Sea Gyro

Theory on gyroscopic stabilizers

Sea Gyro (LLC).

www.seagyro.com
email: sales@seagyro.com

Theory on the gyroscopic stabilizer

SI Units

Moment of inertia:	$kg\text{-}m^2$ (kilogram meters squared)
Angular velocity:	rad/s (radians per second)
Angular momentum:	N-m-s (Newton meter second)
Torque:	N-m (Newton meter)

The primary component of the gyro is a flywheel that has a Moment of Inertia, J, and an angular velocity w_F. The moment of inertia of the flywheel is determined by its mass and the distribution of its mass relative to its shaft. Increasing mass at the flywheel's outside diameter and/or increasing the flywheel's diameter increases its moment of inertia. The Angular Momentum, L, of the flywheel, the product of its moment of inertia and its angular velocity, is a measure of the extent to which the flywheel will continue to rotate about that point unless acted upon by an external torque. The higher the angular momentum the more ability for the flywheel to react to external torques i.e. in our case more ability to cancel boat roll.

A gyroscope has three axes; a spin axis, and input axis, and an output axis. The spin axis is the axis in which the flywheel is spinning and for our gyro the spin axis is horizontal (athwartship). The input axis is the axis on which inputs are applied. In our case, the principal input axis is the longitudinal axis of the boat since that is the axis around which the boat rolls. The principal output axis is the vertical axis about which the gyro rotates or precesses in reaction to an input.

Let's look at numbers on a M70 Gyro system for a 34m motoryacht

Moment of inertia $J = 74.0\ kg\text{-}m^2$ for the flywheel
Angular velocity: $w_F = 250$ rad/s (approx 2,400 rpm)
Angular momentum: $L = J \times w_F = 6.7\ kg\text{-}m^2 \times 1047$ rad/s = 18,500 N-m-s

When the boat rolls, it acts as an input to the gyro. This input causes the gyro to generate rotation around its output axis such that the spin axis rotates to align itself with the input axis. This output rotation is called precession and in our case the gyro is rotating around the vertical axis.

Dampers are coupled to the gyro's precession axis to act as a brake which controls the gyro precession rate. These dampers are set at commissioning to match the roll characteristics of the vessel.

The maximum output force applied to counteract the boat roll (the input to the gyro) is governed by the following equation:

$T_o = w_P \times L$

where T_o = output torque about the gimbal axis (N-m)
w_P = maximum output rotation rate or precession rate (rad/s)
L = angular momentum (N-m-s)

Plugging in the numbers for the M70 Gyro system for the vessel with a roll period of 5.4 seconds and a precession angle of 2 radians:

w_P = 0.75 rad/s,

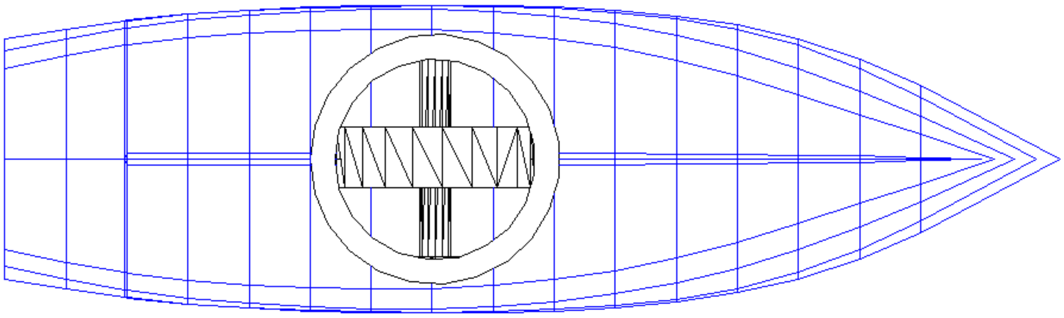
L = 18,500 N-m-s

$T_o = w_P \times L$ = 0.75 rad/s × 18,500 N-m-s = 13,875 N-m

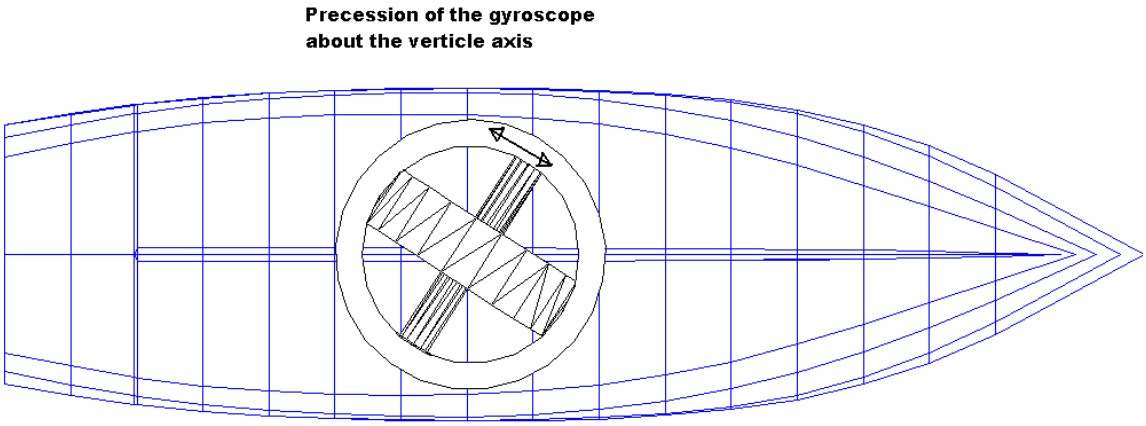
At anchor the 34 metre vessel generates 27,000 N-m of torque about the roll axis.

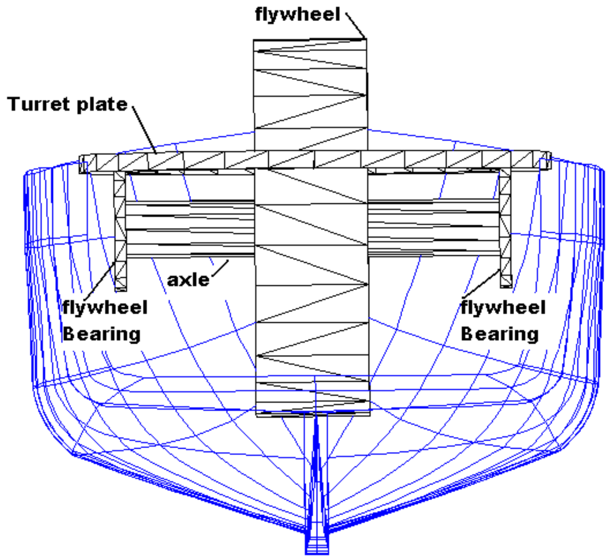
Therefore it would require two M70s to control this rolling torque 2 x 13,875 = 27,750 N-m

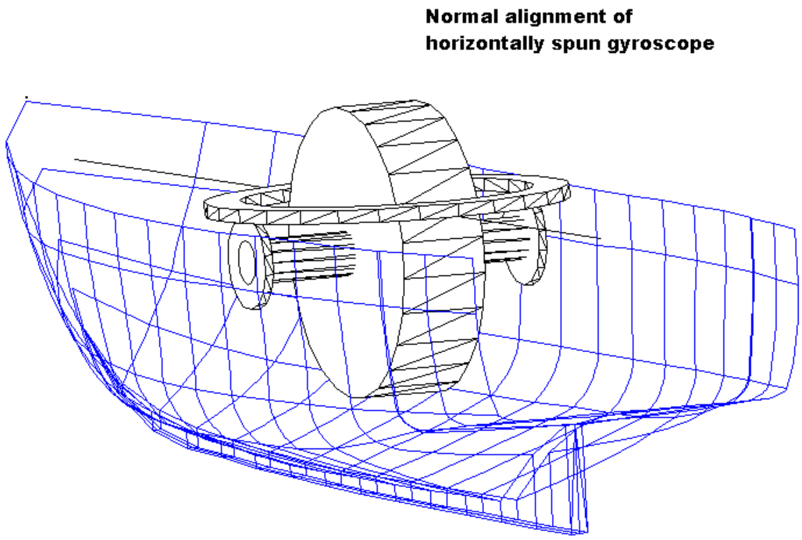
This output axis torque is coupled back into the boat's hull to counteract the roll of the boat.

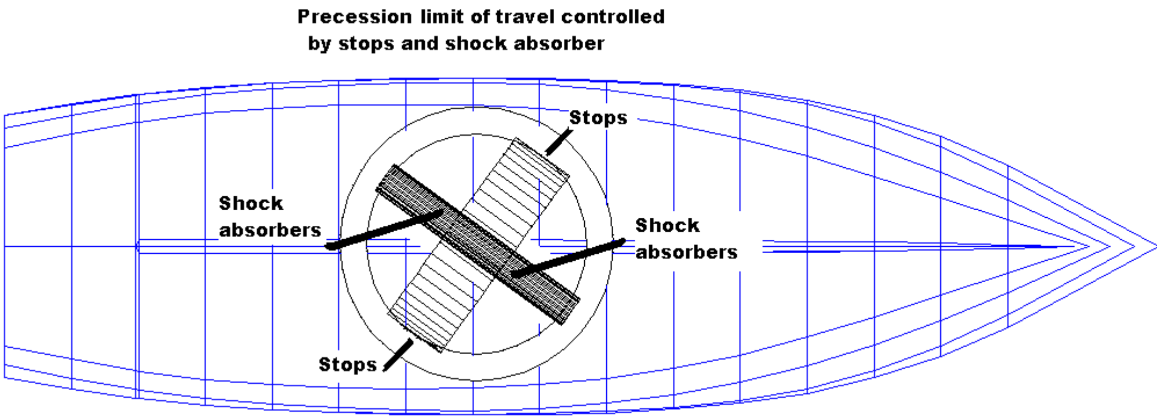


Plan view of gyroscope with horizontal turret plate

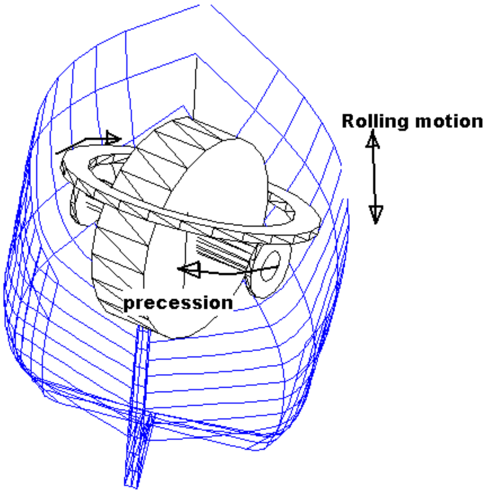

Precession of the gyroscope
about the verticle axis


flywheel
Turret plate
axle
flywheel
Bearing
flywheel
Bearing

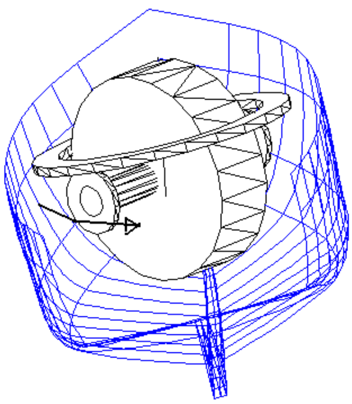

Normal alignment of
horizontally spun gyroscope


Precession limit of travel controlled
by stops and shock absorber
Stops
Shock
absorbers
Shock
absorbers
Stops

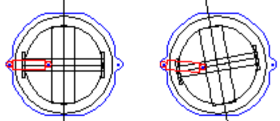
Precession action
as vessel rolls



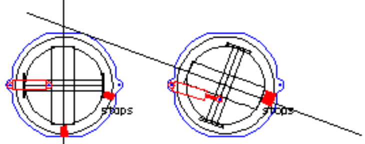
Precession of gyro as
vessel rolls back



Non-linear breaking



small angles of precession giving minimium damper travel and little lever arm, thus little precession breaking and maximium gyroscopic effect



large angles of precession giving maximium damper travel and maximium lever arm, thus maximium precession breaking and reduced gyroscopic effect. Therefore minimium impact on limiting stops