WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

DESIGN OF MACHINE ELEMENTS
ME-3320, C'2005

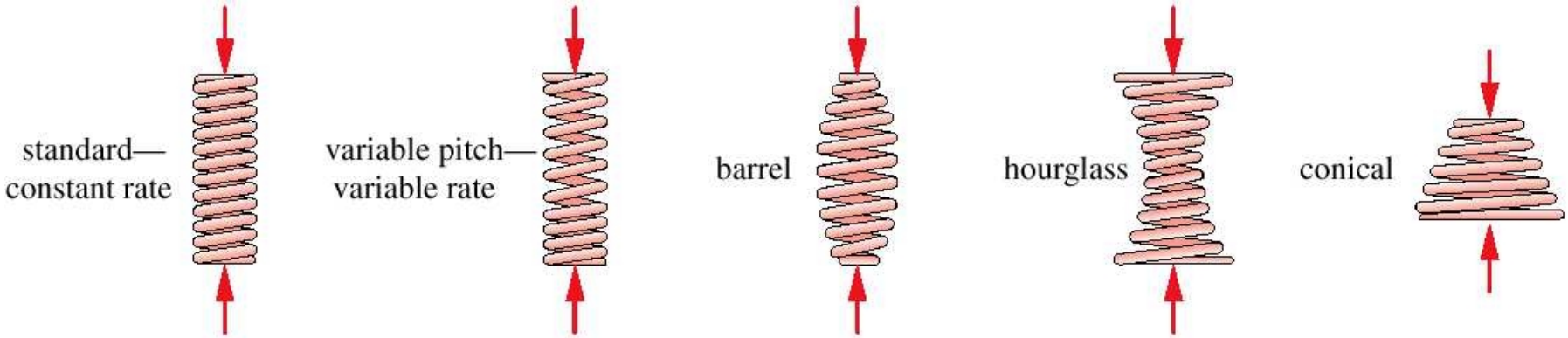
Lecture 29

March 01, 2005

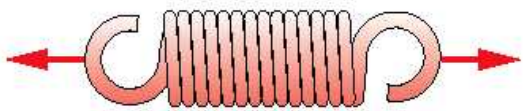
C. Furlong

Springs

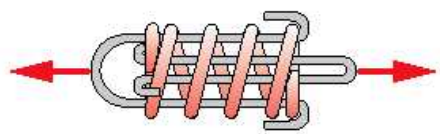
Types of springs



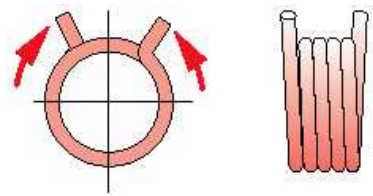
(a) Helical compression springs. *Push*—wide load and deflection range—round or rectangular wire. Standard has constant coil diameter, pitch, and rate. Barrel, hourglass, and variable-pitch springs are used to minimize resonant surging and vibration. Conical springs can be made with minimum solid height and with constant or increasing rate.



(b) Helical extension springs. *Pull*—wide load and deflection range—round or rectangular wire, constant rate.



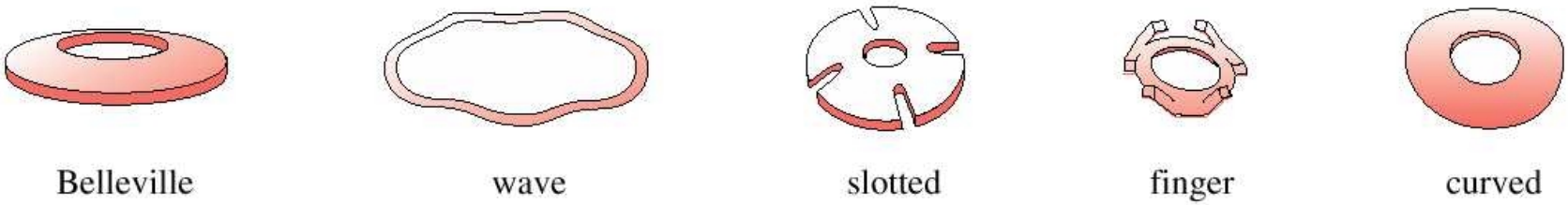
(c) Drawbar springs. *Pull*—uses compression spring and drawbars to provide extension pull with fail-safe, positive stop.



(d) Torsion springs. *Twist*—round or rectangular wire—constant rate.

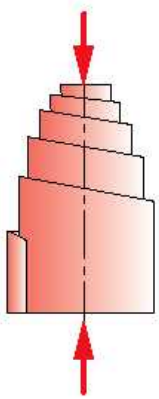
Springs

Types of springs

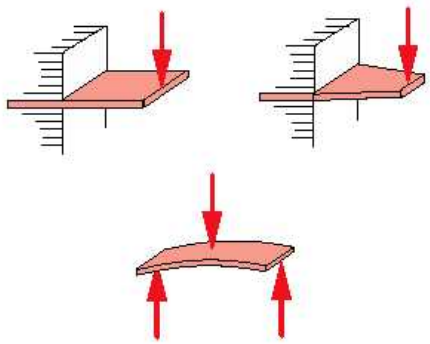


Belleville wave slotted finger curved

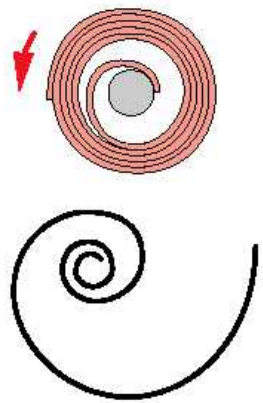
(e) Spring washers. *Push*—Belleville has high loads and low deflections—choice of rates (constant, increasing, or decreasing). Wave has light loads, low deflection, uses limited radial space. Slotted has higher deflections than Belleville. Finger is used for axial loading of bearings. Curved is used to absorb axial end play.



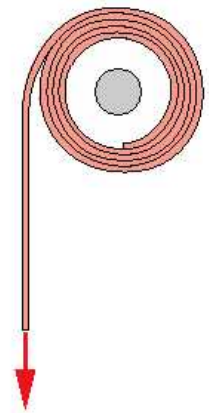
(f) Volute spring. *Push*—may have an inherently high friction damping.



(g) Beam springs. *Push* or *Pull*—wide load but low deflection range—rectangular or shaped cantilever, or simply supported.



(h) Power or motor springs. *Twist*—exerts torque over many turns. Shown in, and removed from, retainer.



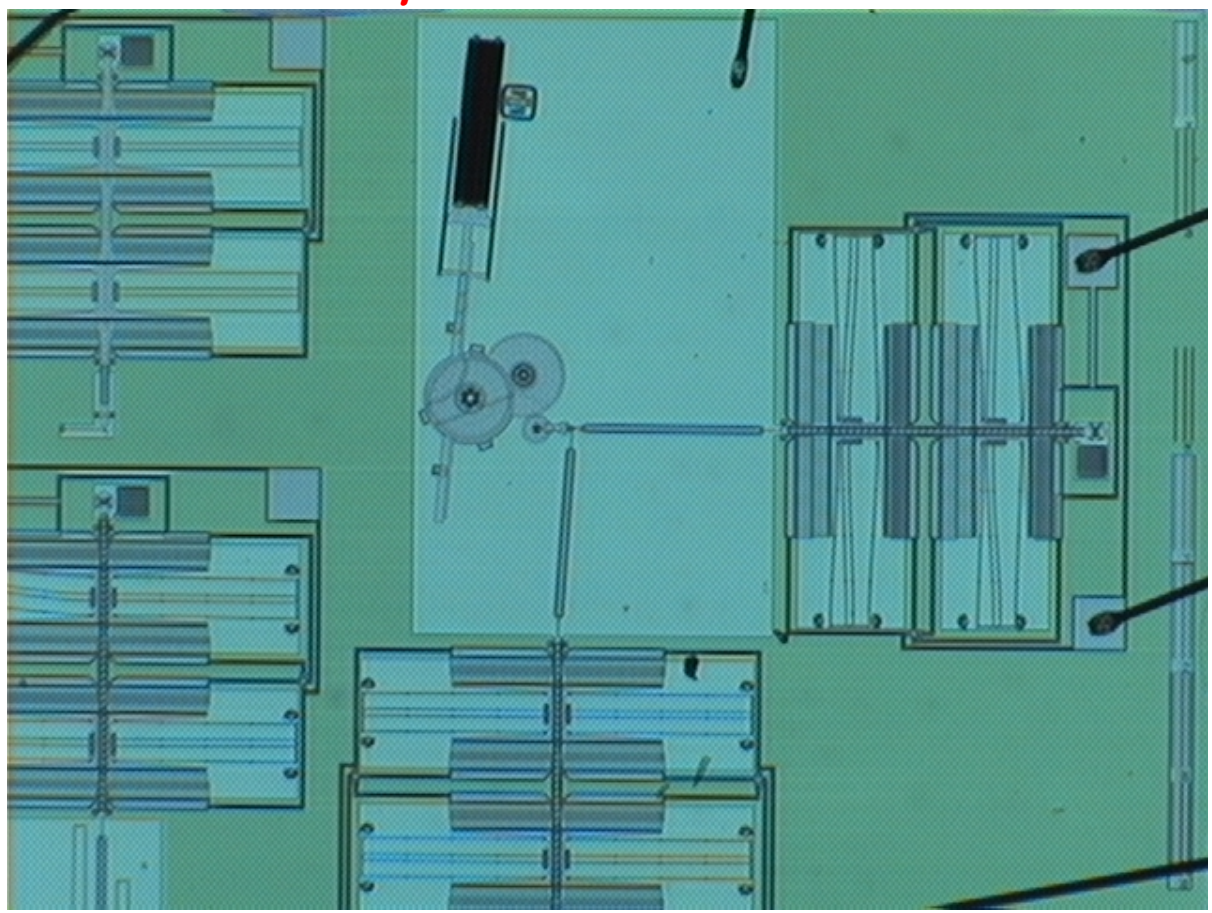
(i) Constant Force. *Pull*—long deflection at low or zero rate.

Springs

Types of springs: Sandia μ-mirror device

State-of-the-art in MEMS technology

Up to 1 million RPMs

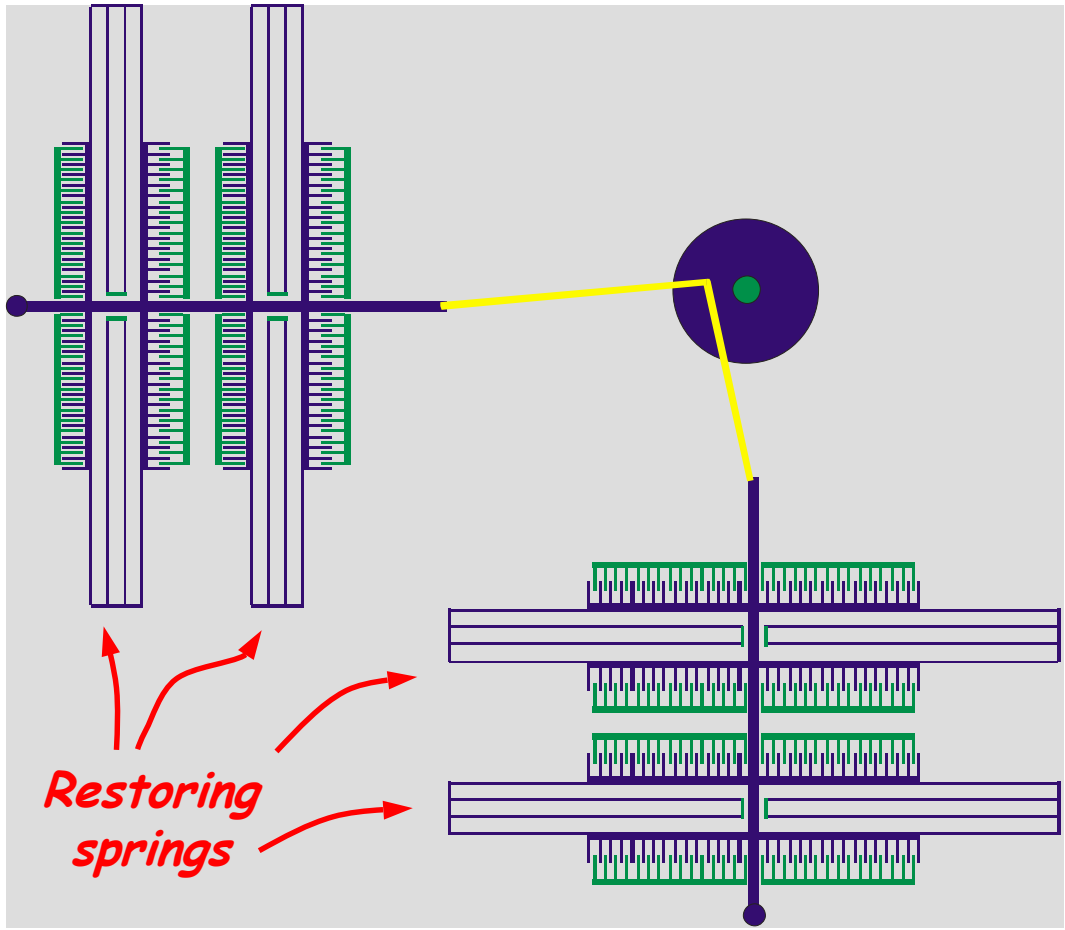


Springs

Types of springs: Sandia μ-mirror device

State-of-the-art in MEMS technology

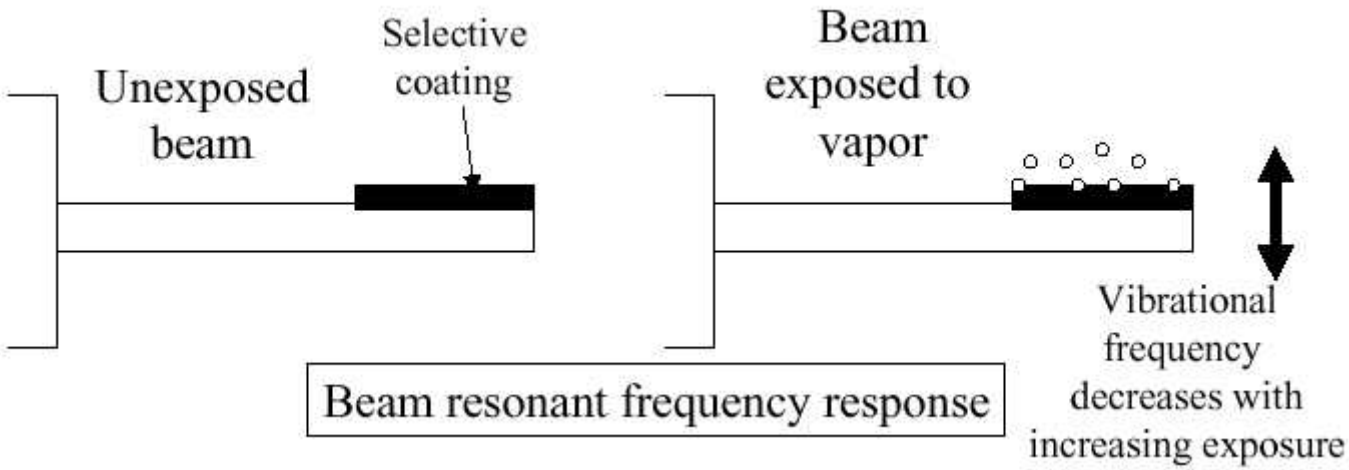
Electrostatically actuated μ-engine



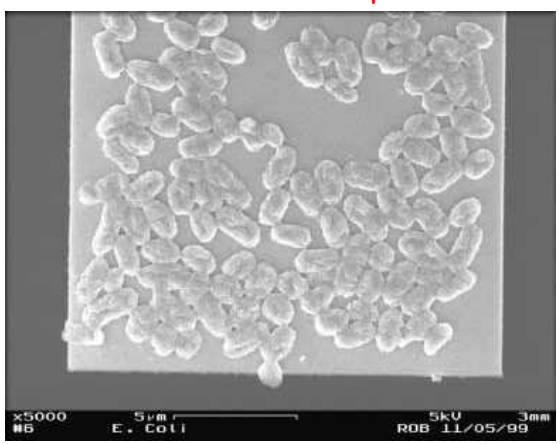
Springs: μ-cantilever beams

Chemical spectroscopy: detection of nanoparticles

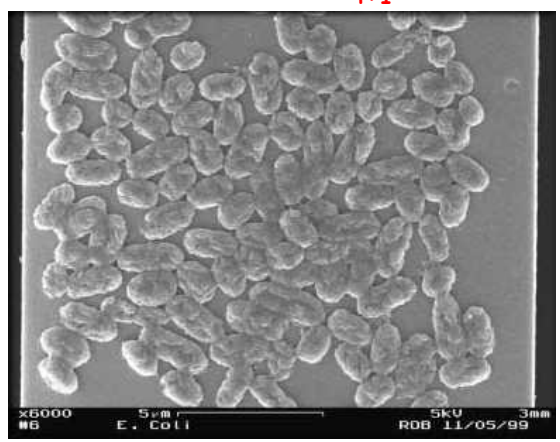
Basic principle



At time t_i

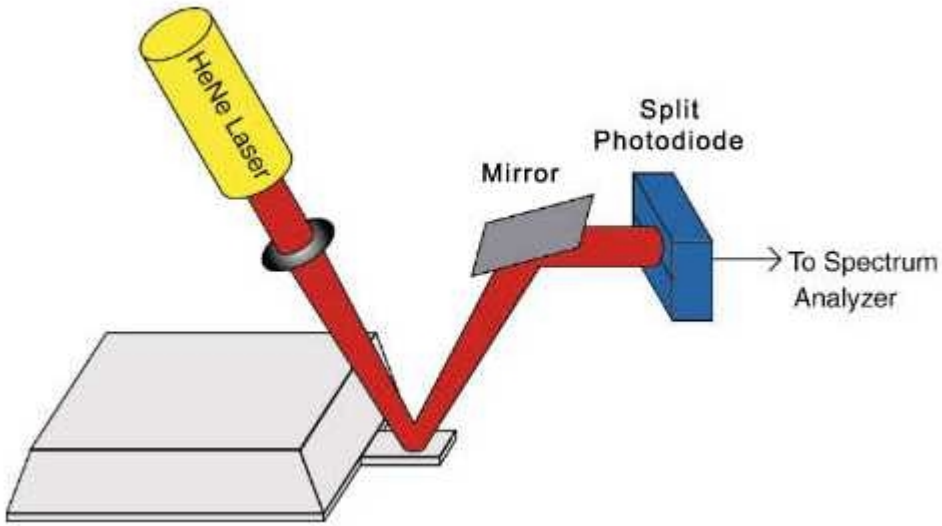


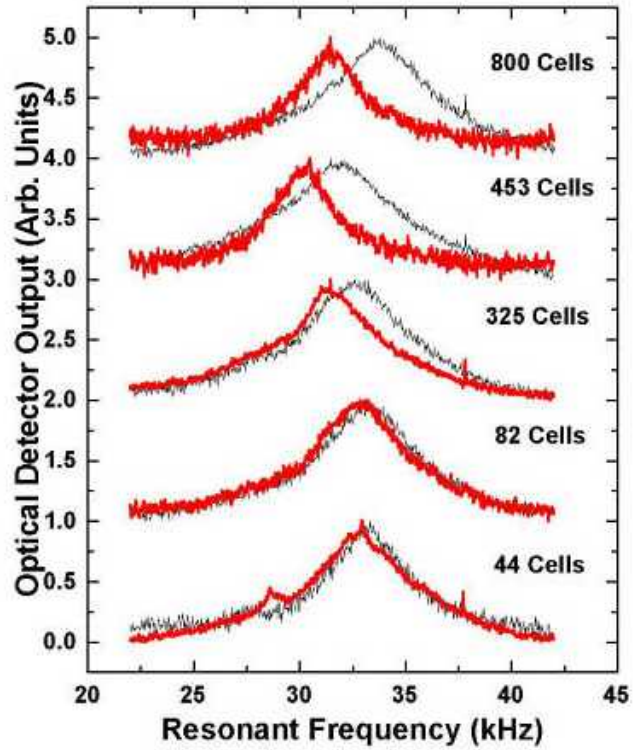
At time t_{i+1}



Springs: μ-cantilever beams

Chemical spectroscopy: detection of nanoparticles





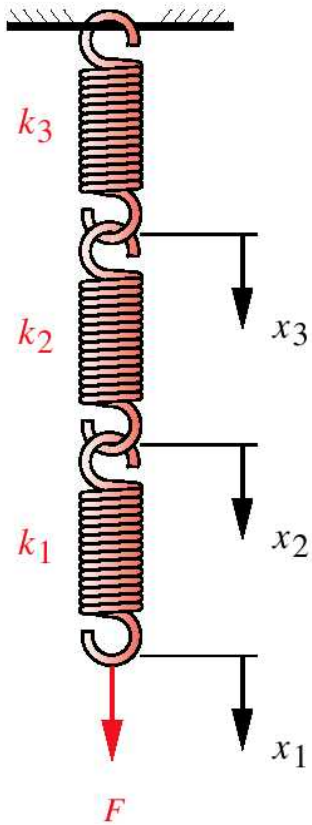
Prof. Craighead, Cornell University

Springs

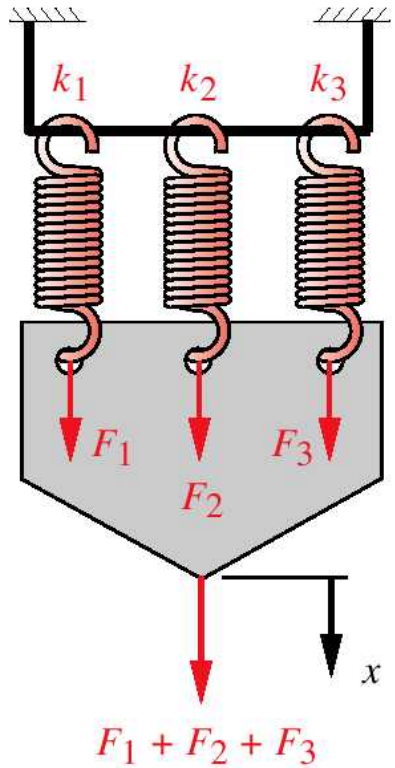
Equivalent springs

$$\frac{1}{k_{total}} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3}$$

$$k_{total} = k_1 + k_2 + k_3$$



(a) Series



(b) Parallel

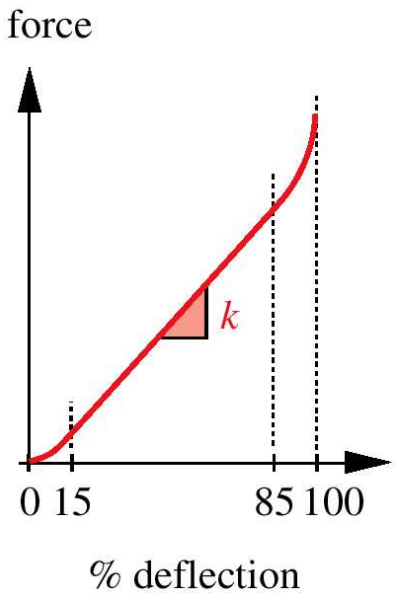
Spring constant:

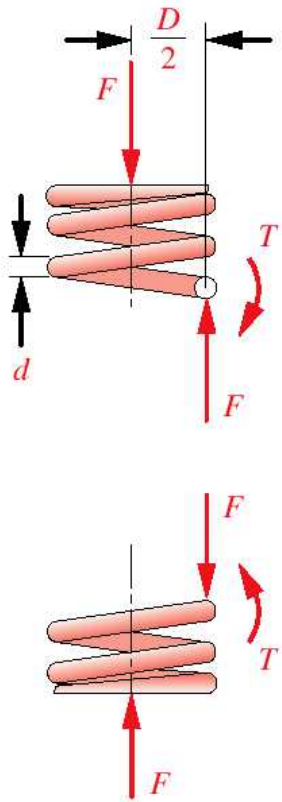
$$k_{total} = \frac{F}{y}$$

Springs

Force deflection curves: helical compression springs

Helical compression spring





Spring index:

$$C = \frac{D}{d}$$

Spring deflection:

$$y = \frac{8FD^3N_a}{d^4G}$$

Spring "rate":

$$k = \frac{F}{y} = \frac{d^4G}{8D^3N_a}$$

(Note: N_a = active coils; see Figure 13-8)

Springs

Materials

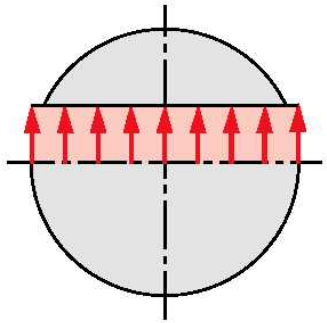
Table 13-1 Common Spring Wire Materials

Source: Reference 2

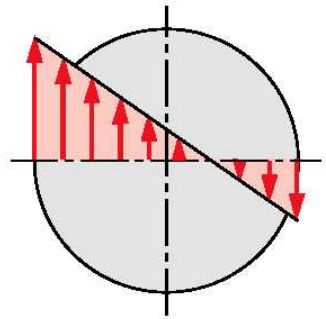
ASTM #	Material	SAE #	Description
A227	Cold-drawn wire ("hard-drawn")	1066	Least expensive general-purpose spring wire. Suitable for static loading but not good for fatigue or impact. Temperature range 0°C to 120°C (250°F).
A228	Music wire	1085	Toughest, most widely used material for small coil springs. Highest tensile and fatigue strength of all spring wire. Temperature range 0°C to 120°C (250°F).
A229	Oil-tempered wire	1065	General-purpose spring steel. Less expensive and available in larger sizes than music wire. Suitable for static loading but not good for fatigue or impact. Temperature range 0°C to 180°C (350°F).
A230	Oil-tempered wire	1070	Valve-spring quality—suitable for fatigue loading.
A232	Chrome vanadium	6150	Most popular alloy spring steel. Valve-spring quality—suitable for fatigue loading. Also good for shock and impact loads. For temperatures to 220°C (425°F). Available annealed or pretempered.
A313 (302)	Stainless steel	30302	Suitable for fatigue applications.
A401	Chrome silicon	9254	Valve-spring quality—suitable for fatigue loading. Second highest strength to music wire and has higher temperature resistance to 220°C (425°F).
B134, #260	Spring brass	CA-260	Low strength—good corrosion resistance.
B159	Phosphor bronze	CA-510	Higher strength than brass—better fatigue resistance—good corrosion resistance. Cannot be heat treated or bent along the grain.
B197	Beryllium copper	CA-172	Higher strength than brass—better fatigue resistance—good corrosion resistance. Can be heat treated and bent along the grain.
-	Inconel X-750	-	Corrosion resistance.

Springs

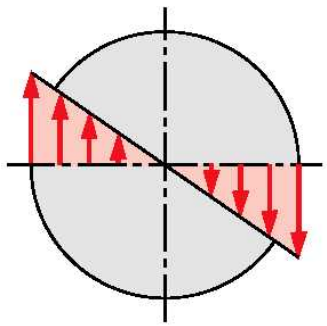
Stresses: helical compression springs



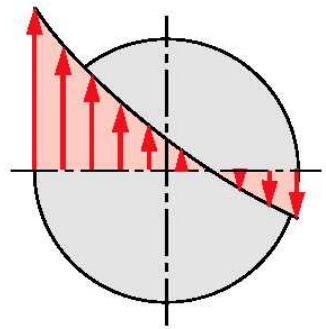
(a) Direct shear stress distribution across section



(c) Combined direct shear and torsional stress



(b) Torsional shear stress distribution across section



(d) Effects of stress concentration at inside edge

Springs

Stresses: helical compression springs

Tensile strength:	Shear strength:
$S_{ut} \cong A\, d^{b}$	$S_{us} \cong 0.67\, S_{ut}$

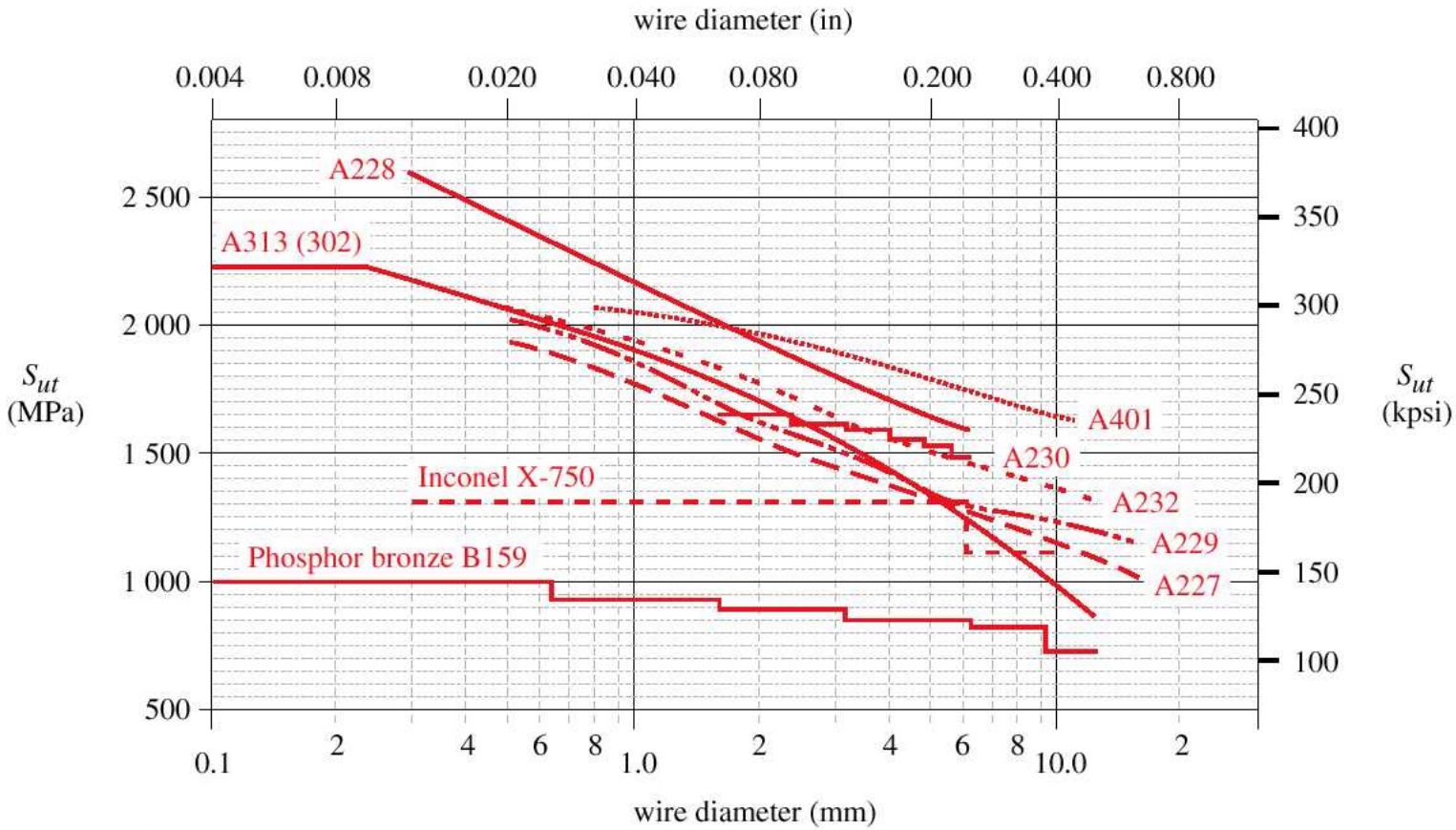


FIGURE 13-3

Minimum Tensile Strengths of Spring Wire—Identified by ASTM Number—See Table 13-1 Source: *Design Handbook: Engineering Guide to Spring Design*, 1987, Associated Spring, Barnes Group Inc., Bristol, Conn.

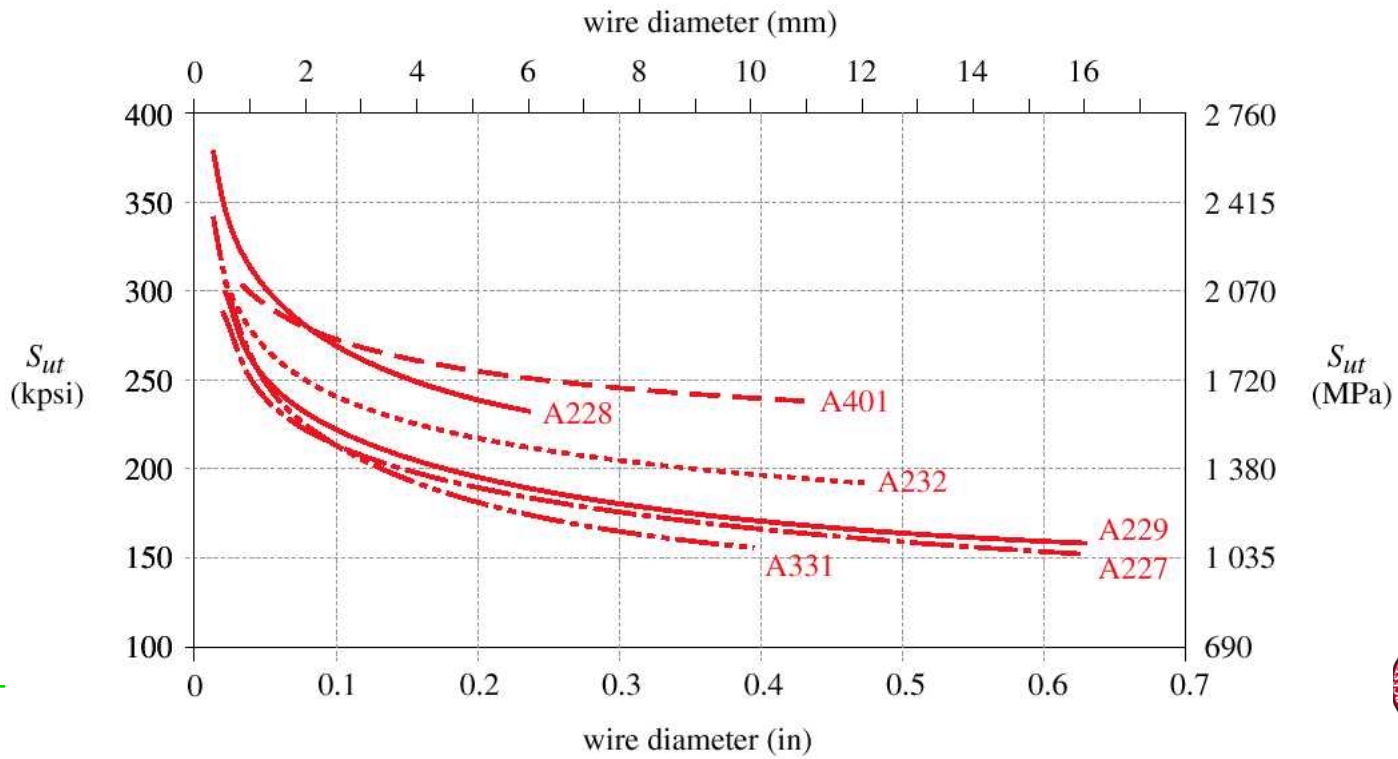
Springs

Stresses: helical compression springs

Table 13-4 Coefficients and Exponents for Equation 13.3

Source: Reference 1

ASTM #	Material	Range mm	Range in	Exponent b	Coefficient A MPa	Coefficient A psi	Correlation Factor
A227	Cold drawn	0.5–16	0.020–0.625	–0.182 2	1 753.3	141 040	0.998
A228	Music wire	0.3–6	0.010–0.250	–0.1625	2 153.5	184 649	0.9997
A229	Oil tempered	0.5–16	0.020–0.625	–0.183 3	1 831.2	146 780	0.999
A232	Chrome-v.	0.5–12	0.020–0.500	–0.145 3	1 909.9	173 128	0.998
A401	Chrome-s.	0.8–11	0.031–0.437	–0.093 4	2 059.2	220 779	0.991



Examples

- Review and Master: Examples 13-1 and 13-2

Reading

- Chapters 13 of textbook
- Review notes and text: ES2501, ES2502, ES2503

Homework assignment

- Author's: 13-1
- Solve: 13-6, 13-13, 13-17