Advanced Materials Research Vols. 765-767 (2013) pp 25-28
Online available since 2013/Sep/04 at www.scientific.net

doi:10.4028/www.scientific.net/AMR.765-767.25

Review of Mechanical Structure of Force Actuator for Optical Astronomical Telescope

Yufang Zhang[1, 2,3,a]

[1.] National Astronomical Observatories / Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, Nanjing 210042, China;

[2.] Key Laboratory of Astronomical Optics & Technology, Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, Nanjing 210042, China;

[3.] University of Chinese Academy of Sciences, Beijing 100049, China

[a]adamyuanfang@163.com

Keywords: Force Actuator, Optics, Astronomical Telescope, Structure, Voice Coil.

Abstract. Reviewed the application of force actuators in the optical astronomical telescopes, and introduced the working principle, mechanical structure, performance requirements and basic components of the force actuators; then compared the advantages and disadvantages of force actuator types which commonly used in astronomical telescopes, finally, propose a outlook of the development trend of the actuator on the great telescope application requirements.

Introduction

The diameter of telescope becomes bigger and bigger, with the increasing demand of modern astronomical observation techniques on imaging capability. Traditional primary mirror cannot meet the requirements any more, because of the great increase in quality, manufacturing, cost and supporting difficulty. Since the 1980s, with the development of active optics, adaptive optics and segmented mirror technology, which successfully applied to the Keck 10m, GTC 10m, HET 9m, SALT 9m， Subaru 8.2m, VLT 8m and Gemini 8m telescope, great diameter telescope have achieved. Thus, the thin mirror active optics, adaptive optics and segmented mirror technology are the key technologies for the construction of large telescopes , and the trends of future technology development.

Fig.1 shows a typical schematic diagram of active optics. For large optical telescopes, active optics is a wavefront correction technology which means real-time detecting deformation of the mirror due to gravity, wind, temperature and other external load factors, then real-time correcting the deformable mirror by the force actuator system, which mounted behind the primary mirror during the observation process, in order to ensure well image quality of telescopes. While adaptive optics is a real-time compensation of wavefront error technology, by real-time detection the wavefront distortion which caused by atmospheric disturbances, ambient temperature changing, vibration and etc. ,through the force actuator system which installed behind the adaptive mirror. According to the material type, thickness and diameter of mirror, the number and distribution of the force actuator of each mirror will different, which will affect the control and correction capability of the mirror surface.

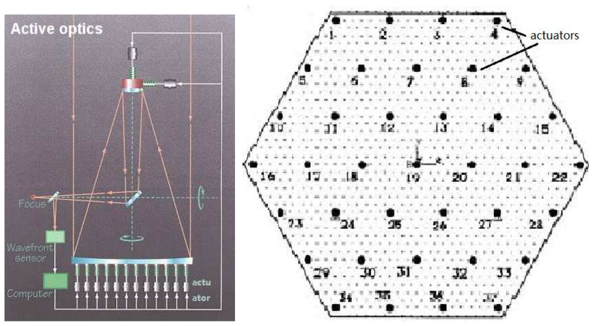

Fig. 1 The schematic diagram of active optics

In this paper, according to the requirements of active optics technology, systemly, reviewed and compared the basic mechanical structure of several types of force actuators to provide a reference for the design of force actuators.

Basic structure of force actuators

Basic technical requirements

In general, the force actuator of optical telescope has the basic requirements as follow:
(l) High precision and small output;
(2) High resolution;
(3) Anti-interference, smooth movement, good linearity, high repeatability, fast response;
(4) Low power consumption;
(5) Small size;
(6) No crawling, no gap;

Basic structure

The basic structure of the force actuator includes the driver, the mechanical transmission, the feed back and the controller. Their relationship can be shown as fig. 2.

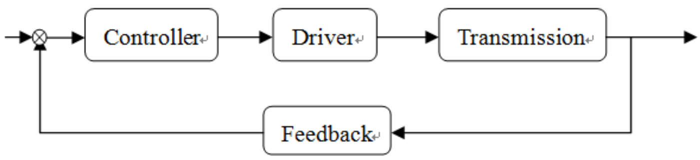

Fig. 2 The basic structure of the force actuator

Driver provides output force. Mechanical transmission connectes force actuator with other telescope parts, plays a role in guiding, coordinates the output force with force resolution, and eliminates or reduces the gap or empty back. Feedback is pull or pressure force sensor generally, which real-time monitors output force effect and passes the results to the controller. Controller adjusts the output of the actuator to ensure the accuracy of the output force by comparing the given signal and the feedback.

Basic types and structure characteristics of force actuators

Force actuators which had been used by international major telescopes can be divided into five basic types according to driver, which can be shown as follows:
(1) Hydraulic, such as AEOS;
(2) Electric, such as SOAR;
(3) Pneumatic, such as MMT, LSST, Gemini and LBT;
(4) Piezo (mainly used for adaptive deformable mirror), such as SUBARU and Keck;
(5) Voice coil (mainly used for adaptive deformable mirror), such as MMT, LBT and VLT.
Main characteristics were shown as Tab. 1.

Tab. 1 The basic types and structure characteristics of force actuators

Driver	Merits	Demerits	Output force /N	Accuracy /N	Bandwidth /Hz
Hydraulic	Smooth motion, Fast response	Leak, Deformation, Friction	≥1000	1	≤1
Electric	Mature technology, Easy to control	Inertia, Friction, Low operating frequency	±10-±500	0.001-0.1	1
Pneumatic	High frequency	Compressible, Nonlinear, Friction, Noise	±100-±1k	0.05-1	10
Voice coil	Contactless, High resolution, No lag, High response, Small size	High heat production	±1-±10	0.001-0.01	100
Piezo	High resolution and Frequency, simple structure	Heat , Non-linear, High voltage, short stroke	±10-±1k	0.01-1	≥100

Hydraulic force actuator

Hydraulic force actuator can output bigger force,with smooth motion, fast response, low impact, high-speed starting, braking and steering, but also with oil leak, deformation of the cylinder, friction and low efficiency. The basic structure of the hydraulic force actuator included hydraulic cylinder, pump, proportional hydraulic valves, force decoupling and pull-push force sensors.

Electric force actuator

Electric force actuator was easy to control, but the mechanical structure was complex, there was friction, mechanical inertia and the operating frequency was generally difficult to achieve more than 1 Hz. Stepper motor and DC motor were commonly used. Stepper motor was the most economical and commonly used. Most of large astronomical telescopes have chosen stepper motor as the driving element of force actuator because of no cumulative error, high starting and operating frequency and low power consumption.

Mechanical transmission part was mainly composed of reducer, coupling, bearings, nut ball screw and guide device. Motor provided the rotation torque, through the coupling and reducer, driven precision nut ball screw rotation, which would converted rotary motion to linear motion of the nut, then produced a linear direction push or pull force. Force sensor, as the feedback part, converted the output force to a voltage signal, which was input to the amplifying circuit. Controller, included motor control card and control software, compared force signal with the set value, through the control algorithm correction, output control signal to the motor driver card which controlled motor rotary and achieved the required force output[1]. Structure and control block diagram of electric force actuator are shown as fig. 3[2].

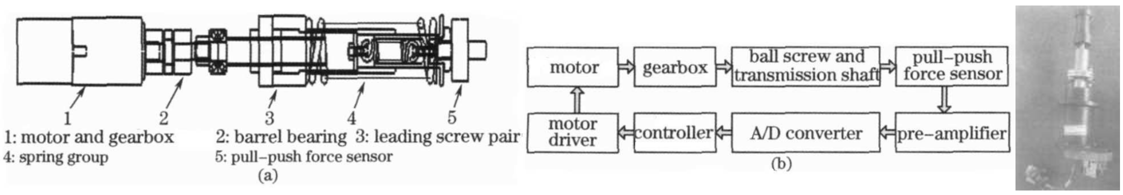

Fig. 3 Structure and control block diagram of electric force actuator

Pneumatic force actuator

Pneumatic force actuator was simple, high frequency, high efficiency , however, was difficult to control due to the compressibility of gas, non-linear and friction factors. The pneumatic force actuator active support system,developed by UKATC, has been applied in the primary mirror of MMT, Gemini and LBT successfully. The basic structure of the pneumatic force actuator included pump, cylinder, proportional pressure valve, the force decoupling controller and pull-push force sensors[3]. Structure and control block diagram of pneumatic force actuator are shown as fig.4

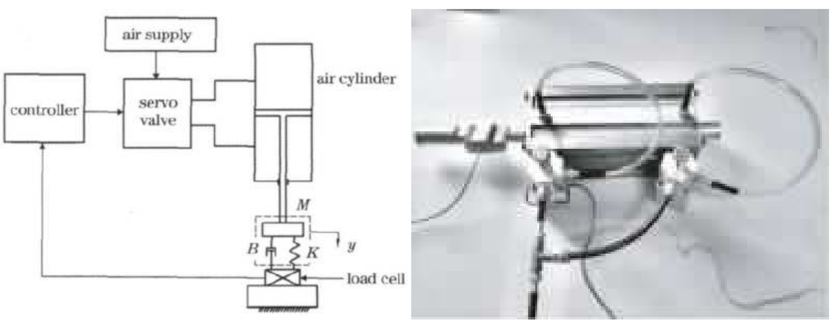

Fig. 4 Structure and control block diagram of pneumatic force actuator

Piezoelectric force actuator

Piezoelectric force actuator is designed by the inverse piezoelectric effect of piezoelectric ceramic material. It is high resolution, fast frequency response, simple structure, easy remote controlled ,and also has short drive chain, which reduces the error introduced by the mechanical structure. However, it is high fever, small stroke, easy to aging and high operating voltage.The piezoelectric force actuators developed by PI are used popular.

Structure and control block diagram of piezoelectric force actuator were shown as fig. 5

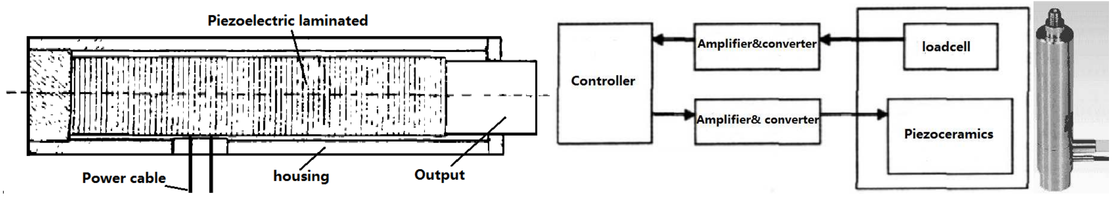

Fig. 5 Structure and control block diagram of piezoelectric force actuator

Voice coil force actuator

Voice coil force actuator was contactless, high resolution, no lag, high response, small size and easy controlled. Since 1993, P. Salinari, the Astrophysical Observatory Aceh Terry, Italy, first proposed the idea that the voice coil electromagnetic force controlled the adaptive secondary mirror. Voice coil force actuator, developed by ADS and Microgate company, has been successfully applied in the adaptive deformable mirror of MMT, LBT and VLT[4,5,6], and also will be used for GMT and E-ELT. The basic structure of the voice coil force actuator comprised permanent magnet, voice coil, voice coil frame, force (or displacement) sensor and controller. Structure and control block diagram of voice coil force actuator are shown as fig. 6

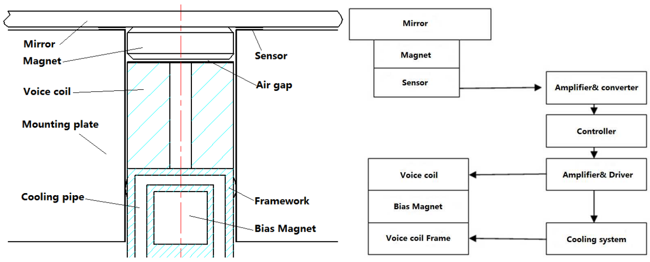

Fig. 6 Structure and control block diagram of voice coil force actuator

Conclusions

This article analyzed the basic structure of the force actuators which already applied to the large telescopes. Most of them were designed on the princeple of hydraulic, electric, pneumatic, potential or piezoelectric. All of them have disadvantage, such as leakage, hysteresis,gap, small stroke, fever, etc.. Hydraulic, electric and pneumatic force actuator were relatively mature when operating frequency was not high and large output force applications. While piezoelectric and voice coil force actuator held advantage in high frequency applications. Depend on the application characteristics, and chose different type or combination of them. In the same time, new type of mechanical transmission, controller and feedback part should be introduced to improve the force actuator parameters and overall accuracy. Such as the application of flexible mechanism in the mechanical transmission part can reduce or eliminate the gap and friction.

Acknowledgements

The financial support of the Main Direction Program of Knowledge Innovation of Chinese Academy of Sciences(No.KGCX2-YW-T17) are gratefully acknowledged.

References

[1] L.M. Zhang and B. Zhang: Optics and Precision Engineering Vol. 20(2012), p.38(in chinese)
[2] X.Q.Cui and X.N.Li: Acta Optica Sinica Vol.25(2005), p.965(in chinese)
[3] Z.Y.Yu and G.P. Li: Chinese Hydraulics & Pneumatics Vol. 9 (2011), p.80 (in chinese)
[4] D. Ricci, A. Riccardi and D. Zanotti: Applied Optics Vol. 47(2008), p.3631
[5] D.G.Bruns,T.K.Barrett and T.J.Brinkley: SPIE Vol. 3126 (1997), p.164
[6] D.Gallieni,E.Anaclerio and P.G.Lazzarini: SPIE Vol. 4839 (2003), p.765

Advanced Information and Computer Technology in Engineering and Manufacturing, Environmental Engineering

10.4028/www.scientific.net/AMR.765-767

Review of Mechanical Structure of Force Actuator for Optical Astronomical Telescope

10.4028/www.scientific.net/AMR.765-767.25