MEASUREMENT OF SHIP'S SPEED OVER GROUND

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A new method of inertial navigation for use aboard ships is proposed. As is known, the function of inertial navigation instruments exists in that the inertial forces arising from accelerations are measured in the craft in the inertial space with reference to a known coordinate system by components, and the values obtained are integrated in an analogue or digital computer, so that finally the instantaneous position of the craft can be read from indicating instruments. An essential part of the inertial navigation instrument is the material presentation of the coordinate system to which the acceleration components refer. Gyro instruments always serve for its mechanical build-up, whereby the gyros in their position are controlled by the acceleration measurements causing the gyros to precess by torquers.

Contrary to the systems so far known, the new proposal derives from the classical two-gyro compass using as system of coordinates the horizon and the north direction, deviated by the speed and course error angle δ. Two accelerometers will suffice; one will measure the acceleration in a north-south direction, the other in an east-west direction, whereby both directions are to be regarded as being deviated by angle δ. Here too a retroaction of the measured acceleration upon the gyro system is necessary. The retroaction, however, does not cause any precession of the gyro system, but exists rather as a variation of the angular velocity of the two gyros about their spin axis. For this only the measurement of the east-west accelerometer is used. To indicate finally the instantaneous speed over ground and the instantaneous ship position, the treatment and utilization of the two values are effected, as usual, by a computer.

As the proposed method differs from other inertial navigation instruments only in its gyro system and coordinate system, these alone are dealt with more fully.

In the first part, with reference to a previous study concerning the development of Schuler's principle, it is stated that a two-gyro compass system accurately indicates north deviated by the speed and course error δ, and simultaneously the true horizontal position, entirely independent of any ship acceleration, if care is taken that the angular momentum of the gyro system is kept proportional to :

$$\Omega = \sqrt{\left(U \cos \varphi + \frac{V}{R} \sin K\right)^2 + \frac{V^2}{R^2} \cos^2 K}$$

$$= U \cos \varphi \cdot \left(1 + \frac{V \sin K}{RU \cos \varphi} + \frac{V^2 \cos^2 K}{2R^2 U^2 \cos^2 \varphi} \cdots\right]$$

$V(t)$ is the speed over ground, $K(t)$ the true course, $\varphi(t)$ the momentary geographical latitude, U the angular velocity of the earth, R the earth's radius, $\Omega(t)$ the angular velocity of the ship's centre of gravity, resulting from the earth's rotation in the inertial space and from the inherent movement of the ship in reference to the earth.

The term $\frac{V \sin K}{RU \cos \varphi}$ amounts to only a few percent.

To accomplish this change in the angular momentum, the angular velocity of the two gyros is varied by means of the three-phase current frequency of the converter. The frequency is thus controlled by the acceleration measurement $b_{EW}(t)$ in an east-west direction, deviated by the angle δ. As explained, the time rate of change of Ω is determined by $b_{EW}(t)$

$$\frac{d\Omega}{dt} = -\frac{1}{R} b_{EW}$$

Thence by means of an integrator the angular velocity Ω can be obtained according to

$$\frac{d\delta}{dt} = \Omega \cos \delta \tan \varphi - \frac{1}{R} \int_0^t b_{EW}(t)\, dt$$

The integration constant is determined by φ_0, the known geographical latitude at the starting-point of the voyage. Then the differential equation system of the first order for the time functions $\delta(t)$ and $\varphi(t)$

$$\frac{d\delta}{dt} = \Omega \cos \delta \tan \varphi - \frac{b_{NS}}{R\Omega}, \quad \frac{d\varphi}{dt} = -\Omega \sin \delta$$

with the initial conditions $\delta = 0$ and $\varphi = \varphi_0$ must be integrated by the computer. $b_{NS}(t)$ is the instantaneous acceleration measured in a north-south direction, deviated by angle δ. The computer must by means of the integrated functions Ω, φ and δ, then still supply the instantaneous north-south and the east-west speed components according to

$$V \cos K = - R\Omega \sin \delta, \quad V \sin K = R\Omega \cos \delta - RU \cos \varphi$$

The second part of the publication deals with the technique of construction of the two-gyro horizontal compass. The gyro sphere, which by its position represents the system of coordinates of north deviated by δ, and of the horizon, is suspended by a frictionless floating bearing with a single pivot. As owing to the many current leads the two accelerometers cannot very well be housed in the gyro sphere itself, they are fitted on the gyrostabilized compass bowl which carries the gyro sphere. The gyrostabilizing of the compass bowl in reference to its three degrees of freedom is also obtained by a two-gyro system. Slow deflections of the stabilizing gyro system with regard to the gyro sphere are measured by pickoffs which act by torquers, causing the stabilizing gyro system to drift back into the desired position with regard to the gyro sphere.