Ring Laser Gyroscope and Their Uses

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Introduction

Historically, rate sensing requirements have been satisfied by conventional spinning mass gyroscopes whose operation depends on the angular momentum generated by a rotating wheel or ball.

In the 1980s, laser gyroscopes began to take over the work of their mechanical, and later, electronic, forebears, without the slightest resemblance in principle or operation to the earlier devices. The idea behind the ring laser gyroscope actually dates back to 1913, when a French physicist, Georges Sagnac, experimented with rays of light moving in opposite directions around a circular cavity on a turntable. Sagnac showed that when he rotated the turntable, the light traveling with the rotation arrived at a target slightly after the light traveling against the rotation. He believed he had proven the existence of ether in space. In fact, he was demonstrating a property of light that came to be understood much better with the invention of the laser in the 1950s.

A laser (light amplification by stimulated emission of radiation) operates by exciting atoms in a plasma to release electromagnetic energy, or photons, in a cavity. Each end of the cavity reflects the energy back and forth, and it forms a standing wave pattern. The wave frequency—its pattern of peaks and troughs—is determined in part by the length of the cavity.

In a ring laser gyroscope, the two counter-rotating beams are channeled to a photo detector. If the vehicle is not rotating, the beams remain in phase. If rotation is occurring, one beam continuously changes phase with respect to the other. A diode translates that moving interference pattern into digital pulses, each pulse representing an angle of rotation (typically 0.0005 degree per pulse, according to Koper). The rate at which the pulses are produced is also a measure of the rate of rotation [1].

Sagnac effect

A schematic diagram of the Sagnac interferometer is represented in figure 1. Two oppositely directed beams, (clockwise CW, and counterclockwise CCW) arising from the same source, propagate inside the interferometer along the same closed path.

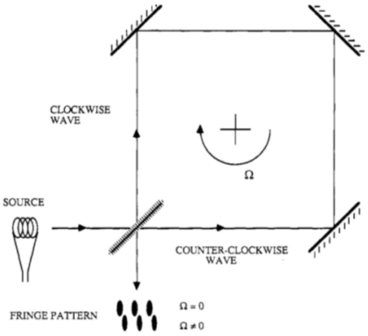

Figure 1 - Classic Sagnac interferometer. The CW and CCW waves interfere to produce the fringe pattern with shifts for **Ω** = 0

At the output of the "ring" interferometer, the CW and CCW waves interfere to produce a fringe pattern which shifts if a rotation rate is applied along an axis perpendicular to the plane of the beam path. The two CW and CCW experience a relative phase difference proportional to the rotation rate, **Ω**. This effect is based on the fact, which, with respect to inertial space, the two counter-propagating light waves take different times to complete a trip around a rotating closed path. A general approach valid for an arbitrary interferometer shape [2] leads to a time difference Δt proportional to Ω:

$$\Delta t = \frac{4A\,\Omega}{c^2}$$

Where A is the area enclosed by the light path, and c the velocity of light.

The optical path difference ΔL between the two waves is:

$$\Delta L = c\Delta t = \frac{4A\,\Omega}{c}$$

It appears from this equation that a Sagnac interferometer is not a very sensitive device:

$$for\ A = 1\ m^2\ and\ \Omega = \frac{10°}{h} : \Delta L \cong 7.10^{-13}\ m$$

In 1925, during a famous experiment, Michelson and Gale [3] measured the earth rotation rate (10^0/h), with a rectangular path of 2.10^5 m^2. For a visible light source the measured path difference was roughly a quarter of a fringe.

Basic Theory of Ring Laser Gyros

Ring Laser Gyroscopes (RLG) combines the functions of optical frequency generation and rotation sensing into a laser oscillator within a ring shaped cavity. Typically, as in Figure 2, ring laser gyros consist of a solid block, either square of triangular, of glass ceramic material into which a lasing medium is introduced. The electrodes provide gain for the lasing medium, generally a helium/neon mixture due to its short coherent length and index of refraction of nearly 1.0, which generates two independent beams direction in opposite directions around the cavity. In order for the optical path to support lasing, there must be an integral number of wavelengths around the path and oscillation will occur at that frequency, f which meets this requirement. The cavity size is adjusted to support oscillation at frequencies optimal to the lasing media [4, 5].

This differential in frequency between the two traveling waves, the beat frequency Δf, is described in the following relationship:

$$\Delta f = \frac{4A\Omega}{\lambda_s P}$$

Where A is the area and p the perimeter of the ring cavity, λs is the wavelength of the light in the lasing medium and Ω is the angular rate of rotation.

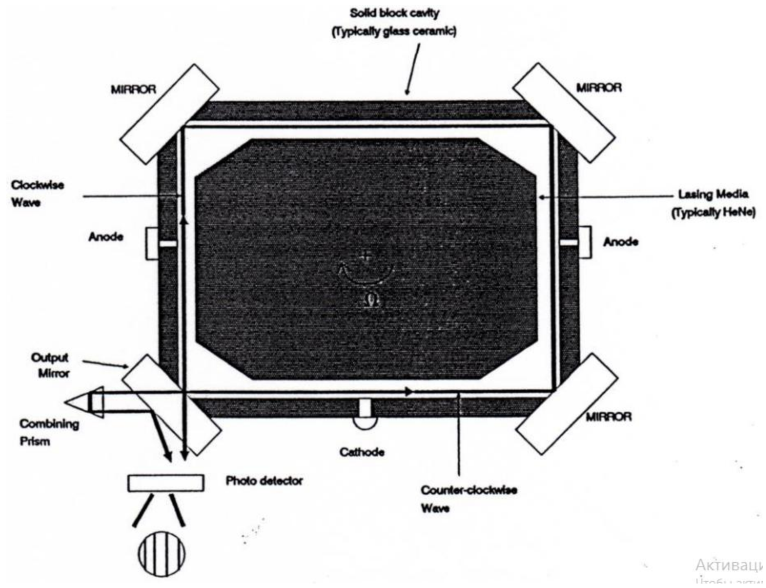

Figure 2 - Typical ring laser gyro [4]

Here, the ratio $4A/\lambda_s P$ is known as the scale factor, K, of the gyro and Δf is directly proportional to the rate of rotation Ω .

The output of the ring laser gyroscope is typically developed by the use of a combining prism which produces two nearly collinear beams interfering to create fringe patterns sensed by the photo detectors [6]. The number of beats during a time interval is directly proportional to the rotation rate and the direction of fringe movement is indicative of rotational direction. In practice, the ring laser gyro is often operated in an integrating mode where each cycle of the beat frequency is counted as one unit of angular displacement.

Limitations of Ring Laser Gyros

The ring laser gyroscope today is well established in the medium and high performance markets. It offers many advantages over mechanical gyros; digital output linear with angular rotation, high sensitivity and stability, quick reaction times, insensitivity to acceleration and immunity to most environmental effects [7]. In spite of these advantages, the RLG remains a specialized instrument that utility varies with the application and several factors limit its selection over modern mechanical system. The exacting cavity geometries and precision mirrors are required for RLG construction and the necessity of assembly under stringent clean room conditions drive its cost beyond economic application to low performance system. The size and weight of the RLG are other limiting factors to theirs use. The solid glass optical block and mechanical dither assembly found in most RLGs unavoidably add to their weight [8]. Attempts to miniaturize the RLG have met with a corresponding decrease in their reliability. While large ring laser gyroscopes have demonstrated over 10,000 hours of operation, smaller units (a few cm diameters) are limited to a few hundred hours of use. Additionally slow leakage of the gas media, insignificant in large systems, may lead to shelf life problems in smaller RLGs.

The power requirements of RLGs are high. To support the lasing action on which RLGs depend, power sources capable of delivering several hundred volts. Typical RLG power requirements are five to ten watts [9].

Conclusions

Figure 3 illustrates schematically the current trends on shortterm regarding the gyro technology, while Figure 4 is an overview of the use of gyro technologies on long term in new applications. Note that the integrated optical and MEMS technologies (IO) will dominate the entire spectrum of mid and low performance applications. Systems that use RLGs and mechanical gyros will be replaced by systems based on MEMS and IFOG (Interferometric Fiber Optic Gyro) technology. However, RLGs have an extremely high scale factor stability compared to IFOGs. Anyway, the replacement of MEMS technology is conditioned by improving performance, increasing safety and decreasing the price.

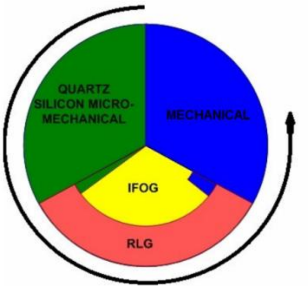

Figure 3 -The use of gyro-sensors technology - a general overview of technologies used in present and in the near future

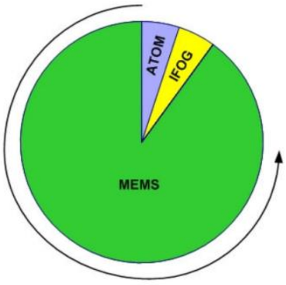

Figure 4 - The use of sensor technologies - a general overview of technologies used in the gyros field on long term

The RLG has excellent scale-factor stability and linearity, negligible sensitivity to acceleration, digital output, fast turn-on, excellent stability and repeatability across the range, and no moving parts. Present day RLG's is considered a matured technology and its development efforts are to reduce costs more than to increase its performance [11].

Summary, it is necessary to note that tends of gyro's development are focused on integration MEMS and RLG technology into one device in future.

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Application of Alternate Current for the Welding of Magnetized Details for Special Directs

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Introduction. Manual metal arc (MMA) welding by direct current (DC) with basic coated electrodes is a common method to produce permanent joints for details repair [1-4]. To provide a spatial and physical stability of the arc discharge, it is necessary to create conditions for eliminating magnetic blow. This elimination is the most difficult to provide in the case of residual magnetization of workpieces, which is caused by application of magnetic methods of inspection. The solution of this problem, as a rule, is carried out with the help of preliminary demagnetization of the workpieces. This approach involves the use of special equipment, the operation of which is characterized by a long process of preparation for work and low labor productivity and requires a highly skilled service personnel.

To eliminate these disadvantages an innovative solution to the problem of arc welding of magnetized workpieces was proposed. The solution is in using a square wave alternate current (AC), which polarity is changed at the moment of critical deflection of the arc from the axis of the coated electrode (Patent RU2245231). Such an algorithm of the welding current polarity switching helps to avoid arc extinction, to stabilize its spatial position and to ensure welding when the value of magnetic induction in the welding zone is up to 0.1 Tesla. To implement the solution, the IST-201 semiconductor inverter was designed. This inverter is to be included into a load circuit of a welding rectifier or a generator with constant current characteristic.

Research purpose is to confirm the suitability of square wave AC in arc welding with coated electrodes of magnetized details. It is necessary to determine the influence of the current type and magnetic flux density in the welding area on the properties of welded joints.

Experimental procedure. Pipes made of 17GSU steel grade were used as samples, which mechanical properties were presented in Table 1. Tube diameter was 1067 mm, wall thickness – 14 mm. Edge preparation (C17) was done according to the requirements of GOST 16037-80. Welding was performed for a pipe in non-rotational position in three passes. Welding parameters are presented in Table 2. Initial value of the magnetic flux density in the gap between the edges to be welded was set by an external inductor. In the absence of a magnetic field in the welding zone (magnetic flux density is equal to 0 mT), positive DC (electrode is connected to positive pole) was