Actuators for Precision Machine Design

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Actuators

- Actuation principles:
  - Screws
  - Levers
  - Belts
  - Friction
  - Electromagnetic
  - Piezoelectric
  - Poisson
  - Electrostatic
## Screws

- **P.O.S. with lapped three-jaw chuck**
- **Fine pitched screws**
  - 8-80
  - ¼-80 or ¼-127
  - How well do you think you can do by hand?
- **Suppliers**
  - Newport
  - Optosigma

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## Screws, cont.

- **Differential screws**
  - Two different pitches, $P_1$ and $P_2$
    - $1/P_{eq} = 1/P_1 - 1/P_2$
  - Very fine adjustments are easily achieved!
    - Ex. 1/4 – 28 and 10 – 32

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Screws, cont.

- Micrometer heads
  - Includes scale or readout
  - Rotating or non-rotating
  - About 1 micron resolution
  - $50 for 25 mm stroke

- Integrated motor drives
  - 13 – 25 mm stroke
  - About 1 micron resolution
  - 5-125 micron/sec
  - <3 micron backlash
  - 0-60 °C
  - $700 for 13 mm stroke

Screws, cont.

- Manufacturers
  - Mitutoyo
  - Fowler
  - Tesa
  - Thorlabs
  - Boeckler
Leadscrews

◆ Thread/Nut type
  ▶ Acme or V with plain nut
    • Solid nut
    • Axially preloaded
    • Radially preloaded
    • Polymer
      ➢ Nylon
      ➢ Turcite
      ➢ Delrin (ask P. Denham at LBL)
  • Metal alloys
    ➢ Brass
    ➢ Bronze

Leadscrews, cont.

◆ Thread/Nut type
  ▶ Ground or rolled thread/ballnut
    • Rolled thread
      ➢ Less expensive - $10 - $20/in.
      ➢ Accuracy: ±0.00025 in./in.
      ➢ Leads: 0.2 in. – 2 in.
      ➢ 75 – 80% efficient
    • Ground thread
      ➢ More expensive - $50/in.
      ➢ Accuracy: ±0.0001 in./in.
      ➢ 85 – 90% efficient
      ➢ Smooth

Leadscrews, cont.

- Preloaded nuts
  - Tradeoff of stiffness and friction
    - Stiffness depends on preload due to Hertzian stresses

Levers

- Angular levers
  - Wedge-type lever
    - Make all of the same material if possible
      - $S/L \rightarrow S(1+\alpha dT)/L(1+\alpha dT)$
      - Ex. Zerodur
    - 1° wedge, 10 mm radius hemispheres for pivot, 50 pitch (0.5 mm lead) micrometer, gave 50 nrad (0.01 arc sec) angular adjustment

Smith and Chetwynd, p. 165
Friction Drives

- Wire and ribbon (band) drives
  - Ex. Pen plotter
  - Ex. Floppy disk drive actuator
- Capstan drive
  - Ex. LODTM x and z axis drive
    - 2 in. dia. drive roller, slightly “barreled”, supported at each end by 3.5 in. diameter oil bearings
    - 1 in. wide steel bar
    - DC torque motor directly coupled to drive wheel
    - 100 lb normal force between drive wheel and tool bar (assume 0.1 coeff. of friction \( \rightarrow 10 \) lb. max force)
Electromagnetic Actuators

◆ Stepper motors
  ❖ Advantages
    • Relatively inexpensive
    • Open loop possible
    • Relatively constant heat dissipation
  ❖ Disadvantages
    • Noise and vibration associated with discrete stepping
    • Relatively large heat dissipation
    • Relatively low speed (<3600 RPM)
    • Be careful of missing steps in open loop operation
    • Resolution will depend on basic step angle and drive electronics (microstepping is possible)

Electromagnetic Actuators

◆ DC Servo motors (brush-type or brushless)
  ❖ Advantages
    • High speed
    • High acceleration
    • Relatively “smooth” motion
  ❖ Disadvantages
    • Relatively higher cost
    • Need feedback sensors (encoder or tachometer, etc.)
Electromagnetic Actuators, cont.

- Voice-Coil Motors
- Linear Motors


Wafer Lithography Tool

Harmonic Drives

- Compact, negligible backlash “gearhead”

Piezoelectric Drives

- Piezo actuators

- Inchworm
- Picomotor
Magnetostriction Drives

- Etrema
  - http://etrema-usa.com

Electrostatic Drives

- Rocking beam force sensor

\[ F = \frac{CV^2}{2d} \]
Elastic Actuator


Poisson’s Ratio Drive

\[ \nu = -\frac{\varepsilon_{yy}}{\varepsilon_{xx}} \]
References

- Differential screw http://www.spie.org/app/publications/magazines/oerarchive/february/feb00/techgrp.html