of fin required a fairly simple calculation is used.

For a moving fin a lift coefficient (C_L) is assumed to be unity where

Lift = $C_L \times \frac{1}{2}\rho A V^2$
V = speed in ft./sec.
A = area of fin in sq. ft.
Lift in lb.

Normally the ship will roll four to five times the amplitude in degrees with fins off as compared to fins on at synchronism. If therefore we design the fins so that in theory they can give the ship a static list of 5 deg. it may be anticipated that they will be capable of reducing a 20 deg. roll to 5 deg. To produce a static lift of 5 deg. moment to be applied is = $GM\theta$ where θ for small angles is in radians. GM = metacentric height and is a measure of the "spring constant".

Applied moment = $GM \sin\theta$

the effective radius (r) can reasonably be taken as approximately 0·56 times the maximum beam, so to find area of fin and assuming $C_L = 1$ we have

$$2Fr = \triangle GM\theta$$
$$F = C_L \times \tfrac{1}{2}\rho A V^2$$
$$\text{so } \rho A V^2 r = \triangle GM\theta$$
$$A = \frac{\triangle GM\theta}{\rho V^2 r}$$

As a corollary, if the fin can produce a theoretical heel of 5 deg. if the fin control is reversed so that a velocity signal orders full fin when velocity is at minimum, the ship will be forced into rolling to 20 deg. each side or 40 deg. out to out. This is a good test for the gear if the ladies and the cook will allow this drastic test which finds out very rapidly what is secured.

Up till now we have considered the effect on the ship of a simplified forcing function in the shape of an effective wave slope representing the effect of a wave disturbance.

There are, however, other factors to be taken into account if a closer approach to the real state of affairs is considered.

In the case of a ship rolling, detailed consideration will

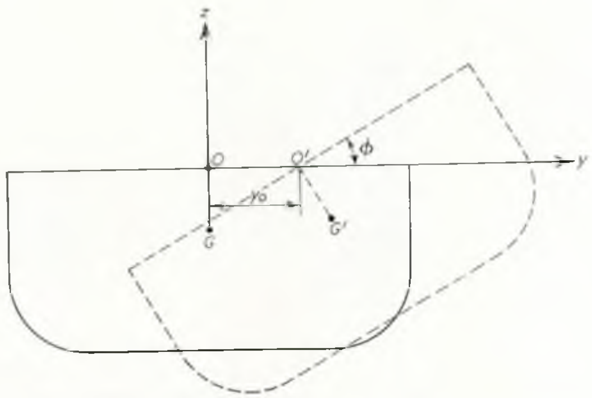


FIG. 11—*Diagram showing coupled motion of sway and roll when centre of roll is assumed in water line and above C of G*

show that the centre of gravity moves transversely, due to the centre of roll being assumed in the transverse water line. It can be understood from Fig. 11 from Vossers, that a couple will be set up due to the sway force = mass × sway acceleration (see above). This in turn, as it does not act through the centre of lateral effort, will cause an angle of drift which is coupled back into roll in a negative direction though of relatively small magnitude at reasonable speed.

The ship is assumed to move with the mass of water it displaces in the wave which therefore makes it subject to the orbital motions at the c.g. which describe a circular path. The ship, therefore, in a completely transverse wave system at 90 deg. to its course, will move transversely each side an amount equal to the orbital diameter at the appropriate depth during the passage of each wave. This motion can be seen quite clearly in a wave making tank such as the Wageningen seakeeping basin when running in a transverse wave system. There is, in effect, an acceleration in the sway direction which results in the ship running in a direction equivalent to the resultant of forward velocity and sway velocity. Suppose, however, the ship is running on a course at 45 deg. (or 135 deg.) to the direction of the wave system, then there will arise a coupling of yaw into roll. The yaw will be set up on account of the difference in the wave profile forward to aft and due to the difference in direction of the orbital flow between wave crest and trough. It will tend to cause a moment additive to the roll caused by effective wave slope. There will also be some reflection effects but in steep wave systems and at high speed the rolling moment due to sway can be quite large.

In certain types of steep irregular sea it can also be envisaged that the fins will meet flow locally which is by no means horizontal, but will be influenced by pitching as well as orbital motions to mention only two factors. These distortions of the flow can amount to as much as 10 deg. in certain circumstances which, in the case of high aspect ratio will lead to stalling of the fin if it should already be at maximum incidence. Only Sperry actually correct for this factor by introducing a signal proportional to fin lift which is derived from a strain gauge in the stock longitudinal axis.

As the drift or sway into roll input contains a V^2 term the effect of sway and drift can become of far more importance than wave slope at high speed. This is one more reason why the fast ship presents a challenge so far as roll reduction is concerned while it is operating at high speed. It is likely that athwartships accelerometers could help here. It is axiomatic though seldom appreciated that rudder control should be equally sophisticated as is roll damping control.

There is a peculiar feature worth mentioning in that although in theory we design a fin capable of producing a static heel of, say, 5 deg. yet, if put hard over, even at full speed, the ship will seldom remain heeled more than 2½-3 deg. The reason for this has never been explained but it has been established that it is not the fin lift which is deficient.

There have, over the years, been a number of efforts to produce a satisfactory system of passive (or active) tanks within the ship which, by suitable design and dimensions, allow a mass of water to be transferred in such a manner that the movement of the ship in roll causes the water so moved to provide a correcting, or damping moment to be applied to the ship 90 deg. out of phase with the wave forcing functions. This can and has been done on a number of occasions by variants of the U-tube or passive tank arrangement such as Frahm tanks which had quite a vogue at one time.

At the present moment a system called the Flume Tank arrangement is experiencing a considerable vogue in the U.S.A. and elsewhere. Motora in Japan has also developed such a system. Here a system of tanks running athwartships is arranged and connected by a nozzle configuration. This tank arrangement is much influenced by what is considered to be the natural rolling frequency of the ship on the understanding that the tank should be arranged to oppose or counteract this magnification range at a relatively narrow frequency band. Unfortunately it is fairly generally admitted now that a ship in a realistic irregular sea seldom rolls in an unique frequency band. It has become important, therefore, to arrange for the tanks to be able to cope with a fairly wide frequency band either side of the natural frequency of the ship.

This is claimed to be achieved by the nozzle or flume arrangement (see Fig. 3) which in effect causes damping and energy absorption. It is, in the present state of the art, difficult to estimate the tank natural frequency by calculation methods alone but quite a lot can be achieved by model tank technique and if it is found that the frequency requires alteration when the ship is built, this can be achieved by altering the depth in the tanks. Of course it must be realized that it is of almost equal importance that the moment application should be 90 deg. out of phase as that the tank natural frequency should be correctly tuned. This also is largely a function of tank geometry. Motora uses the idea of separate side or saddle tanks to deal with the high frequency cases.

As a side issue there is quite an effective method of stabilizing, at least at model scale, which makes use of a mass running on athwartship rails. The ideal here is that the "car" should be stationary and on the opposite side to the maximum roll amplitude so that as the ship returns to opposite heel angle the car runs uphill against the roll. This is certainly a matter of correct phasing.

RELATIVE MERITS

Now for the question as to which is the best. This is difficult because for one thing the author is a purveyor of activated fin stabilizers.

However, there is tending to be a good deal of literature on the passive tanks now and a careful scrutiny will lead one to suppose that practically speaking 50-60 per cent average roll reduction is doing quite well and this is probably applicable only to that part of the spectrum in the neighbourhood of the natural frequency. What really counts is the total area under the roll spectrum curve compared for the case of fins "on" and "off". This is liable to give a much more useful stabilization criterion if the author has correctly interpreted the authors of that most valuable paper *Roll Stabilization by Means of Passive Tanks*[1] (S.N.A.M.E. 1962). The activated fin in suitable conditions can reach 90 per cent reduction factor *at synchronism* compared to 75 per cent for the passive tank. It can also deal with a theoretical 5 deg. wave slope capacity as compared with about 2 deg. for the case of the passive tank. This is probably the most important factor.

This is quite important in considering the magnitude of waves which can be dealt with.

Essentially, the passive tank arrangement consists in a free surface of liquid across the full beam of the ship and as such has an effect of reducing the static stability (GM). It can be understood that for a case of a very slow heeling motion due to a side wind or a turn under constant helm it will be quite possible for all the liquid to run over to one side. It is, therefore, necessary to have a reserve of stability to meet this case. There will also be sway accelerations which dynamically will help to stabilize the ship for the frequencies which are of interest. It is the requirement for reserve stability which limits the wave slope capacity.

On the other hand, of course, this type of stabilization is essential if low or zero speed is considered to be an operational condition likely to have to be met.

The U-tube arrangement fulfils much the same function and there is some advantage in fitting a sluice valve between the two arms of the "U" which, when adjusted, has the effect of controlling the frequency of the tank system.

There have also been "active" passive systems where a pump controlled by roll acceleration helps the situation to a considerable extent.

ACKNOWLEDGEMENTS

The author desires to express his gratitude to various members of Vosper Ltd. for the great assistance rendered to him in the course of preparing this paper.

In particular he would like to mention Mr. Peter Shepherd, manager of the Roll Damping Division, and also Mr. David Cole, Engineer Chief Draughtsman, both of whom have helped considerably in the preparation of sketches in this paper.

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INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting Held at the Memorial Building on Tuesday, 14th January 1964

An Ordinary Meeting was held by the Institute on Tuesday, 14th January 1964, when a paper entitled "Actuating Forces in Controllable Pitch Propellers" by H. Klaassen and W. Arnoldus, was presented by Mr. Klaassen and discussed.

Commander F. M. Paskins, O.B.E., R.D., R.N.R. (Chairman of Council) was in the Chair and forty members and guests attended the meeting.

In the discussion which followed five speakers took part.

A vote of thanks to the authors was proposed by the Chairman and received warm acclamation.

The meeting ended at 6.45 p.m.

Scottish

A joint meeting with the Institution of Engineers and Shipbuilders in Scotland, was held on Tuesday, 7th April 1964, in the Weir Hall of the Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, at 6.45 p.m.

Professor A. S. T. Thomson, B.Sc., Ph.D., President of the I.E.S., was in the Chair, and after welcoming the sixty-two members and visitors present, introduced Mr. F. R. Farmer, B.A., who read his paper entitled "Safety in Nuclear Ships". After dealing with the various features of the types of reactors at present under development, Mr. Farmer, who illustrated his talk with slides, pointed out that their evolution as useful and economic systems, however, would have to await the accumulation of experience through research and prototype tests.

A most interesting discussion followed and the author dealt with the various questions in a most competent manner.

Commander A. J. H. Goodwin, O.B.E., R.N. (Chairman of the Scottish Section) proposed a vote of thanks to Mr. Farmer and this was carried with enthusiasm.

South East England

A meeting of the Section was held on Tuesday, 5th May 1964, at the Royal Clarendon Hotel, Gravesend, at 7.30 p.m.

Mr. G. F. Forsdike (Chairman of the Section), presided at the meeting which was attended by thirty-five members and guests.

Due to business commitments Mr. B. Cheeseman, author of "Marine Insurance" the paper which was to have been read, was obliged at the last minute, to cancel the reading.

The Section was fortunate however, and was deeply indebted to the management and staff of the BP Refinery (Kent) Limited, who made their projector and films available for the meeting.

Amongst the four films shown was the award winning film "The Home Made Car" which seemed to have been the dream of every motorist present, while the showing of "Pitcairn Island" brought back memories of those who were now based ashore.

A vote of thanks to the British Petroleum Company and the operator was proposed by the Chairman and acclaimed by the meeting.

West Midlands

A meeting of the Section was held on Thursday, 23rd April 1964, at the Engineering and Building Centre, Broad Street, Birmingham, at 7.0 p.m., when a lecture entitled "Development of the Hovercraft" was presented by Mr. G. C. Keen.

Mr. R. R. Gilchrist, M.A. (Chairman of the Section), was in the Chair and forty-nine members and guests attended the meeting.

With the aid of slides, the development of the hovercraft was fully detailed, and it was interesting to note that much larger designs were now being contemplated.

The lecture was concluded by the showing of a 16 mm. colour film showing the first running trials and the first paying passenger service of the hovercraft.

A most interesting and lively discussion followed the lecture, with all questions being ably dealt with by the speaker.

The meeting closed at approximately 9.0 p.m.

West of England

A combined senior and junior meeting was held on Wednesday, 8th April 1964, at the City of Bath Technical College Lecture Theatre, Avon Street, Bath, at 7.30 p.m., when a paper entitled "Atomic Energy in Relation to Marine Nuclear Reactors" was read by the author, Mr. J. Smith, B.A., a scientist at the Atomic Energy Establishment, Winfrith. Mr. J. P. Vickery (Vice-Chairman of the Section), presided, and the meeting was attended by twenty-eight members and visitors.

Mr. Smith gave the lecture with the aid of slides, and in this way was able to give a good illustration of the types of reactors fitted in the n.s. *Savannah* and the U.S.S.R. *Lenin*.

He spoke of the improvement in design of the more modern pressurized water reactors suitable for marine propulsion, and gave a good account of three significant types. Details of weight/power ratio were given, also size of reactors, types of fuel, working pressures and temperatures of the primary and secondary systems, life span of reactor cores, and many other important aspects of this plant were enumerated.

The positioning of reactors and associated heat exchangers and pumps in a vessel was important, as damage from collision and grounding had to be considered, also the strengthening of the hull of the ship in way of the reactor was very necessary, although this was becoming increasingly less important as the weight of the reactor was being reduced in the light of more modern design.

The weight of *Savannah's* reactor, and shielding to give 22,000 s.h.p. was 2,500 tons. A modern reactor and shielding for the same s.h.p. could weigh as little as 500 to 700 tons. This was a considerable advancement for marine application, and vessels in the future might have an aftermost machinery arrangement with the reactor in the for'ard end of the engine room.

Mr. Smith spoke of the future possibility of lifting a whole reactor out of the vessel after its span of life, and putting in a replacement unit—instead of refuelling the reactor *in situ*. This operation had, however, created much controversy, the economics of which were still being carefully studied.

In all, the paper proved of tremendous interest to the assembly, and many questions were put to the author. The Chairman proposed a vote of thanks to the speaker, and the meeting concluded at 9.15 p.m.

Election of Members

Elected on 6th May 1964

MEMBERS

Reginald Alfred Amey, Eng. Lt. Cdr., R.N.
Robert Gordon
Leslie Edward Holt
Stanley Everett Hopkins, Cdr., M.Sc. (Ottawa), R.C.N.
William Stephen Hutchison
Desmond Percy Knapman
Anthony Lowson
William Weston McCully
James Matheson McKay
John Duncan McKillop
Archibald Mason
John Alexander Nichols
Andrew Panayotou
Henry Greenwood Mackson Thompson
Francis Urquhart

ASSOCIATE MEMBERS

Vinod Prakash Agrawal
George David Armstrong
Ashoke Kumar Banerjee
Edgar William Bell
Brian William Butler
Laurence James Cleall-Harding
Geoffrey Arthur Connolly
Ormon Mezer Cox
John Leslie Dobbing
Alan Evans, Eng. Lieut., R.N.
Ajoy Kumar Ghosh
Samar Ranjan Ghosh
William John Gill
Kenneth Gowland
John Steven Greenwood, B.Eng. (Liverpool)
Donald James Hammerton
Zafar Haq
David John Steward Johnson
John Johnsone Knox
Parkash Nath Mehrotra
Krishna Dharma Patil
Keith Austin Pearcey, Lieut., R.N.Z.N.
Herbert Roland Percy, Lieut., R.C.N.
Ronald Robert Richards, Lieut., R.C.N.
Norman Joseph Saulnier, B.Eng. (Dalhousie, Halifax, N.S.)
Carlisle McDonald James Thompson Scott
George Brown Sutherland
Brian William Taylor
Yaqub Ali Tehsin
Andrew Wallace, Lt. Cdr., R.N.

ASSOCIATES

Eric Samuel Aubin
Philip John Norster Aubin
Mark Thompson

GRADUATES

Keith Edward Bowen
Leslie Joseph Fernandes
Trilok Nath Ghabru
Santhanam Sampath Kumar
Kevin John Middleton
Paul Pearson
Pratap Narain Tickoo, Lieut., I.N.

STUDENTS

William Burrough
Trevor Cretney
Peter David Jeffrey
E. Johnson
Henry Beattie Johnston
Christopher Nind
Frederick Babs Ogundipe
Rodney George Pickering
George William Retford
John Edward Smith
Roger Smith
Seng Kong Tang
Donald Keith Waller

PROBATIONER STUDENTS

Michael Frederick Baker
George Paul Behrens
Christopher Bryan Cheney
Stephen Jackson

TRANSFERRED FROM ASSOCIATE MEMBER TO MEMBER

Judah Benjamin
Donald Clyde Bootle
Samuel Gordon
Kenneth Grant
Franklyn Moore
Frank Henry Muller
Trevor Derek Maunder, Lt. Cdr., R.N.
Tulsidas Mohanlal Sanghavi, B.E.
Alan Slater
Leslie Joseph Spencer
Leslie Richard Thomas
James Francis Kikham Tobin, B.Sc. (Durham)
Malcolm Cumming Wilson
William George Wise

TRANSFERRED FROM ASSOCIATE TO MEMBER

Walaja Anantha Raghavan

TRANSFERRED FROM GRADUATE TO ASSOCIATE MEMBER

Surajit Chakravarty
Anthony John Daw, Lieut., R.N.
Brij Raj Kishore Gupta
Manjit Singh Sidhu
William Jack Gordon Smith
Vernon Val Wilson
Robert Yarr
Lai Chung Young

TRANSFERRED FROM STUDENT TO ASSOCIATE MEMBER

Leonard Elves

TRANSFERRED FROM PROBATIONER STUDENT TO ASSOCIATE MEMBER

Brian George Beesley

TRANSFERRED FROM STUDENT TO GRADUATE

Alan David Gambles
John Brian Robson

TRANSFERRED FROM PROBATIONER STUDENT TO STUDENT

Joseph William Boulton
Edward Clark
James Benvie Menzies
John Wilfred Osborne
David Henry Thompson
Michael Albert Turner

OBITUARY

John Gilmour Galloway (Companion 6548), whose death occurred on 13th February 1964, had been associated with the Institute for many years, having been elected a Companion on 3rd November 1930.

Born on 17th March 1882, he was educated at Glasgow High School and, from 1900 to 1906, served an apprenticeship with R. B. Lindsay and Co., marine engine packing manufacturers. After completing his indentures, he remained with the firm, assisting in the management; he became a partner in 1911 and Senior Managing Partner in 1930. From the latter year until 1956, he also acted as consultant for marine sales to the Cape Asbestos Co. Ltd.

He leaves a widow and family.

Isaac MacKinnon-Pearson (Companion 5155) was educated at Glasgow High School and Sedbergh School in Yorkshire. He left the latter establishment in 1914 and, in April 1915, shortly after his eighteenth birthday, volunteered for service in the Army. As he was too small he was turned down, but, by dint of a private course of physical education, was able, a few months later, to enlist as a private in the Glasgow Highlanders (Highland Light Infantry). Except for one period when he was recovering from wounds, he spent the whole war in the trenches. He reached the rank of Corporal, but on principle refused the commission which was offered him.

After 1919, he worked first for the Belgian Consulate in Glasgow and, very shortly after, joined Association Petrolière, in Paris. This was a difficult time for him as, in addition to learning his job in a foreign country, he had to acquire mastery of the French language. His efforts were crowned with success and in 1934, he was running the shipping side of the Anglo-Persian Oil Company in Paris. About this time the company built a number of tankers in France, which involved him in a great deal of work.

Mr. MacKinnon-Pearson had a pronounced artistic bent, which he expressed, during his sojourn in Paris, in painting and etching. It was his custom to spend all the winter months working at a single etching for exhibition at the Spring Salon. One of his etchings was bought by the State and another by the City of Paris. He was also made Officier de la Légion d'Honneur (Palmes Académiques).

Sometime in 1938 he retired from business life. He had begun to feel that what he most wanted to do was paint and the increasing strain of his work with Association Petrolière was making this more and more difficult.

In April 1939, he left France to take his wife back to her home in Canada, where they settled down in the Province of Quebec. He now became interested in another sphere of artistic endeavour, wood sculpture. His work was most successful and always consisted of models of ships, the sea and ships being his favourite subject.

He and his wife returned to France in 1952 and set up house about thirty miles from Paris. His wife was killed in a car accident in 1959 and his death occurred on 7th October 1963.

To his many friends, Mr. MacKinnon-Pearson seemed an exceptionally gifted man. In addition to his artistic work, he had a very wide range of interests and could speak with authority on a great number of subjects.

He had been a Companion of this Institute since 8th September 1924.

Martin Kent O'Grady (Associate 23524), whose death occurred on 22nd April 1964, began his seagoing career as chief engineer of a fishing trawler working out of New Bedford, Massachusetts. He had already been employed as an engineer by the United States Air Force during the Second World War and was the holder of a First Class Department of Transport Certificate (Canada).

He returned to St. John's, Newfoundland, to accept an appointment as an instructor with the local Vocational Institute but had to relinquish this due to ill-health. He resumed work, as chief engineer of the local fire tug, operated by the Department of National Defence. After a short period, he left that service to work as chief engineer on the Great Lakes, for four years.

Returning once again to St. John's, he took up the position of Supervisory Engineer with the Newfoundland Transportation Company. He held this post at the time of his death at the age of forty-six years.

Mr. O'Grady was elected an Associate of the Institute on 13th March 1961. He served as Honorary Treasurer of the Newfoundland Section from its inception in 1962, as Honorary Secretary and Treasurer throughout 1963 and up to his final illness, and was a member of the Section Committee for 1964.

He leaves a widow.

Lieutenant-Commander George Frederick Winterburn, R.C.N.R. (Member 8127), of North Vancouver, has died at the age of sixty-five years. He had been a Member of the Institute since 15th May 1956.

Lieutenant-Commander Winterburn was born in Hong Kong. He attended school at Victoria, B.C., and served his engineering apprenticeship at H.M.C. Dockyard, Esquimalt. Joining the Royal Canadian Navy in 1916, he served in the submarines CC-1 and CC-2, as a seaman. Between the two world wars, he was a naval reserve officer and also served as a marine engineer with the Canadian Government Merchant Marine and the R.C.M.P. marine service. He had been a watchkeeper engineer in R.M.S. *Empress of Asia* and had served as fourth to chief engineer with Canadian National Steamships. He survived the sinking of the s.s. *Canadian Planter* in a collision in the Atlantic.

He later spent a few years in shore employment, first as a boiler inspector for the Ocean Accident Insurance Co. and later as a designing draughtsman and stationary engineer. However, in 1940, he rejoined the R.C.N. to serve as an engineer officer in H.M.C.S. *Ottawa*. Subsequently he became resident naval overseer at Trenton, N.S. and prior to his retirement was a chief operating engineer with the Department of National Defence.

Lieutenant-Commander Winterburn served the Institute as a member of the Vancouver Section Committee, having been elected in 1963. He was a member of the Naval Officers Association of B.C. and a life member of the Missions to Seamen.

He is survived by his wife, two sons and a daughter.