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New Angle Sensor Design and Accuracy Measurement

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Abstract： Angle sensor and positioning orientation device is the basis of achieving the goal sharing and collaborative combat.In order to achieve the absolute angle measurement between the turret and body.The paper presents two possible solutions:the first program uses the non-gap fork lever mechanism,combining with the photoelectric encoders to achieve high-precision measurement.The second program uses the coupling of ring gear and elimination gap gear.Based on the above technical solutions,the paper designs two type angle sensors with different accuracy and tests the products' accuracy.

Introduction

By driving of the information technology, combat style has developed into the network, information war. Once the main force of land warfare must adapt to the new military needs. We need to integrate into the information system in the equipment in order to achieve the ability from single target strike to multi-target continuous strike, from single platform fire control to multi-platform fire control attack, we need improve the ability to share goals.

The current main battle equipment uses the hunting - fighter fire control system. The driver is mainly responsible for the target searching. The gunner completes the target strike task. The driver and the gunner form a hit mode of search-hit (hunting - fighter). This attacking mode exists some questions:

1) Searching and aiming-hitting must be carried out in sequence, can not be separated;
2) Once force can only aim at the relative position of the turret coordinate system, can not hit the space target from the situation map information;
3) The target found by the vehicle can not be shared to friends, can not achieve information sharing.

By installing the angle sensor and positioning the orientation device,the system can share the target location information based on the inertial space, and realize the multi-target continuous attacking. Searching device continues to search for targets, the gunner chooses the target, weapon system achieves automatic targeting combat. Searching and combatting can run independently, and the target information can be shared with friends.As a result,angle sensor and positioning device are the basis for achieving target sharing and collaborative combatting[1,2].

Angle sensor technology program

The traditional turret angle sensor uses a rotary connector, a gear train, and a bearing structure to measure the angle of the turret's rotation . The main sources of error are: turret seat ring's processing error so that the tooth shape has a certain degree of oval, there is a transmission and an idle error when meshing with the sensor gear; gear train design has transmission error, axial misalignment error of the two gears; coaxial error and gap error between the rotary connector and the gear. Overall, the more complex the structure of the system, the more transmission train, the more the error there. The traditional angle sensor's measurement accuracy is low, has been unable to meet the accuracy requirement of the modern equipment on the turret angle measurement.

In order to solve the problem of using a high-precision positioning device at the same time to achieve artillery orientation and body navigation,we need to develop a new angle sensor.The new angle sensor need to measure real-time relative angle between the turret and the body.

There are a variety of technical solutions for angle measurement. There are two possible technical programs using mechanical transmission:the one program uses the encoder, no gap dial fork lever mechanism, the main sources of error of this program are installation error and error of different axes. Another program uses the method of seat ring coupling. Gears use double gap elimination gears. This structure can eliminate the airborne error between the ring and the sensor gear[3]. Angle sensor has photoelectric encoder, photoelectric encoder, rotary transformers and other options.

Angle sensor design

In this paper, two sensors are designed, named as rough angle sensor and precise angle sensor. Two sensors cooperate to achieve high precision angle measurement. Figure 1 shows the rough angle sensor. The sensor adopts gear transmission structure of eliminating the gap, combined with high precision encoders, using the coupling mechanism of the ring gear. The absolute angle of the turret and the body is obtained by real-time calculation.

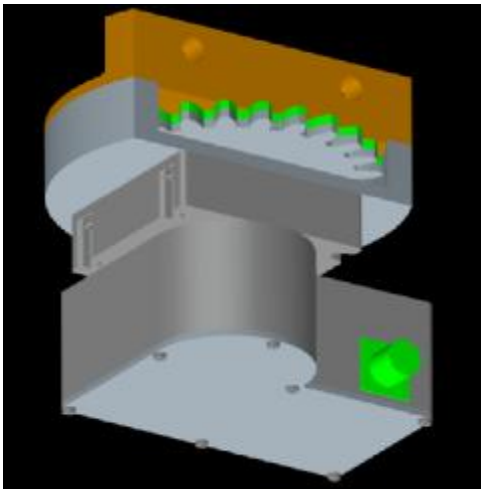

Figure.1 The rough angle sensor

The precise angle sensor is to install the multi-side guide rail on the seat ring, adopting the parallel transmission structure to carry out the small range accurate measurement, and obtain the angle between the turret and the vehicle body in real time. As shown in Figure 2 below.

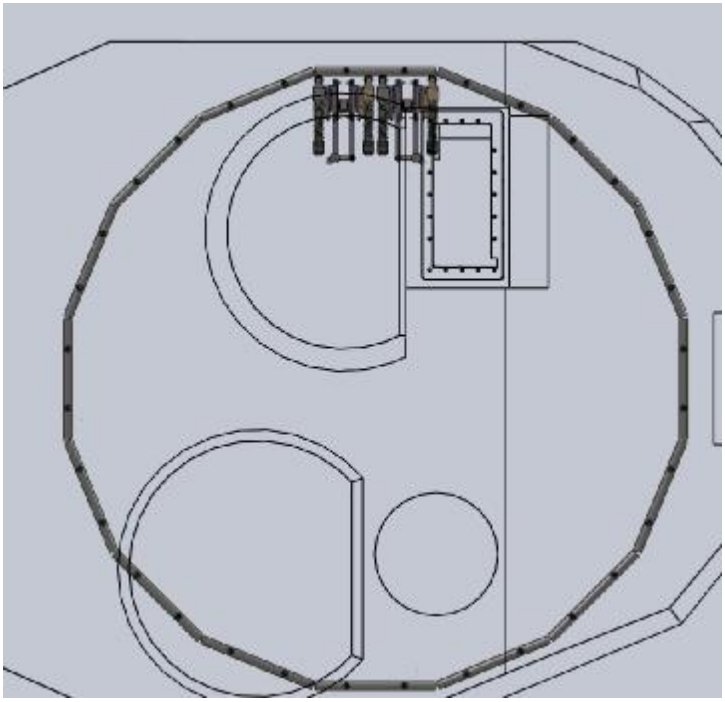

Figure.2 The precise angle sensor

There are four sets of rollers in the precision sensor mechanism. The roller always resiliently presses the rails. With the encoder installed in the transfer structure, the precise angle sensor can achieve high-precision measurement. The precise angle sensor is mainly used to eliminate the measurement error caused by deformation and clearance of the ring during the movement of the vehicle.

Main design parameters

1) Target accuracy: 0.45mil;
2) Ring diameter: 2r = 2100mm;
3) Pitch circle diameter of elimination gap gear: 2R=120mm;
4) Error range of ring radius: 1～3mm;
5) The allowable coaxiality tolerance of the encoder: Φ0.03mm;
6) The allowable axis tolerance of the encoder : g6
7) Encoder accuracy: 0.092mil。

Error and control measures

For the errors of the angle sensor, we mainly take the following methods to control or eliminate:

1) Machining accuracy of the elimination gap gear

Select light weight, high hardness, wear-resistant material - steel 45, improve processing accuracy, control gear error.

2) Machining accuracy of coupling axis between the gear and encoder

Improve the machining accuracy, control the coupling axis error.

3) Encoder measurement accuracy

Select high-resolution multi-turn absolute value rotary encoder.

4) Coaxiality between coupling axis and the gear

Use a larger radius of the transmission gear to reduce the impact of different axis.

5) Rounding error of numerical calculation

Use floating-point processor to calculate angle,use the high-speed A/D interface chip and the independent controller to process the encoder data.

6) Accumulated error of numerical calculation of angular position

Circle closed calibration and numerical processing are used to reduce the cumulative error.

7) Calibration error caused by ambient temperature change

When the ambient temperature changes, the ring diameter will produce a small change, the change can be closed by re-calibration, adjust the calculation parameters can be eliminated.

8) Transfer error of link mechanism

Use high-precision bearings, improve the machining accuracy of structural parts.

9) The machining precision of the guide rail

The guide rail is independently machined and connected to the vehicle body by means of bolts and brackets.

Precision test of the two sensors

The measurement accuracy of the encoder directly affects the angle sensor's accuracy, therefore, the accuracy of the encoder was first tested. Only the accuracy can meet certain requirement, the sensor will be installed on the sensor to test.

Figure 3 is the encoder's accuracy test platform.

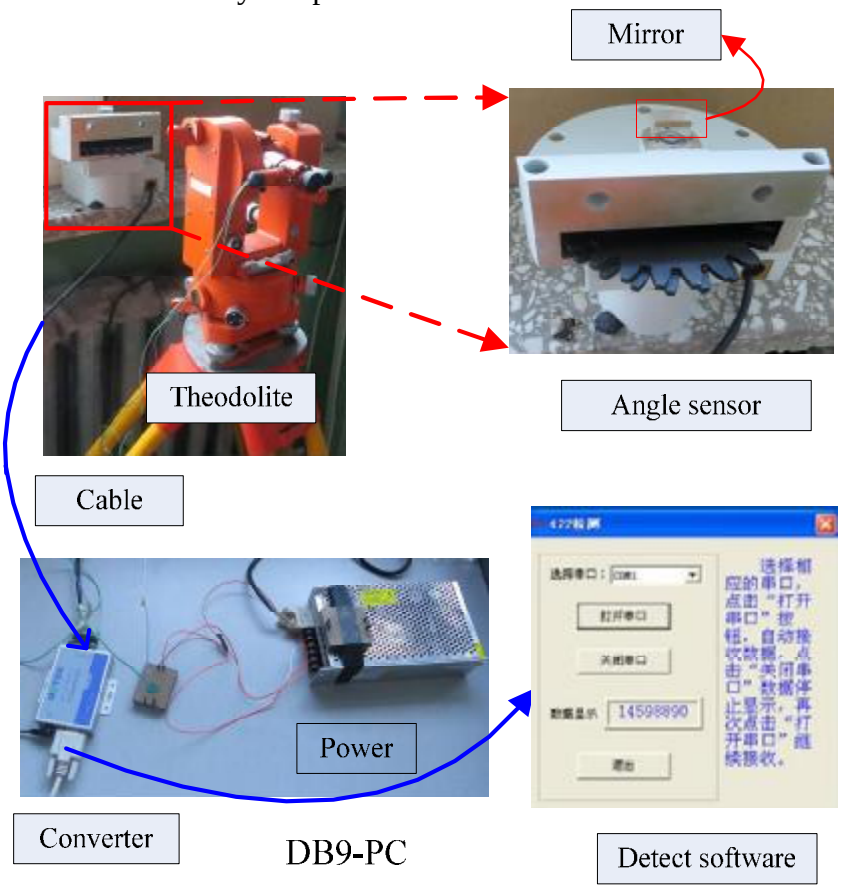

Figure.3 The encoder's accuracy test platform

We need install a mirror vertically on the axis center of the angle sensor, it's vertical surface and the central plane of the central axis are in the same plane, using the theodolite to read the angle of the encoder rotation.On the other hand,connect the cable of the encoder and RS422→RS232 converter. Through the DB9 to connect PC serial port. The data of the encoder rotation is read by the "422 detection software " . By comparing these two angle values to judge whether the accuracy of the encoder to meet the requirements.

The test data is shown in Table 1. As can be seen from Table 1, all the test data can meet the accuracy requirement.

Table 1 Test Data Record Table

	sensor measurements		theodolite measurements		error /mil |A-B|
	RS422 value	difference A/mil	read the angle value	difference B/mil	
0	14598897		208°20′31″		
1	14607082	5994.873047	208°3′15″	5995.203704	0.330656829
2	14615269	5996.337891	207°48′57″	5996.027778	0.310112847
3	14623454	5994.873047	207°31′04″	5995.032407	0.159360532
4	14631650	6002.929688	207°42′35″	6003.199074	0.269386574
5	14639841	5999.267578	207°39′45″	5999.212963	0.054615162

Accuracy measurement principle of the angle sensor is shown in Figure 4. Based on the principle, we tested the accuracy of the precise angle sensor and the rough angle sensor.

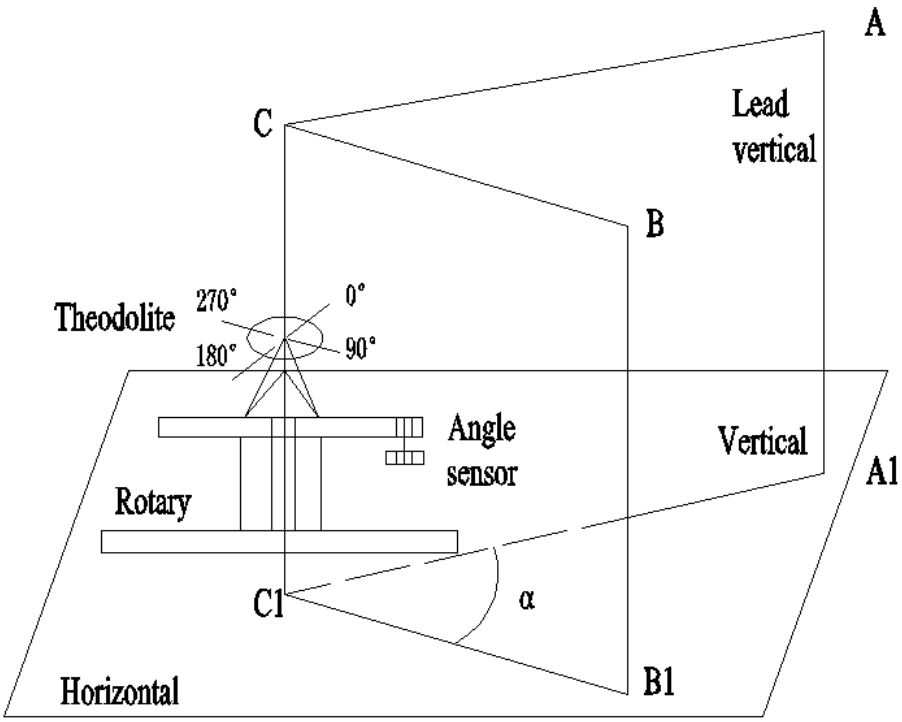

Figure.4 angle sensor accuracy measurement diagram

The rough angle sensor's bench test results

Install the rough angle sensor on the turret, as shown in Figure 5. A repeatability test was performed and the test results are shown in Table 2.

Figure.5 The rough angle sensor's installation test chart

Table 2 Repeat accuracy test table

Reference point	Test point readings	Error（mil）
13577311	13577312	0.73
13577311	13577311	0
13577311	13577311	0
13577311	13577312	0.73
13577311	13577311	0
13577311	13577312	0.73

From the test data can be seen, static repeat accuracy's maximum of the rough angle sensor is 0.73mil.

The precise angle sensor's test results

The angle sensor is installed on the simulation turret, and the accuracy test is carried out. The test is shown in Figure 6, the theodolite is placed on a fixed platform. A mirror is attached to the bracket of the simulated body to monitor the change in the angle of the simulated body bracket. Install a second mirror on the simulated turret to measure the turret rotation angle. The angle difference of fixed mirror and rotating mirror is the actual rotation angle of the turret. Finally, compared with the angle sensor's output value, the test results are shown in Table 3.

Table 3 The precise angle sensor's test results

Number	Reference mirror angle (°)	Rotating mirror angle (°)	Actual rotated angle (°)	Sensor output value（mil）	Relative zero error value（mil）
0	183.0636	181.7150			
1	183.0630	182.6483	0.9338	15.9304	-0.3656
2	183.0630	184.7483	3.0338	50.1716	0.3931
3	183.0636	186.7455	5.0305	83.8636	-0.0209
4	183.0630	188.4719	6.7575	112.7031	-0.0781
5	183.0630	190.4125	8.6980	144.3808	0.5867
6	183.0655	192.0866	10.3697	172.3049	0.5238

Fig.6 Test bench of the precise angle sensor

From the test data can be seen,the accuracy maximum of the precise angle sensor is 0.59mil, the standard deviation is 0.38mil.

Conclusions

In this paper, two new high-precision angle sensors are designed for the target sharing requirement of future cooperative operations. And the physical accuracy was verified. The results show that the two angle sensors can meet the accuracy requirements of the angle measurement. Using the angle information provided by the two sensors in the text, the following three main tasks can be completed:

1) The vehicle can determine the precise space location of the target found by the vehicle, provide the location information to the neighbors and the command system.
2) After receiving the target of the command system, using the angle sensor information, you can control the artillery or sighting device to aim at the target precisely.
3) Using the angle information to compensate for the firing element, can improve the dynamic hit probability.

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