ULTRAPRECISION TOOL POSITIONER

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The original objective of the tool positioner program was to develop a linear displacement actuator for the generation of optical elements in highly stable materials. It is evident that a positioner developed for such purpose will also be suitable for actively controlling the figure of a lightweight astronomical mirror since both applications require high sensitivity and a high degree of repeatability.

While positioners that are accurate to within one-tenth of a wavelength* have been developed, they suffer from a common disadvantage—the effective range of these positioners is limited to a few wavelengths.* The problem then was to design a linear actuator with a range of several centimeters and more. The solution was to combine two independently functioning devices and form an improved tool positioner (Figure 1). This positioner includes front and rear sliding holders in addition to an incremental driver. Each of the two sliding holders can be independently restrained from moving along the base track by a locking mechanism, which can be, depending on the application, piezoelectric, electromagnetic, or mechanical in origin. In our unit, it is electromagnetic. By alternate locking and unlocking of the sliding holders and sequential operating of the piezoelectric incremental driver, motion of the tool positioner comparable to the movements of a caterpillar is achieved.

The advantages of this positioner over other displacement actuators are

(1) Simplicity of construction—dimensional tolerances can be met without expensive instrumentation.

(2) Large displacement range, which is only limited by the length of the base track.

*6328 Å Ne^{20} laser radiation.

(3) Bidirectional displacement, so that the motion of the positioner can be reversed from push to pull.

(4) Ability to work against opposing force, so that various loads can be supported by this particular positioner by varying the current applied to the electromagnets.

During calendar year 1970, an engineering model positioner was manufactured and tested. The tool positioner system includes an electronic switching circuit and a laser interferometer gage. Figure 2 shows the response of the positioning device under a 1.0-kg load. The slanted curve represents that portion of a cycle in which the incremental driver advances under a voltage increase from 0 to 900 V dc. The vertical curve reflects the behavior of the positioning device during the switchover in which the locking sequence of the holders is reversed and the voltage applied to the incremental driver drops from 900 to 0 V dc. This recycling is performed automatically by a control device at a rate up to 10 Hz. Fine positioning sensitivity is presently limited to one-eighth wavelength, which is the measuring accuracy of the laser interferometer used with this experiment.

Figure 3 shows the performance of the positioner under varying loads: no load, 0.5 kg, and 1.0 kg, over a range of about 55 μm. The curves shown in this figure were also plotted from data acquired through the laser interferometer readout when it was operated in the manual mode. Displacements shown are those for each complete cycle. A total of 11 cycles were plotted; the range of this device, of course, is only limited by the length of the base track.

It has been demonstrated that, by combining a holding mechanism and a driving mechanism, the capabilities of an otherwise limited positioning device can be greatly extended. Displacements of more than 5 cm are possible with a sensitivity of better than 7×10^{-8} m. The device has an opposing force capacity of 1 kg, which can be further increased depending on the application; it is bidirectional and simple in construction.

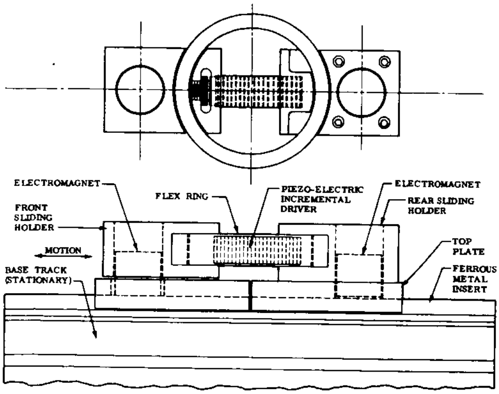

Figure 1—Positioner components.

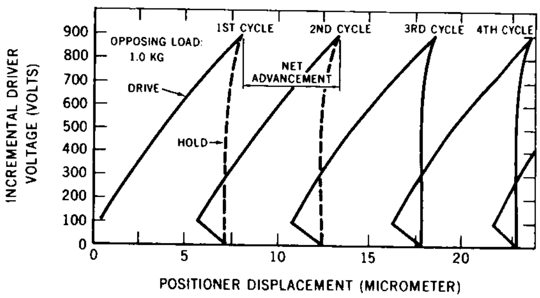

Figure 2—Cyclic variation as a function of holding and drive operation.

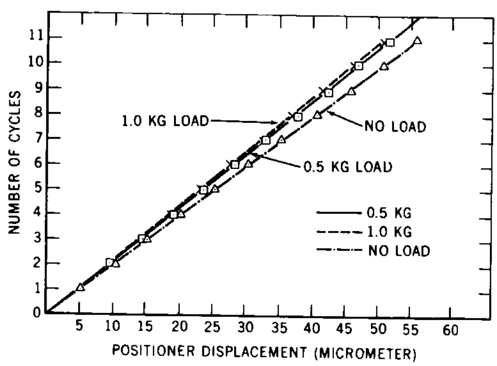

Figure 3—Positioner performance under various loads.