Method and Implementation of Accuracy Measurement on Rotation Angle of Antenna-driven Component

Jiaping Song [1,a*] and Yushu Bian [2,b]

[1]School of Mechanical Engineering and Automation，Beihang University，China
[2]School of Mechanical Engineering and Automation，Beihang University，China
[a]517871631@qq.com, [b]448316653@qq.com

Key words: antenna-driven component; accuracy measurement; photoelectric autocollimator; MFC

Abstract：The antenna-driven component is an important unit used to drive an antenna to its prescribed position. In this paper, an accuracy method for measuring rotation angle of the antenna-driven component is proposed and the corresponding measurement equipment is developed. The working principles of accuracy measurement and error analysis are presented at detail. The PC application software associating with the measurement equipment is developed. The related experiments are conducted. The experiment results demonstrate the correctness and effectiveness of the method.

Introduction

The antenna-driven component is an important unit used to drive an antenna to its prescribed position. It is necessary to measure the rotation angle in the stage of product acceptance, product loading, and performance test during the development of driven component [1].

Usually, small angle measurement methods contain three categories, i.e. mechanical methods, electromagnetic methods and photoelectric methods [2-4]. Among these methods, most of mechanical methods and electromagnetic methods have to be implemented manually, and can only obtain limited measurement accuracy. In contrast to above methods, photoelectric methods possess such characteristics as non-contact and high sensitivity, thus have attracted much attention.

In this paper, an accuracy method for measuring rotation angle of the antenna-driven component is proposed and the corresponding measurement equipment is developed. The working principles of accuracy measurement and error analysis are presented at detail. The PC application software associating with the measurement equipment is developed. The related experiments are conducted. The experiment results demonstrate the correctness and effectiveness of the method.

Scheme of Accuracy Measurement System

The accuracy measurement system is designed based on the scheme of the turntable and Photoelectric Autocollimator. It is mainly composed of test platform, motion control unit, optical measurement unit, monitoring and information processing unit. Test platform mainly includes the turntable, optical platform, operating floor. Motion control unit used to control the movement of the turntable and drive component mainly includes industrial control, the turntable servo system, driven component motion servo system. Optical measurement unit used in the optical measurement and data acquisition mainly includes Photoelectric Autocollimator, plane mirror and related accessories. Monitoring and information processing unit is mainly responsible for human-computer interaction, information processing, power control, etc. The scheme of accuracy measurement on rotation angle of antenna-driven component is shown in Figure 1.
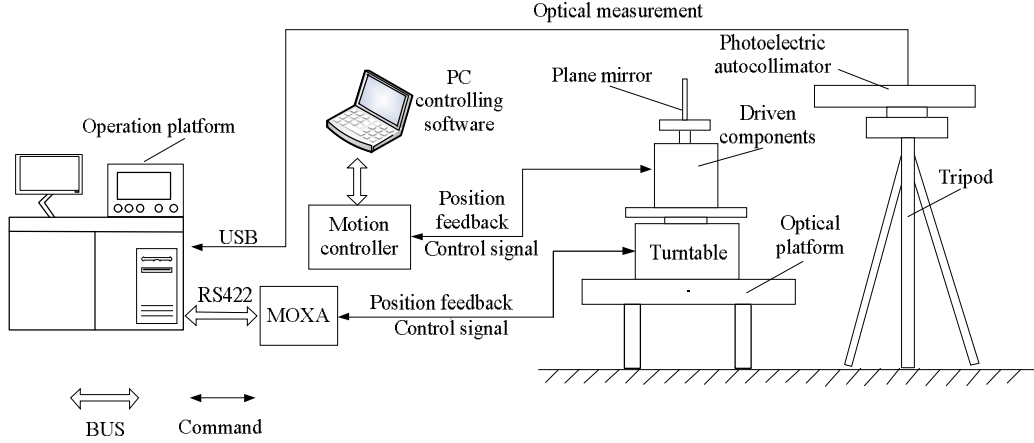
Fig.1 Scheme of accuracy measurement on rotation angle of antenna-driven component

Principle of Accuracy Measurement System

The following equations will be used to measure accuracy on rotation angle.

$$X_i = P_i' - P_i; \quad \overline{X} = \frac{1}{m}\sum_{i=1}^{m} X_i; \quad R = \sqrt{\frac{1}{m}\sum_{i=1}^{m} X_i^2}; \quad s = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}(X_i - \overline{X})^2} \qquad . \tag{1}$$

Where X_i : position deviation; $\overline{X}$: average of position deviation; R : root mean square value of position deviation; s : standard deviation of position deviation; P_i' : actual position; P_i : target position; m : numbers of accuracy measurement; $i:1,2,\ldots,m$.

The working principle of accuracy measurement scheme is addressed as follows. First, the antenna-driven component is instructed to rotate an angle. Obviously, the plane mirror will rotate the same angle as well. Second, the turntable is driven to rotate the same angle in the reverse direction. Third, the rotation angle of the turntable is measured using the autocollimator and the plane mirror. Finally, the error between the rotation angle of the antenna-driven component and that of the turntable is calculated. If motion accuracy of the turntable is high enough and can be viewed as "absolutely" accurate, then this error can be considered as the rotation angle accuracy of the antenna-driven component.

The initial value of Photoelectric Autocollimator on X-axis is q_X, while the initial angle of antenna-driven component is q_T . The antenna-driven component is driven by controller to rotate an angle q_L using the software. The value of q_L is the initial angle of rotation of antenna-driven component. The angle of antenna-driven component q_T' will be recorded after finishing rotation. Then the turntable is driven to rotate the angle of q_L in the reverse direction by the commands of software. After all these finished, the value of Photoelectric Autocollimator on X-axis q_X' and the angle of turntable q_L' will be recorded. Assume that clockwise rotation is the positive direction. Then the following equations will be concluded.

$$\Delta c = (q_X' - q_X) - (q_L' - q_L) \qquad . \tag{2}$$

$$\Delta c_b = (q_T' - q_T - q_L) - [(q_X' - q_X) - (q_L' - q_L)] \qquad . \tag{3}$$

Where Δc : angle deviation of antenna-driven component, Δc_b : the encoder errors.
The following equations will also be concluded after test several times.

$$\Delta c_i = (q_{X\,i}' - q_{Xi}) - (q_{L\,i}' - q_{Li}) \qquad . \tag{4}$$

$$\Delta c_{bi} = (q'_{Ti} - q_{Ti} - q_{Li}) - [(q'_{Xi} - q_{Xi}) - (q'_{Li} - q_{Li})] \qquad . \tag{5}$$

Where Δc_i: angle deviation of antenna-driven component for the i time, Δc_{bi}: the encoder errors for the i time; $i : 1, 2, \ldots, m$; m: numbers of precision test.

Then the following equations will be concluded.

$$R_C = \sqrt{\frac{1}{m}[(q'_{Xi} - q_{Xi}) - (q'_{Li} - q_{Li})]^2} \qquad . \tag{6}$$

Where R_C: root mean square value of angle deviation of driven component after test m times.

Software Development and Implementation of Accuracy Measurement System

The PC application software associating with the accuracy measurement system is developed by using Microsoft Visual Studio application, through which the functions of calibration of accuracy measurement system, angle measurement of antenna-driven component, data processing and storage, and the generation of test reports will be implemented. The main function modules on the PC application software of accuracy measurement system are shown in Figure 2. The process of accuracy measurement system is shown in Figure 3.
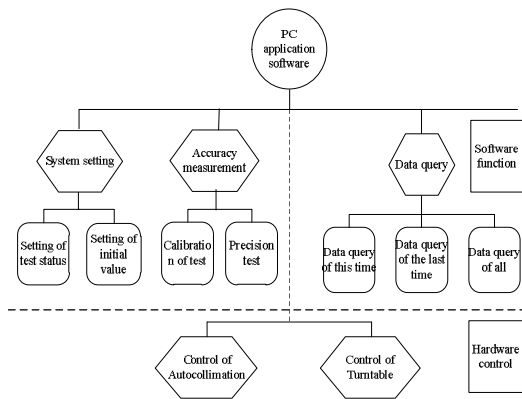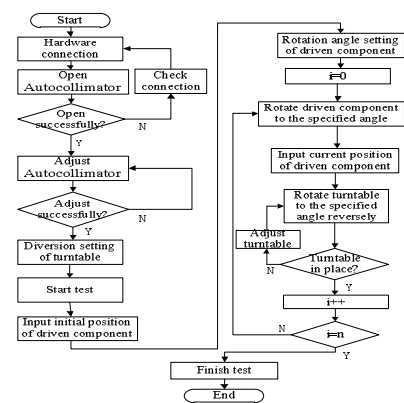

Fig.2 Main function modules on the PC software system

Fig.3 Process of accuracy measurement

Result of Accuracy Measurement Experiment

It is necessary to calibrate the accuracy measurement system before angle measuring of antenna-driven component. After finishing the angle measurement of driven component, the test report of experiment data will be generated to analyze and evaluate its performance. The experiment of accuracy measurement of driven component by using turntable, plane mirror and Autocollimator is shown in Figure 4. The result of accuracy measurement experiment is shown in Table1.

Fig.4 Experiment of accuracy measurement of antenna-driven component

Table1 Result of accuracy measurement experiment

NO.	Rotation angle of turntable(°)	Position of turntable(°)	Rotation angle of driven component(°)	Position of driven component(°)	Autocollimator reading(″)	Errors of encoder (″)	position deviation (″)
1	-20.04950	-20.04956	20.049504	53.83301	-19.2	0.65	-18.45
2	-20.04950	-20.04958	20.049504	73.88855	26.2	-23.09	27.02
3	-20.04950	-20.04956	20.049504	93.93311	-10.7	-3.94	-9.92
4	-20.04950	-20.04956	20.049504	113.97766	-31.6	-0.89	-30.81
5	-20.04950	-20.04958	20.049504	134.02771	-12.3	-18.24	-11.50
6	-20.04950	-20.04958	20.049504	154.08325	17.7	-26.57	18.56
7	-20.04950	-20.04956	20.049504	174.11682	-39.6	-26.58	-38.78
8	-20.04950	-20.04958	20.049504	194.18884	17.2	-2.31	18.00
9	-20.04950	-20.04956	20.049504	214.22791	-11.5	-11.14	-10.74
10	-20.04950	-20.04953	20.049504	234.27795	-12.2	-8.39	-11.55
11	-20.04950	-20.04956	20.049504	254.32800	-9.4	-9.31	-8.67
12	-20.04950	-20.04953	20.049504	274.38904	13.7	9.20	14.35
13	-20.04950	-20.04953	20.049504	294.42810	-18.6	3.89	-17.94
14	-20.04950	-20.04953	20.049504	314.48364	-18.4	25.37	-17.69
15	-20.04950	-20.04956	20.049504	334.52800	-8.4	-3.21	-7.63
16	-20.04950	-20.04956	20.049504	354.58374	5.0	5.82	5.80
17	-20.04950	-20.04958	20.049504	14.61731	-44.2	-2.35	-43.40
18	-20.04950	-20.04958	20.049504	34.67834	18.7	-23.76	19.51

Table1 shows that the maximal positive position deviation of driven component is 27.02″, while the maximal negative position deviation is -43.04″. The average of position deviation is -6.88″. The root mean square value of position deviation is 21.01″. The standard deviation of position deviation is 20.42″. The root mean square value of position deviation is less than 25″, which has satisfied the design requirement of antenna-driven component.

Summary

A method of accuracy measurement on rotation angle of antenna-driven component is proposed and the corresponding measurement equipment is developed. The working principles of accuracy measurement and error analysis are presented at detail. The PC application software associating with the measurement equipment is developed. The related experiments are conducted. The experiment results demonstrate the correctness and effectiveness of the method.

References

[1] Zhang Wei-Wen. Modeling and precision analysis of space-driven component. Harbin Institute of Technology University. 2009

[2] Huang Yin-guo, Lin Yu-chi, Wang Wei, Zhao Mei-rong. Laser Autocollimation Measurement of Small Angle Based on Cross Correlation. Nanotechnology and Precision Engineering. 2010.3, 8(2):20-25.

[3] Tao Jing-qiao, Sun Xiao-song, Li Ming. Accuracy analysis for spin satellite test turntable. Aerospace Control and Application. 2010.4, 36(2):20-24.

[4] Deng Huiyu, Wang Xinli and Ma Peisuna, A study of wavelet analysis based error

compensation for the angular measuring system of high-precision test turntables, ISA Transactions .44 ,15–21(2005)