Sources of Error

BACKLASH

Imagine a positioner that is being driven in a positive direction by a motorized actuator. If the motor reverses its direction, the positioner will not immediately move in the reverse direction. This effect is commonly referred to as backlash.

Backlash results from the buildup of manufacturing tolerances in the threaded or geared pieces that constitute the finished device. By careful design and quality manufacturing, backlash can be minimized, but it cannot be completely eliminated. One way to minimize backlash is apply a compressive force, usually with a spring mechanism, to force the components in the mechanical train to remain in contact at all times. This method, called *preloading*, is commonly found in high-quality optical stages.

CROSS COUPLING

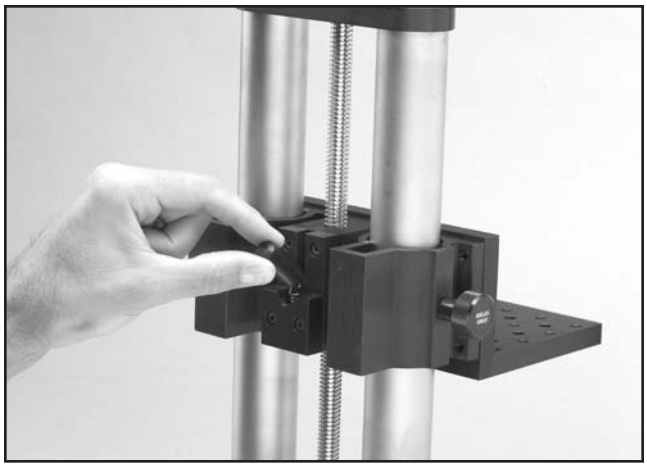
The tendency of a motion along one degree of freedom to cause motion in an orthogonal degree of freedom is referred to as *cross coupling*. In an ideal x-y-z stage, a movement along one axis should cause absolutely no movement in the other two axes. Unfortunately, this is not the case with real-world devices because of manufacturing imperfections, design tolerances, and other considerations. For example, if the axes of an x-y stage are misaligned by 1 arc minute, 100 mm of travel along the x axis will cause 0.1 μm of travel along the y axis—inconsequential in most applications, but still present. Some devices have cross coupling built into the design. Inherent in their design, kinematic and flexure mirror mounts, discussed earlier, have significant cross coupling between their rotational and linear axes, and some cross coupling among their rotational axes, whereas gimbal mirror mounts do not. A stack of single-axis stages used to emulate a multiaxis stage will almost always have more cross coupling than a multiaxis stage itself.

FREE PLAY

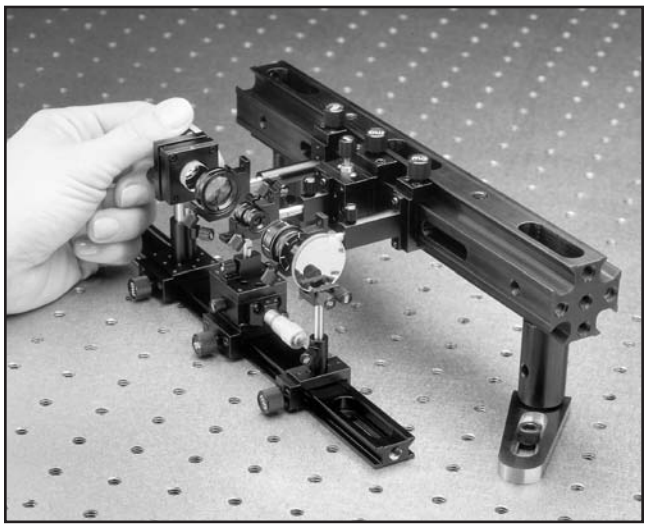
A close relative of backlash, *free play* can be defined as the amount of movement that can be made to the part at the beginning of a mechanical train (e.g., a series of gears) without causing motion at the end of the train. Obviously, the more parts there are in the mechanical train, the greater the free play will be. Precision mechanical devices typically have very little free play, but through frequent use, wear will gradually cause the free play to increase. Operating the device outside of the manufacturer's recommended operating specifications, or a lack of regular maintenance, can accelerate this process.

STICTION

When one tries to slide a heavy load on the floor, the object may refuse to move at first, but, once it starts moving, it is much easier to keep it going. This is the result of friction. There are two types of friction: moving friction and static friction (aka *stiction*). The coefficient of static friction is larger than the coefficient of moving friction; consequently, it requires a greater force to get the load moving than it does to keep it moving. If the coefficient of static friction is much larger than the coefficient of moving friction, a disproportionate amount of force may be applied to the load when it first starts to move causing it to over accelerate or "jump." This is often referred to as the stiction effect.



Backlash in screw mechanisms can be minimized through preloading.



Optical setup errors are the result of the mechanical imperfections in the adjustment mechanisms.