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Rough north seeking method based on tracking speed detection method

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Abstract. When the north angle is greater than 40^0, a certain gyro theodolite of The PLA 1001 Factory can not normally find the North. In this paper, the author deduces a mathematical formula between pendulum gyro in the tracking state speed and the north angle, a coarse north seeking method based on tracking speed detection method is proposed. Analysis and experimental results show that this method can achieve omni-directional north seeking at any initial erecting azimuth within 2 minutes, accuracy can meet the requirements of coarse north finding, shortened the time and improve the fitting accuracy, solve the problem of north seeking large azimuth.

1. Introduction

North seeking technology has been widely used in aerospace, mining, undersea tunnel, geographic mapping, energy exploration and military fields. The development direction of the current gyro theodolite is high precision, fast and full automation, but high precision and fast is often a pair of contradictory requirements [1]. GYROMAT series gyro theodolite of German DMT company representative the international advanced level [2][3].

Domestic research on the precision of the north seeking algorithm is more mature, but the research on the rough north seeking is backward, relevant literature is relatively small ［4］. Literature ［5］ proposed a full azimuth fast forward method based on swing speed detection, Time and accuracy are greatly improved, the problem is that there is no theory and documentation to show whether the follow-up of the shell can be tracked on the gyro swing. Literature ［6］ proposed use of one-fourth-cycles to find out rough north, use the method of integral precision complex north of north.

In this paper, the author studied mathematical models of gyro trail and gyro sensitivity of the trail, a coarse north seeking method based on tracking speed detection method is proposed.

2. Coarse north seeking method

2.1 Principle.

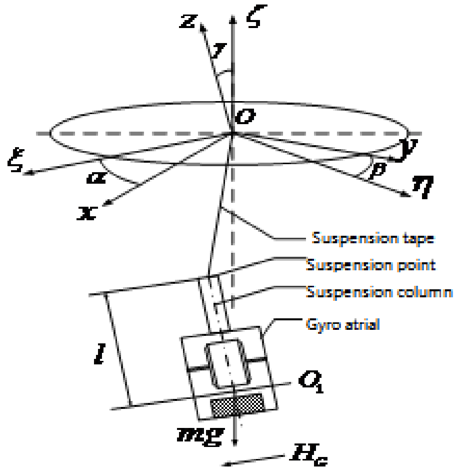
Established the dynamics model of gyro sensitive parts, as shown in figure 1 [7].The gyro sensitive part is suspended from the O point of the instrument case through a suspension belt. O_1 for the sensitivity of the center of gravity, the center of gravity O_1 and the distance between the suspension point L is called the heart of high, the moment of inertia of the gyro is around Ox, Oy, Oz axis Jx, Jy, Jz (Jx does not include the moment of inertia of the gyro rotor, Jy = Jz); mg for the sensitivity of the Ministry of gravity, H_G for the gyro rotor moment of momentum [8].The kinetic equation of pendulum gyroscope:

$$\begin{cases} H_G(\omega_e \sin\varphi\cos\beta - \omega_e\cos\varphi\sin\beta\cos\alpha + \dot{\alpha}\cos\beta) = mgl\beta \\ H_G(\omega_e\cos\varphi\sin\alpha + \dot{\beta}) = -D_B \triangle\alpha - K_D\dot{\alpha} \end{cases} \tag{1}$$

According to Euler dynamic equation, ignore minor factors, the equation of motion of the gyro sensitive part is as follows[9]:

$$\begin{cases} H_G(\omega_e \sin\varphi + \dot{\alpha}) = mgl\beta \\ H_G(\omega_e \cos\varphi \sin\alpha + \dot{\beta}) = -D_B(\alpha - \alpha_0) - K_D\dot{\alpha} \end{cases} \tag{2}$$

ω_e for earth self rotation speed, α_0 for azimuth of suspension with zero torque, D_B for suspension with torque coefficient, K_D for damping coefficient.



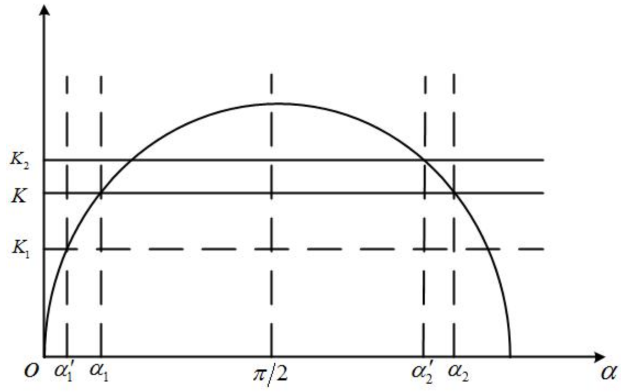


Fig. 1 Mechanical model of pendulous gyroscope Fig. 2 Schematic diagram of solution

Due to the air damping is very small, ignore K_D, since the sensitive part is in the tracking state, the self zero position is very small, and can be neglected. order $D_K = H\omega_e \cos\varphi$, $\omega_o = \sqrt{mgaD_K} / H_G$, the α satisfies the equation:

$$\ddot{\alpha}_o + \omega_o^2 \sin\alpha = 0 \tag{3}$$

The change law of α can be obtained by the above formula, the α derivative:

$$\frac{d\alpha}{dt} = f(\alpha) = \omega_t \tag{4}$$

ω_t is for the gyro sensitive part swing speed, will ω_t into formula (3):

$$\omega_t' + \omega_0^2 \sin\alpha = 0 \tag{5}$$

$$\alpha = \arcsin\left(-\frac{\omega_t'}{\omega_0^2}\right), \alpha \in \left(-180^0 \sim +180^0\right) \tag{6}$$

2.2 Solution of two value problem.

There are two azimuth, one is in the range of $+0^o$ to $+90^o$ （$-0^o \sim -90^o$） ,another is in the range of $+90^o$ to $+180^o$（$-90^o \sim -180^o$）,'$+$'represents the east side, '$-$'represents the west side. By rotating ΔN degrees to the direction of the rough north to solve the two value problem. The principle is shown in Figure 2.

$$\sin\alpha = -\frac{\omega_t'}{\omega_o^2} = K \tag{7}$$

K is a constant, when $K > 0$, the type (7) can get two solutions:

$$\alpha_1 = \arcsin K \tag{8}$$

$$\alpha_2 = \pi - \arcsin K \tag{9}$$

Definition α_1 is in the range of $+0^o$ to $+90^o$, Gyro sensitive part rotation ΔN angle to the coarse north direction.The type (7) can get the other two solutions:

$$\alpha_1' = \alpha_1 - \Delta N = \arcsin K_1 \tag{10}$$

$$\alpha_2' = \alpha_2 - \Delta N = \arcsin K_2 \tag{11}$$

$$K_1 < K < K_2 \tag{12}$$

The following conclusions can be drawn: when the ΔN angle is rotated to the coarse north direction, if the value of $\sin\alpha$ is larger, the azimuth angle is within the range of $+90^o$ to $+180^o$, if the value of $\sin\alpha$ becomes smaller, the azimuth angle is within the range of $+0^o$ to $+90^o$.When $K<0$, we can get the azimuth angle similarly.

3. Test verification

3.1 Composition of test system.

After measurement, the motor voltage is about 14V, while the NI acquisition card measurement range is 10 V, need to design the buck circuit, the collected data is reduced to half of the original. Instrument parameters are as follows: $H_G=0.392kg\bullet m^2/s$, $\omega_e=7.29\times10^{-5}rad/s$, m=0.85kg, l=0.15m, $g=9.8m/s^2$, $\varphi=34^o$.

The experimental platform is composed of five parts, including North Finder experiment platform, three tripod, NI data acquisition card, control box, notebook computer, as shown in Figure 3. Burn the program to the north finder control panel, NI data acquisition card real-time acquisition of motor signals, and store the data to the notebook computer, north seeking instrument experimental platform connect with control box and NI data acquisition card, the button of Control box used to control the process of the experiment.

Fig. 3 Connection of experimental instrument

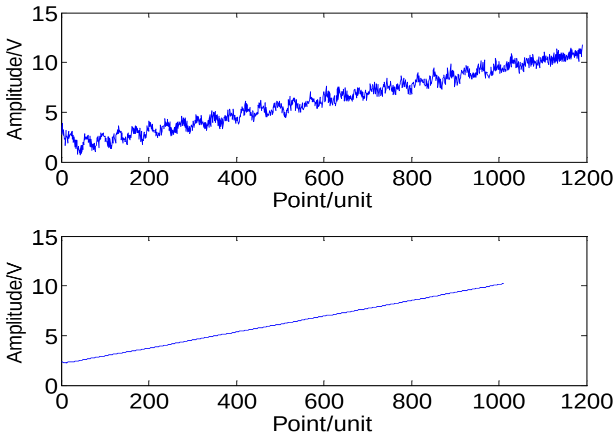


Fig. 4 Spectrum analysis of the 90^0 of partial West

Based on the above analysis, design the process of north seeking. First start gyro motor to rated speed, and lower the gyro sensitivity, case following swing of the sensitive part driven by servo motor, collecting experimental data, determine the size of swing speed of gyro and motor speed, if $\omega_0<\omega_c$,indicates that the shell can still track the sensitive part and continue to collect the data; if $\omega_0>\omega_c$,indicated that the shell can not track the swing of the sensitive part, and should lock the sensitive part at this time, calculate the azimuth angle according to the collected data, and then the instrument rotates the corresponding angle to reach the coarse north position, complete rough north seeking.

Specific steps are as follows:

① Set up test platform, connection test equipment;

② Set up the gyro theodolite in $+30^0$ position, and leveling gyro theodolite

③ After power, enter the factory settings by press "." and enter the password,enter manual operation mode by press "4",press "6" and press OK, after the gyro rotor is accelerated to the rated speed,began to lower the gyro sensitivity by press "4", the red light is bright at this time,

④ When the red light is off, start tracking gyro by press "8", start recording time, when the instrument is in a state of temporary stop, stop tracking gyro by press "8", stop recording time, deflection alidade and record the North Point

⑤ Lock gyro sensitive part by press "5", and brake gyro sensitive part by press "7",

⑥ Record and store the collected data

⑦ Remove instrument and analyze test data.

3.2 Test result analysis.

Experimental measurements are in the range of -180^o to $+180^o$, transform a position Every 30 degree, 6 groups of experimental data were collected in each location, 31'01.11" benchmark for 0^o,acquisition frequency is 60 HZ. The results of the experiment are shown in Table 1, the filtering results are shown in Figure 4. Analysis table 1, the tracking speed detection method can realize the full azimuth pre orientation, coarse north seeking maximum results for $6^0 27'$ 59", coarse north seeking time is 75 s , basically meet the requirements of rapid north seeking.

Table 1 Experimental result

Position	North seeking results	North direction recording	Time /s	Position	North seeking results	North direction recording	Time /s
+30°	+14⁰11´42"	+18⁰07´48"	30	-30°	-15⁰26´53"	-19⁰09´43"	43
+60°	+35⁰26´11"	+39⁰31´46"	27	-60°	-38⁰33´45"	-41⁰12´33"	29
+90°	+66⁰45´53"	+69⁰15´06"	32	-90°	-76⁰51´23"	-73⁰05´57"	40
+120°	+101⁰22´18"	+98⁰34´28"	34	-120°	-98⁰43´24"	-101⁰31´30"	31
+150°	+131⁰44´24"	+126⁰32´51"	56	-150°	-123⁰06´18"	-128⁰50´54"	51
+180°	+147⁰06´21"	+142⁰17´46"	75	-180°	-139⁰24´31"	-145⁰52´23"	69

4. Summary

Aiming at the problems existing in the prototype, based on a detailed analysis of the motion law of large azimuth, a tracking speed detection method is proposed, short the north seeking time and improve the efficiency of north seeking, the intended results can meet the accuracy requirements, achieve a full range of north seeking, improve the reliability and flexibility of the system.

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