Synopsis :
"The adjustment mechanisms: types and their application in optical systems"

Chua Chern Fei
chernfei@email.arizona.edu

Introduction

The author, Aness Ahmad, presented an excellent summary which discusses about the adjustment mechanism. It covers the essential part of the adjustment mechanism, namely the interface, actuator, coupling methods, preloading methods, and locking methods. In the paper, it discusses 3 types of adjustment mechanisms, namely, linear adjustment, rotary adjustment, and the tilt adjustment. For this synopsis, it only covers the linear adjustment. This synopsis provides good guideline to mechanical engineer who wants to design opto-mechanical parts that require adjustment, be it coarse or fine adjustment for optical system.

Overview

Table 1 shows the possible choices of the components for a linear adjustment purpose. The choice depends on the frequency of adjusting, range of adjustment, resolution of adjustment. It also depends on the size, cost, load capacity, shock resistance, etc.

Interface	*Actuator*	*Pre-load*	*Locking*	*Coupling*
Flexure	Coarse screw	Compression spring	Set screw	Ball /cone
Kinematic	Fine screw	Extension spring	Jack screw	Ball/flat
Ball bearing	Micrometer	Flat spring	Lock nut	Ball/socket
Roller bearing	Differential micrometer	Belleville washer	V clamp	Threads
Air Bearing	DC motor	Curved washer	Collar clamp	Flexible coupling
Dovetail Slide	Stepper motor		Epoxy	Lead screw
Flat slide	Piezoelectric		Control system	

Table 1: Choice of component for linear mechanism

The interfaces

The general guideline is summarized in table 2:

Interface	**Characteristics**	**Application**
Ball Bearing	Low friction	Long travel range, frequent adjustment
Roller slide	"Upgrade" version of ball bearing. Higher load capacity and accuracy, but more expensive	Long travel range, frequent adjustment
Dovetail	High stiffness, low cost High friction	High load capacity
Air bearing	Free of friction, no wear (damage) Negligible cross-axis run out. High cost, and high complexity.	For high performance optical system which requires long travel range, high accuracy and load capacity
Flexure	Backlash free, does not require lubricant.	High accuracy adjustment, but with only short travel range.
Sliding contact	High friction, low accuracy (linear translation with slight plane rotation)	Low cost, light load system. Non-frequent adjustment

Table 2: Characteristic and application for various types of interfaces

The actuators

The actuator is categorized as motorized actuator and manual adjustor.

Motorized actuators are used for making frequent adjustment in real time. These include DC, linear and stepper motors, and piezoelectric devices. The main advantages are long travel range, high resolution and velocity, and readout capability. It can also come with built in position encoder, or used in a closed loop control system for real time positioning control and monitoring.

Piezoelectric actuator is used for very short travel range with extremely high resolution. It can withstand high load, but it suffers from hysteresis, creeping and nonlinearity.

Manual adjustors are usually in the form of screws or micrometers. Differential screws or micrometers are especially used for cases with high resolution requirement, but the travel range is limited.

The coupling methods

The main idea of coupling is such that a position is well defined, it is hence common to see rounded ball tip (polished) actuator contacting with a flat surface, cone surface or spherical socket. Flat surface contact is most common type, but the point contact leads to high contact stress. The ball/cone interface results in a line contact can take higher load, but it comes with increased cost.

Another common type of coupling is that the moving component is physically attached to the actuator through a threaded attachment or a flexible type of coupling. However, the threaded coupling is not quite commonly used because any slight misalignment of the line of travel leads to rapid wear and damage to the actuator. On the other hand, the flexible coupling does not have such problem, it is generally more bulky and heavy, and more expensive.

For large travel and high load application, it's common to see the actuator coupled to the moving part through a lead screw. The actuator is coupled to the main screw while the moving component is attached to the nut. Backlash and wobble of the nut can be minimized with preloading. Friction can be reduced by using ball or roller bearing between the screw and nut.

The preloading methods

The essential purpose of preloading is to ensure a positive movement, free of backlash while adjusting the parts. For long travel range adjustment, a compression or an extension spring should be used for preloading the moving part against the fixed part. The figures below show the most common type of preloading with springs:

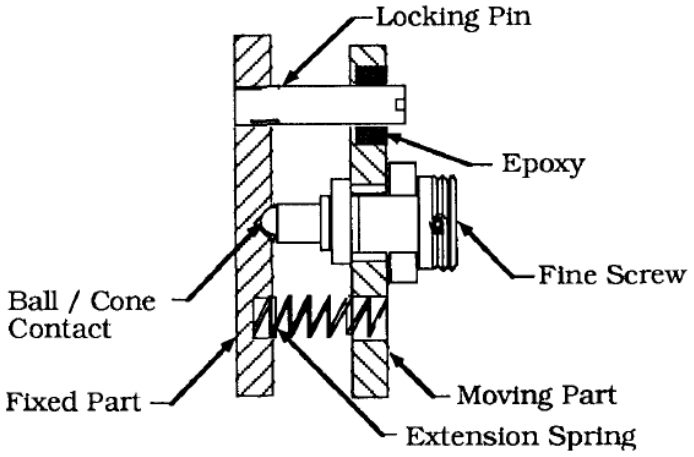

Figure 1: A linear mechanism with a ball/cone interface, epoxy locking and extension spring preloading

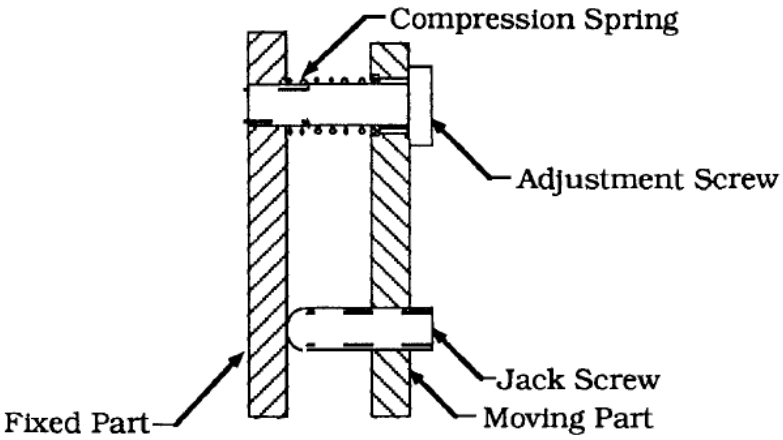

Figure 2: A mechanism with a compression spring for preloading and a jack screw for lockin

Another form of preloading is using Belleville or curved washer, providing high preloads over very small travel range. Since it has very high stiffness, it is suitable for high shock application. These washers are compact in size and very economical.

The locking methods

Once the element of interested is correctly adjusted, it has to be locked in place to retain its position. For the most common type of actuator, namely the micrometer or screw type actuators, a simple caps, nut or cover can be used to prevent accidental movement.

Another option is to positively lock the moving element against the fixed structure. For one-time adjustment (such as assembly), it can be locked in place by using epoxy bonding. It's very low cost but it's not a reversible process.

Jack screws or locknuts, are the common and economical ways to achieve locking, but the precision are not great because of the large forces are exerted when they are tightened against adjusted element, causing little movement.

For motorized actuators, locking can be achieved with closed loop feedback control system.

Original paper

Anees Ahmad, Adjustment mechanisms: types and their applications in optical system, Proc. SPIE CR43, Optomechanical Design, 1 July 1992.