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The Application of Gyro in Vehicle Angle Measurement

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ABSTRACT:*The traditional angle sensor in angle measurement of vehicle has some disadvantages such as low stability, low reliability and anti-interference ability. Based on inertiadeviceshas a high sensitivity and little affected by magnetic interference in the measurement of angle .It does not rely on external information and stability advantages. Using gyroscopes, is developed to replace the traditional method for measuring the angle of angle sensor for vehicle, and random error in measurement results are filtered. The programme uses a CRS03-04S gyro, installed on the vehicle front wheel shaft, used to measure the angular speed of the front wheels, in order to calculate the actual angle of the front wheels. Finally, using Kalman filtering to deal with the random error in measurement results separately, so as to provide accurate real-time information around the corner on the steering control. Experimental results show that thisprogramme than with traditional sensor has better stability, reliability, and timeliness, but also is more accurate.*
KEY WORDS: *gyroscope,kalman filtering,angle testing,random error*

Ⅰ. INTRODUCTION

With the rapid development and rapid popularization of intelligent vehicle, the vehicle driving environment become more and more complex and diverse. Therefore, the vehicle control precision demand more and more higher than before. Due to various reasons, the vehicles in the process of driving, there will be an offset between front wheel and the vehicle main body inevitablely.Offset of the front wheel can lead to the vehicle from a predetermined path. In order to make the vehicles are driven at predetermined trajectory, which requires constantly in the process of vehicle real-time measurement for front wheel steering Angle of the vehicle,so as to provide the vehicle's path control the real-time and accurate Angle information and correct the offset of the front wheel.

At present, the Angle sensor was generally uesd to measure the vehicle's front wheel steering angle, but the measuring methods of large defects is low stability ,low precision and vulnerable to outside interference .These defects greatly restrict the improvement of the intelligent vehicle control precision, also to some extent hindered the forward development of intelligent vehicle .For dynamic carrier, it should not only meet the low cost ,high precision ,small volume ,light weight , good stability and high frequency dynamic detection ability, also has a good anti-interference ability.

With the development of inertial technology, especially with the inertia constant optimization, it became conspicuous that the inertial device itself has the advantages of autonomy and stability, so it will be the focus on the development of navigation. As a kind of sensitive angular rate inertial device, gyro has a good stability, little influence of the magnetic characteristics of higher sensitivity, and presents a variety performance steadily improving trend, thus opens up an effective and reliable channels to solve the defects of traditional Angle sensor to measure the vehicle's front wheel steering angle.

This article is based on the vigorous development of the gyroscope, adopt a kind of MEMS gyroscope instead of the traditional Angle sensor to the front wheel Angle measurement in the process of vehicle .Then, using kalman filter to deal with random error that exist in the measured results .This filter method could afford the more accurate real-time vehicle front wheel Angle, so as to provide the vehicle's steering control precision of Angle information. The use of this method, greatly improves the vehicle front wheel Angle measuring accuracy and stability, effectively overcome the use of the defects of conventional Angle sensors for Angle measurement, which laid a foundation for the intelligent vehicle's widespread use in a variety of environments.

Ⅱ. EXPERIMENTAL PLATFORM AND THE GRYOSCOPE MODEL

2.1 EXPERIMENTAL PLATFORM

FIG.1 vehicle

The experiment platform is a automatic electric driving car which has a hydraulic steering system.The traditional tool for automatic vehicle front wheel Angle measurement is Angle sensor based on hall sensor. This kind of sensor measurement accuracy is limited, not only the stability is bad, and the installation link mechanism is needed to connect the sensor and measuring object .The sensors used in complex environment, driving stability is very poor, also can not meet the requirements of precise that the precision control needed, the defect is very obvious, which bring very great limitations to the intelligent vehicle development. Carrier for dynamic Angle measurement, should not only meet the low cost, high precision, small volume ,light weight, good stability and high frequency dynamic detection and has good anti-interference ability.Obviously, the traditional hall Angle sensor can not adapt to the request, and at the time of the measuring ,inertial components do not rely on the external environment, nor outward radiation, which have very strong autonomy, and good stability. Aimed at the defects of the traditional hall sensor and excellent inertial device, this scheme adopts the gyroscope inertial device for vehicle Angle measurement.

2.2 **GRYOSCOPE**

2.2.1 THE GRYOSCOPE MODEL

Experiment using gyroscope MEMS gyro CRS03-04s for a company, its appearance is shown in **FIG.2**

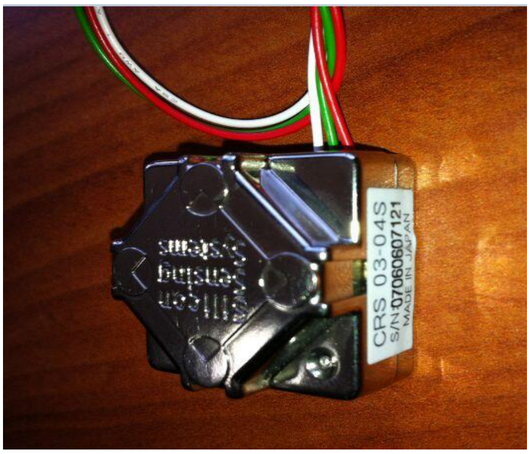


FIG.2 gyroscope

CRS03-04s is a kind of gyro based on coriolis force to sensitive carrier motion uniaxial angular rate, small volume and low cost. This type gyro use the silicon MEMS technology, because the plane annular structure,it coulde maintain excellent performance under the condition of severe shock and vibration, effectively reduce the gyro output signal in some puzzling data Moreover, the gyroscope temperature drift is small and easy to implement compensation, it brought great convenience for using .After running, it can output the accurately analog dc voltage signal that proportional to the rotating angular velocity.

2.2.2 THE MAIN TECHNICAL PARAMETERS OF GYROSCOPE

The main technical parameters of CRS03-04s:

①RANGE: ±200°/s

②VOLTAGE: 5±0.25V(DC)

③ZERO OFFSET: ±60Mv
④OPERATING TEMPERATURE: －40～＋85℃
⑤BANDWIDTH: ＞10Hz
⑥STARTING TIME: ＜0.5s
⑦POWER DISSIPATION: ＜50Mw
⑧OUTPUT IMPEDANCE: 100ohm
⑨CROSS AXIS SENSITIVITY: ＜1％
⑩SHOCK RANGE: 99G
⑪SIZE: 29×29×18.4mm
⑫APPEARANCE:encapsulation
⑬CONNECTOR:electric wire

In the process of measurement with gyroscope, due to the interference of the external environment, there will be a certain amount of random noise in the output signal affected the accuracy of measurement, therefore, in order to provide the Angle of information for the control system , the gyro signal need to filter . The traditional filtering method is mainly by using kalman filter to error compensation, kalman filtering processing object is a series of random signal with noise, the filtering purpose is to estimate all the processing of signal, white noise excitation system and measurement noise are take advantage of as useful message in the state estimation.

Ⅲ. KALMAN FILTERING

3.1THE DESIGN OF KALMAN FILTERING

Kalman filtering is a kind of method based on the observation data of state ,then process a vector linear, unbiased, minimum variance least-square estimation.Considering a state space description of a linear system:

$$\begin{cases} y_{k+1}=A_k y_k+B_k u_k+\Gamma_k \zeta_k \\ w_k=C_k y_k+D_k u_k+\eta_k \end{cases} \qquad (1)$$

$\{\zeta_k\}$, $\{\eta_k\}$ is zero mean gaussian white noise sequence, On the basis of equation of state, can get the kalman filtering process of linear stochastic system:

$$\begin{cases} P_{0,0}=Var(x_0) \\ P_{k,k-1}=A_{k-1}P_{k-1,k-1}A_{k-1}^T+\Gamma_{k-1}Q_{k-1}\Gamma_{k-1}^T \\ G_k=P_{k,k-1}C_k^T(C_kP_{k,k-1}C_k^T+R_k)^{-1} \\ P_{k,k}=(I-G_kC_k)P_{k,k-1} \\ x_{0|0}=E(x_0) \\ x_{k|k-1}=A_{k-1}x_{k-1|k-1} \\ x_{k|k}=x_{k|k-1}+G_k(v_k-C_kx_{k|k-1}) \\ k=1,2,3\cdots \\ v_k \text{ is observation sequence} \end{cases} \qquad (2)$$

The algorithm can be done by the way of **FIG.3**:

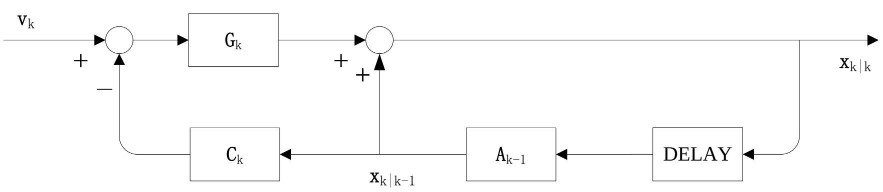


FIG.3 Kalman filtering algorithm structure diagram

3.2 THE ESTABLISHMENT OF THE GYROSCOPE RANDOM ERROR MODEL

According to the working principle of the kalman filtering , need to make sure that the error of the gyro output signal model. Because of special working principle of the gyroscope, the output of the angular rate signal inevitably exists some random drift erro.Usually take gyro random drift model as:

$$\varepsilon = \varepsilon_b + \varepsilon_r + \varepsilon_g \qquad (3)$$

The ε_b is random constant, ε_r for the first order markov process, ε_g is white noise.

CRS03-04s uniaxial gyroscope output model as below:

$$S_0V_0=[I+D][1+10^{-6}\varepsilon_k]^{-1} \qquad (4)$$

S_0 for scale factor, V_0 is the output voltage of the gyro, I for the output angular velocity, D for gyro drift, ε_k for scale factor error.

ε_k scale factor error can be expressed as:

$$\varepsilon_k=\varepsilon_T\Delta T+f(I) \qquad (5)$$

Among them, the ε_T temperature sensitive coefficient for scale factor, $\varepsilon_T\Delta T$ for scale factor error of temperature sensitive, f (I) for the input angular rate of the scale factor error.

To sum up, the **FIG.4** gives the CRS03-04s gyroscope random error model:

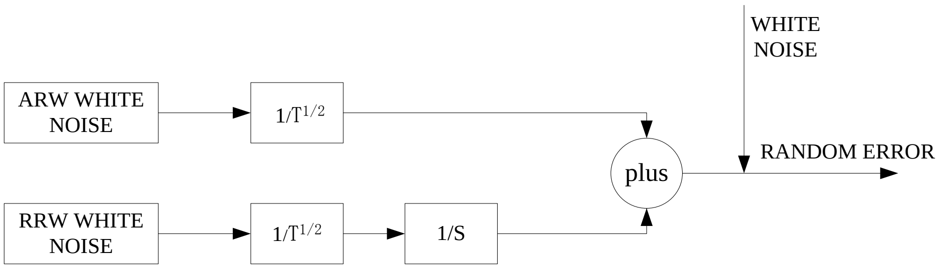


FIG.4 Gyroscope random error model

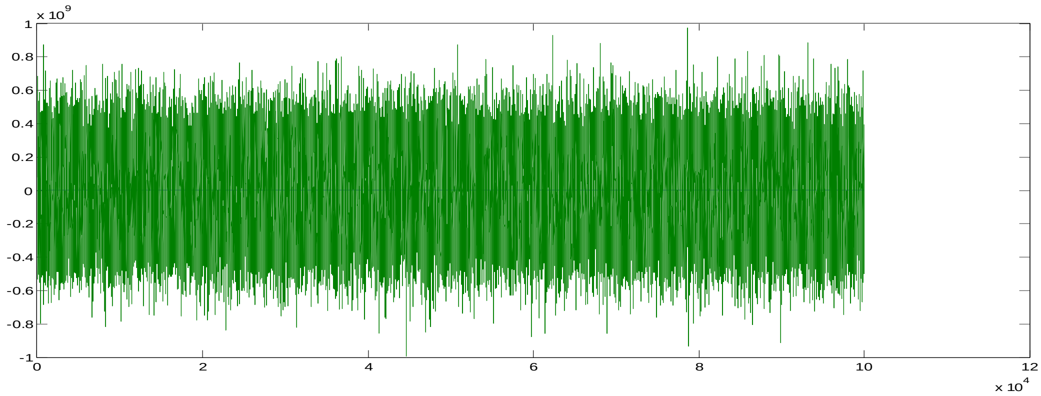
Among them, the ARW white noise as the Angle of the gyroscope random walk noise, RRW is the rate of gyroscope random walk noise.

3.3 GYROSCOPE RANDOM DRIFT DATA SAMPING AND PROCESSING

When experiment, sampling the gyro output signal, the sampling frequency of 10 hz, the sampling time of 10000 s, the Angle random walk noise variance for Ka = 7.3213 e-12 rad/s$^{1/2}$, rate random walk noise variance for K_b = 3.672410^{-12} rad/s$^{3/2}$, according to the random error model experiments, the random error in gyro output signal can be obtained and time of the wave as shown in the figure below:

FIG.5 CRS03-04s gyroscope random error signal and time diagram

Using kalman filter to filter the signal, processing can be obtained after the waveform as shown in the figure below:



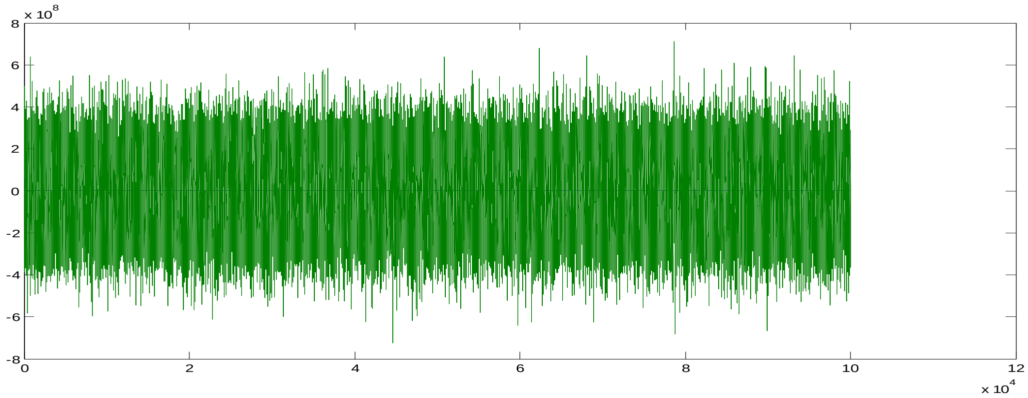


FIG.6 random noise and time diagram after kalman filtering

By comparing the two groups before and after signal, which can be found that after kalman filter, the random noise of gyro signal decreased nearly one order of magnitude, greatly improve the measurement precision of the gyroscope.

Ⅳ. CONCLUSION

With intelligent vehicle working environment becomes more and more complex, the traditional hall sensor for vehicle front wheel Angle measuring already can not adapt to the change. The accuracy of traditional hall sensor in the complex road conditions will be greatly reduced, the stability is not assured, and the rapid development of inertial technology for measurement of vehicle front corner opens up a new way .Gyroscope as a kind of inertial sensor, the good little autonomy by magnetic interference, do not rely on the external environment, and its remarkable characteristics of anti-interference ability makes it the best alternative for hall sensor.

Therefore, this study based on gyro Angle measurement conducted a series of research, and through the establishment of reasonable random drift error model, then using kalman filter to estimate the error compensation, effectively eliminate the gyro output signal of most random noise .The experimental results show that the Angle measuring gyroscope in the vehicle has a good stability and interference ability, can adapt to different environment Angle measurement of vehicle especially in the complex road conditions, more show its beyond the traditional hall the superior performance of Angle sensor .As the kalman filter is based on the predictions of a linear system - estimation method, therefore, filtering effect is not ideal in nonlinear system, so the scheme of the key lies in how to design a reasonable and effective method to remove random drift .

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