Coriolis Vibratory Gyroscope

INNALABS® CVG25
Single axis gyroscope

TEST PLAN

November, 2008

Innalabs Holding, Inc. 21525 Ridgetop Circle, Suite 260, Dulles, VA 20166
Phone: +1 (703) 880-4222 Fax: +1 (703) 935-8377
e-mail: info@innalabs.com
www.innalabs.com

1. General information

1.1. **Objective:** testing is conducting to verify the accuracy parameters of Innalabs CVG25-## gyroscopes

1.2. **Testing samples:** Innalabs CVG25-## gyroscopes' testing samples are Coriolis vibratory gyroscopes with 25 mm cylindrical resonator. Resonator is inserted in the vacuum and connected due to the buffer with digital electronic board, providing data acquisition. Innalabs CVG25-## outputs are digital codes proportional to measuring angular rate and temperature under gyroscope frame.

2. Test conditions

2.1. Testing is done in laboratory conditions at the constant temperature +25 ±1 ^{o}C, humidity not exceeding 70 %, under atmospheric pressure, and over the temperature range -40 +50 ^{o}C in the temperature chamber.

2.2. During scale factor testing (dynamic tests) gyroscope is settled on alighting surface that IA is parallel to the rotation platform angular rate and nominally directed up vertically.

2.3. All tests have gyroscope data acquisition frequency in 1 Hz.

3. Test methods

The testing process consists of 6 parts:

<u>Scale factor parameters determination (SF)</u>
(1) SF measurement and its linearity
(2) SF turn-on to turn-on repeatability determination
(3) SF temperature sensitivity determination

<u>Bias stability parameters determination</u>
(4) Absolute Bias measurement, random walk and bias stability, bias repeatability at a constant temperature + 25 ^{o}C
(5) Random walk and bias stability at the maximum and minimum constant temperature of the operative range -40 +50 ^{o}C
(6) Bias stability and random walk over the temperature range [-40; +50] ^{o}C

3.1. SF measurement and its linearity

3.1.1.Establish temperature +25 ±1 ^{o}C in the temperature chamber. Keep gyro turning off at the constant temperature1.5 hours at the temperature chamber.

3.1.2.Turn on gyro, start gyroscope data acquisition.

3.1.3.Set cross section of angular rates (see Fig. 3.1). (Ω= -/+1; -/+5; -/+10; -/+20; -/+50; -/+80; -/+120; -/+160; -/+200 °/s).

Innalabs Holding, Inc. 21525 Ridgetop Circle, Suite 260, Dulles, VA 20166
Phone: +1 (703) 880-4222 Fax: +1 (703) 935-8377
e-mail: info@innalabs.com
www.innalabs.com

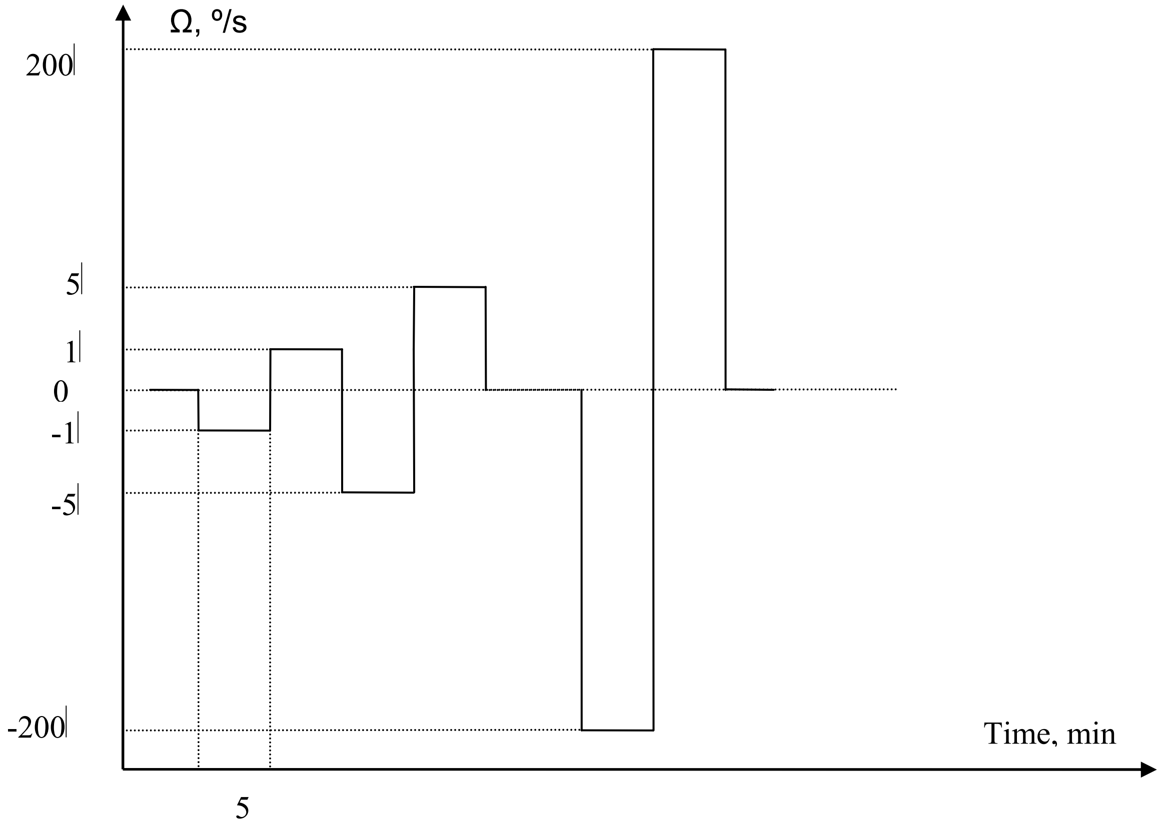

Fig.3.1. Cross section of angular rates in establishing gyroscope SF at the constant temperature.

3.1.4. Determine SF at each angular rates (see clause 4.1), calculate SF average and its linearity as a standard deviation, divided by the average.

3.2. SF turn-on to turn-on repeatability determination

3.2.1. Turn off gyro and keep at the constant temperature at the temperature chamber for 1 hour.

3.2.2. Turn on gyro, record gyro output for 30 minutes, then carry rotation with angular rate Ω=-/+50º/s (see Fig.3.2).

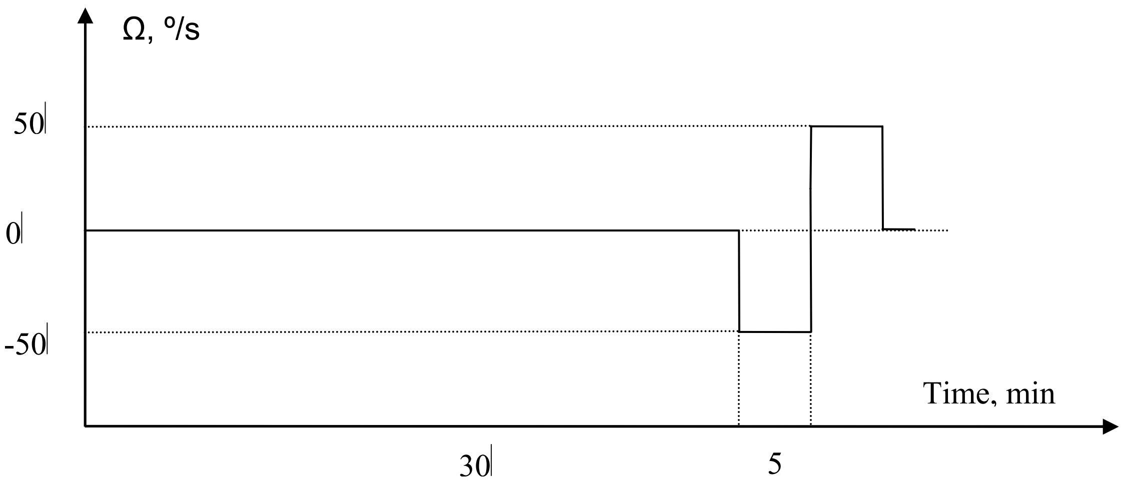

Fig. 3.2. Angular rates gyro rotation cross section for determining SF turn-on to turn-on instability.

3.2.3. Repeat clause 3.3.1 and 3.3.2 4 times, then estimate gyro SF for each acceleration.

Innalabs Holding, Inc. 21525 Ridgetop Circle, Suite 260, Dulles, VA 20166
Phone: +1 (703) 880-4222 Fax: +1 (703) 935-8377
e-mail: info@innalabs.com
www.innalabs.com

3.2.4. Using calculated SF gyro value at the angular rate of rotation speed surface Ω=50 º/s according to the clauses 3.1.4 and 3.3.3, calculate SF turn-on to turn-on gyro repeatability as a standard deviation divided by the average.

3.3. SF temperature sensitivity determination

3.3.1. To repeat tests following clause 3.1.1 – 3.1.4 for the maximum and minimum temperature meaning of the operating range [-40…+50]ºC.

3.3.2. Evaluate SF temperature sensitivity according to the formula of the clause 4.2.

3.4. Absolute Bias measurement, random walk and bias stability, bias repeatability at a constant temperature + 25 ^{o}C

3.4.1. Set temperature at the temperature chamber. Keep gyro turned off at the constant temperature 1 hour at the temperature chamber.

3.4.2. Turn on gyro, to begin gyro data acquisition.

3.4.3. Keep for 3 hours and record gyro output. According to the results, calculate Random Walk, Bias stability by Allan variance (see clause 4.3), Long term BS and Short term BS (see clause 4.4) and established Absolute bias value (with the deduction of 100 first seconds will be warm-up time).

3.4.4. Turn off gyro and keep at the constant temperature at the temperature chamber for 1 hour.

3.4.5. Turn on gyro, record gyro output for 3 hours.

3.4.6. Repeat clause 3.5.4 and 3.5.5 again, and then estimate bias repeatability turn-on to turn-on as a standard deviation divided by the average.

3.5. Random walk and bias stability at the maximum and minimum constant temperature of the operative range -40 +50 ^{o}C

3.5.1. Fix -40 ^{o}C temperature at the temperature chamber. Keep gyro turned off at the constant temperature 1 hour at the temperature chamber.

3.5.2. Turn on gyro, start gyro data acquisition.

3.5.3. Keep for 3 hours, record gyro output. According to the results calculate Random Walk, Bias stability by Allan variance, Long term BS, Short term BS and established bias value.

3.5.4. Turn off gyro.

3.5.5. Repeat tests according to the clause 3.5.1-3.5.4 for temperature +50 ^{o}C.

3.6. Bias stability and random walk over the temperature range [-40; +50] ^{o}C

3.6.1. Set temperature + 25 deg C at the temperature chamber. Keep gyro turned off at the constant temperature 1 hour at the temperature chamber.

3.6.2. Turn on gyro, to begin gyro data acquisition.

3.6.3. Record gyro output during temperature change at the temperature chamber by profile that presented on figure 3.3. Temperature ramp rate shall be 1 ^{o}C/min. Total dwell time at each temperature is 4hrs.

Innalabs Holding, Inc. 21525 Ridgetop Circle, Suite 260, Dulles, VA 20166
Phone: +1 (703) 880-4222 Fax: +1 (703) 935-8377
e-mail: info@innalabs.com
www.innalabs.com

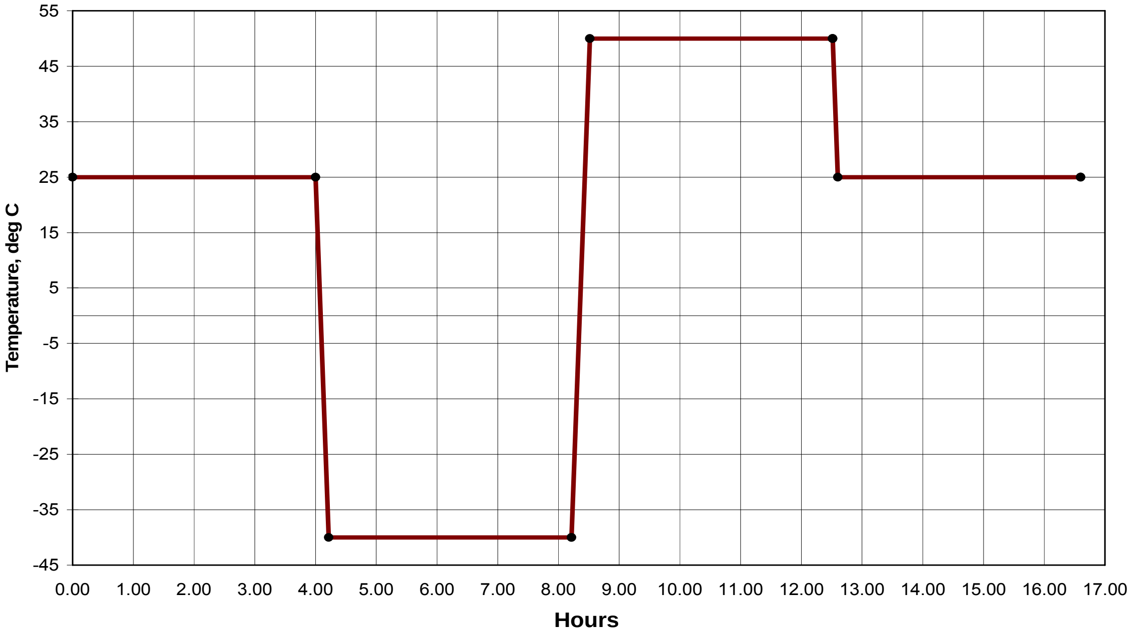

Fig. 3.3. The profile for measurement of Bias stability over the temperature range

3.6.4. According to the results calculate Random Walk, Bias stability by Allan variance, Long term BS, Short term BS over the temperature.

4. Parameters' analysis methods

4.1. Scale factor analysis.

Gyro scale factor on the angular rate Ω is determined according to the formula:

$$K = \frac{N^- - N^+}{2\Omega} \text{ [mV/°/sec]},$$

где N^- - gyro output average at the surface rotation with angular rate –Ω (Counts), N^+ - gyro output average at the surface rotation with angular rate +Ω (Counts).

4.2. Scale factor sensitivity value to the temperature.

Scale factor temperature sensitivity температуре is determined by the formula:

$$\frac{K(T_{\max}) - K(T_{\min})}{K(T_{cp})\Delta T}[ppm/{}^0C].$$

4.3. Random Walk and Bias Stability analysis is carried out by Allan variance curve.

Allan variance dependence on average time is determined by the formula:

$$\sigma^2(T) = \frac{1}{2(N-2n)} \sum_{k=1}^{N-2n} [\overline{\Omega}_{next}(T) - \overline{\Omega}_k(T)]^2 ,$$

where

- $\overline{\Omega}(T) = \frac{1}{T}\int_{t_k}^{t_k+T} \Omega(t)dt$ - gyro output average for the average time T on the sector, that begins with k gyro output value and contains n points ($T = nt_0$, t_0 – output discrete);
- $\overline{\Omega}_{next}(T) = \frac{1}{T}\int_{t_{k+1}}^{t_{k+1}+T} \Omega(t)dt$ (where $t_{k+1} = t_k + T$) – gyro average output for the average time T on the next average sector;

Innalabs Holding, Inc. 21525 Ridgetop Circle, Suite 260, Dulles, VA 20166
Phone: +1 (703) 880-4222 Fax: +1 (703) 935-8377
e-mail: info@innalabs.com
www.innalabs.com

- $1 \le n \le (N/2 - 1)$.

Bias Stability value is determined by the horizontal tangent transversion to the low point of Allan variance schedule, built in the logarithmic and coordinate axes. Random Walk value is situated in the tangent transversion point to Allan variance schedule, drawing at the angle 26.5651° (arctg(-1/2)), and axis (see Fig. 4.1).

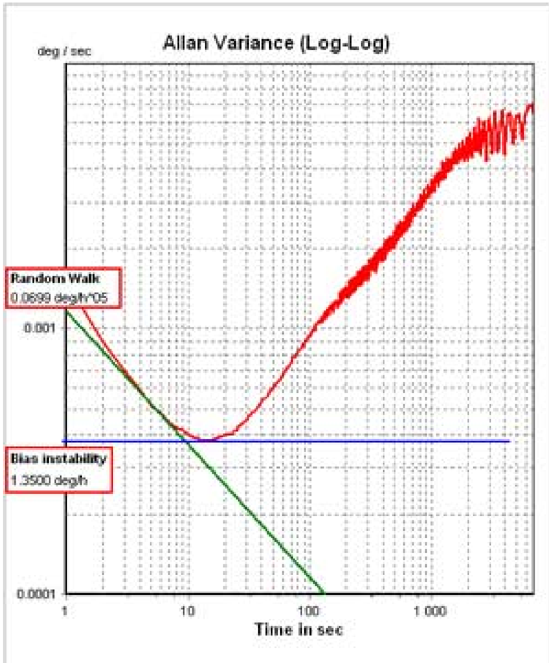

Fig. 4.1. Walk and Bias Instability analysis by Allan variance schedule

4.4. Long-term and short-term bias stability analysis.

For long-term BS and short-term BS estimation the gyro output recording is dividing accordingly into intervals in 100 and 3600 seconds, output values on these intervals are averaging, then the standard deviation of these averaged values is finding according to this formula

$$s = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2},$$

where $\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$.

Innalabs Holding, Inc. 21525 Ridgetop Circle, Suite 260, Dulles, VA 20166
Phone: +1 (703) 880-4222 Fax: +1 (703) 935-8377
e-mail: info@innalabs.com
www.innalabs.com