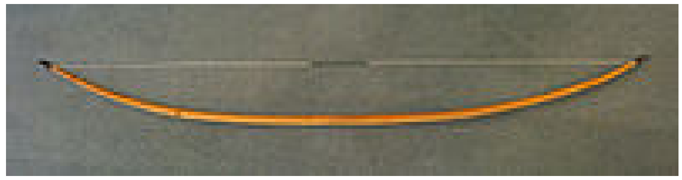
# Perfection Spring and Stamping Corp.

## Defining What We Do & Glossary of Terms

## Coiled Springs


Helical or *coil* springs designed for tension


The English longbow - a simple but very powerful spring

A spring is an elastic object used to store mechanical energy. Springs are usually made out of hardened steel. Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current (because of its low electrical resistance).
The rate of a spring is the change in the force it exerts, divided by the change in deflection of the spring. That is, it is the gradient of the force versus deflection curve. An extension or compression spring has units of force divided by distance, for example lbf/in or N/m. Torsion springs have units of force multiplied by distance divided by angle, such as N·m/rad or ft·lbf/degree. The inverse of spring rate is compliance that is if a spring has a rate of 10 N/mm, it has a compliance of 0.1 mm/N. The stiffness (or rate) of springs in parallel is additive, as is the compliance of springs in series.

***Depending on the design and required operating environment, any material can be used to construct a spring, so long the material has the required combination of rigidity and elasticity: technically, a wooden bow is a form of spring.***

Simple non-coiled springs were used throughout human history e.g. the bow (and arrow). In the Bronze Age more sophisticated spring devices were used, as shown by the spread of tweezers in many cultures. Ctesibius of Alexandria developed a method for making bronze with spring-like characteristics by producing an alloy of bronze with an increased proportion of tin, and then hardening it by hammering after it is cast.

Coiled springs appeared early in the 15th century,[1] in locks.[2] The first spring powered-clocks appeared in that century [3][2][4] and evolved into the first large watches by the 16th century.

In 1676 British physicist Robert Hooke discovered the principle behind springs' action, that the force it exerts is proportional to its extension, now called Hooke's law.

**Springs are classified according their properties.**

Depending on load they may be classified as:

- Tension/Extension spring
- Compression spring
- Torsional spring

In tension/extension and compression there is axial load. On the other hand in the torsional spring there is torsional force.

Depending on spring material it can be classified as:

- Wire/Coil spring
- Flat spring

The most common types of spring are:

- Cantilever spring - a spring which is fixed only at one end.
- Coil spring or helical spring - a spring (made by winding a wire around a cylinder) and the conical spring - these are types of torsion spring, because the wire itself is twisted when the spring is compressed or stretched. These are in turn of two types:
    - Compression springs are designed to become shorter when loaded. Their turns are not touching in the unloaded position, and they need no attachment points.
        - A volute spring is a compression spring in the form of a cone, designed so that under compression the coils are not forced against each other, thus permitting longer travel.
    - Tension springs are designed to become longer under load. Their turns are normally touching in the unloaded position, and they have a hook, eye or some other means of attachment at each end.

Hairspring or balance spring - a delicate spiral torsion spring used in watches, galvanometers, and places where electricity must be carried to partially-rotating devices such as steering wheels without hindering the rotation.

Leaf spring - a flat springy sheet, used in vehicle suspensions, electrical switches, bows.
V-spring - used in antique firearm mechanisms such as the Wheelock, flintlock and percussion cap locks.

<u>Other types include:</u>

Belleville washer or Belleville spring - a disc shaped spring commonly used to apply tension to a bolt (and also in the initiation mechanism of pressure-activated landmines).

Constant-force spring — a tightly rolled ribbon that exerts a nearly constant force as it is unrolled.

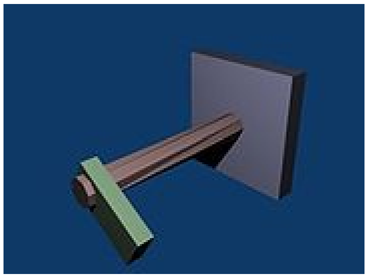
Gas spring - a volume of gas which is compressed.

Ideal Spring - the notional spring used in physics: it has no weight, mass, or damping losses.

Mainspring - a spiral ribbon shaped spring used as a power source in watches, clocks, music boxes, windup toys, and mechanically powered flashlights

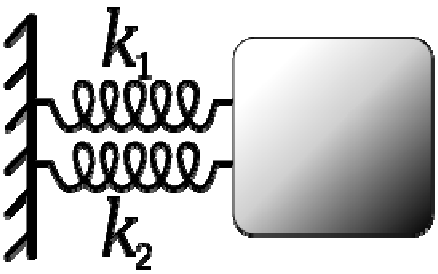
Rubber band - a tension spring where energy is stored by stretching the material.

Spring washer - used to apply a constant tensile force along the axis of a fastener.


A torsion bar twisted under load

Torsion spring - any spring designed to be twisted rather than compressed or extended. Used in torsion bar vehicle suspension systems.

## *Physics*



Two springs attached to a wall and a mass. In a situation like this, the two springs can be replaced by one with a spring constant of $k_{eq}=k_1+k_2$.

### Hooke's law

Most springs (not stretched or compressed beyond the elastic limit) obey Hooke's law, which states that the force with which the spring pushes back is linearly proportional to the distance from its equilibrium length:

$$F = -kx,$$

where

> x is the displacement vector - the distance and direction in which the spring is deformed
> F is the resulting force vector - the magnitude and direction of the restoring force the spring exerts
> k is the spring constant or force constant of the spring.

Coil springs and other common springs typically obey Hooke's law. There are useful springs that don't: springs based on beam bending can for example produce forces that vary nonlinearly with displacement.

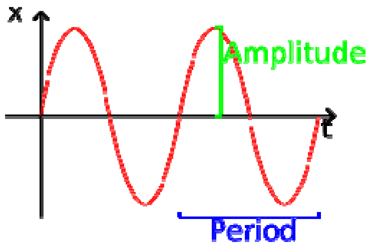
There are also linear springs which don't follow Hooke's law: a Negator spring (the spring that a self retracting tape measure uses) provides a constant force.[citation needed]

Simple harmonic motion

Harmonic oscillator

Since force is equal to mass, m, times acceleration, a, the force equation for a spring obeying Hooke's law looks like:

$$F = ma \quad \Rightarrow \quad -kx = ma.$$




The displacement, x, as a function of time. The amount of time that passes between peaks is called the period.
The mass of the spring is assumed small in comparison to the mass of the attached mass and is ignored. Since acceleration is just the second time derivative of x,

$$-kx = m\frac{d^2x}{dt^2}.$$

This is a second order linear differential equation for the displacement x as a function of time. Rearranging:

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0,$$

the solution of which is the sum of a sine and cosine:

$$x(t) = A\sin\left(t\sqrt{\frac{k}{m}}\right) + B\cos\left(t\sqrt{\frac{k}{m}}\right).$$

A and B are arbitrary constants that may be found by considering the initial displacement and velocity of the mass. The graph of this function with B = 0 (zero initial position with some positive initial velocity) is displayed in the image on the right.

### *Theory*

In classical physics, a spring can be seen as a device that stores potential energy by straining the bonds between the atoms of an elastic material.

Hooke's law of elasticity states that the extension of an elastic rod (its distended length minus its relaxed length) is linearly proportional to its tension, the force used to stretch it. Similarly, the contraction (negative extension) is proportional to the compression (negative tension).

This law actually holds only approximately, and only when the deformation (extension or contraction) is small compared to the rod's overall length. For deformations beyond the elastic limit, atomic bonds get broken or rearranged, and a spring may snap, buckle, or permanently deform. Many materials have no clearly defined elastic limit, and Hooke's law can not be meaningfully applied to these materials.

Hooke's law is a mathematical consequence of the fact that the potential energy of the rod is a minimum when it has its relaxed length. Any smooth function of one variable approximates a quadratic function when examined near enough to its minimum point; and therefore the force — which is the derivative of energy with respect to displacement — will approximate a linear function.

Force of fully compressed spring: $F_{max} = (Ed^4(L - nd)) / (16(1 + nu)(D - d)^3 n)$
where

- E - Young's modulus
- d - spring wire diameter
- L - free length of spring
- n - number of active windings
- nu - Poisson ratio
- D - spring outer diameter

# Coiling/Spring Terms

**Active Coils ($n_a$)**
Those coils which are free to deflect under load.

**Angular relationship of ends**
The relative position of the plane of the hooks or loops of extension springs or the legs of a torsion spring to each other.

**Baking**
Heating of electroplated springs to relieve hydrogen embrittlement.

**Buckling**
Bowing or lateral deflection of compression springs when compressed, related to the slenderness ratio (Free Length/Mean Coil Diameter).

**Closed ends and squared**
Ends of compression springs where pitch of the end coils is reduced so that the end coils touch and are square with the spring axis.

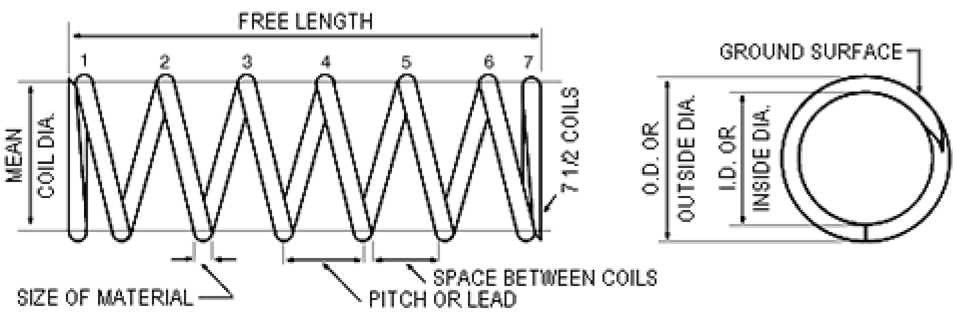
**Closed and ground ends**
As with closed ends, except that the end is ground to provide a flat plane.

**Closed length**
See Solid height

**Close-wound**
Coiled with adjacent coils touching.

**Coils per inch**
See Pitch.

**Compression Spring**
Helical compression springs have applications to resist applied compression forces or in the push mode, store energy to provide the "push". Different forms of compression springs are produced. There are conical, barrel, hourglass, or straight conical compression springs. These compression springs can be made with or without variable spacing between coils. Round wire springs can store more energy than rectangular wire compression springs.

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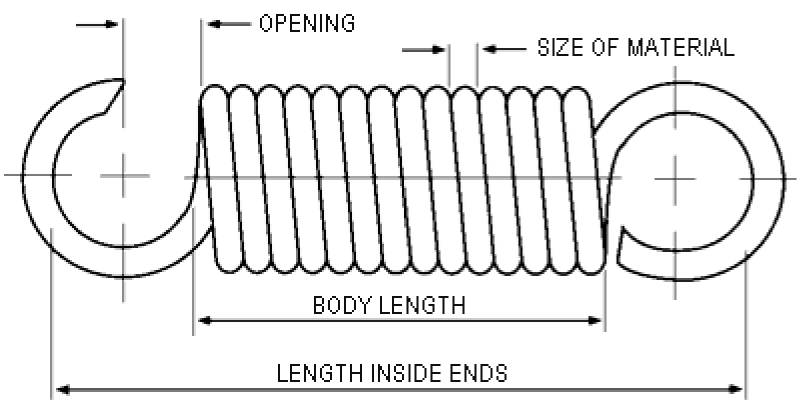
**Deflection (F)**
Motion of spring ends or legs under the application or removal of an external load (P).

**Elastic limit**
Maximum stress to which a material may be subjected to without permanent set.

**Endurance limit**
Maximum stress at which any given material will operate for a determined number of cycles without failure for a given minimum stress.

**Extension Spring**
Extension Springs exert a pulling force or energy. They are usually close wound with initial tension and are mostly made from round wire. The design of the extension springs' ends are limitless. Hooks, loops, bends, crossbars, etc.

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**Free angle**
Angle between the legs of a [torsion spring] which is not under load.

**Free length (L)**
The overall length of a spring which is not under load.

**Gradient**
See [Rate (R)].

**Heat setting**
Fixturing a spring at elevated temperature to minimize loss of load at operating temperature.

**Helix**
The spiral form (open or closed) of [compression], [extension], and [torsion springs].

**Hooke's Law**
Load is proportional to displacement.

**Hooks**
Open loops or ends of [extension springs].

**Hot pressing**
See [Heat Setting].

**Hydrogen embrittlement**
Hydrogen absorbed in electroplating or pickling of carbon steels, tending to make the spring material brittle and susceptible to cracking and failure, particularly under sustained loads. Proper baking is required to relieve the hydrogen.

**Hysteresis**
The mechanical energy loss that always occurs under cyclic loading and unloading of a spring, proportional to the area between the loading and unloading load-deflection curves within the elastic range of a spring.

**Initial tension ($P_i$)**
The force that tends to keep the coils of an [extension spring] closed and which must be overcome before the coils start to open.

**Load (P)**
The force applied to a spring that causes a deflection (F).

**Loops**
Formed wire shapes at the ends of extension springs that provide for attachment and force application.

**Mean coil diameter (D)**
Outside spring diameter (OD) minus one wire diameter (d).

**Modulus in shear or torsion (G)**
Coefficient of stiffness for extension and compression springs. (Modulus of Rigidity)

**Modulus in tension or bending (E)**
Coefficient of stiffness used for torsion and flat springs (Young's Modulus E).

**Moment (M)**
A product of the distance from the spring axis to the point of load application, and the force component normal to the distance line. See Torque.

**Open ends, not ground**
End of a compression spring with a constant pitch for each coil and the last coils not touching adjacent coils.

**Open ends ground**
"Open ends, not ground" followed by an end grinding operation.

**Passivating**
Acid treatment to remove contaminants and improve corrosion resistance of stainless steel.

**Permanent set**
A material that is deflected so far that its elastic properties have been exceeded and it does not return to its original condition upon release of load has taken a "permanent set."

**Pitch (p)**
The distance from center to center of the wire in adjacent active coils (recommended practice is to specify number of active coils rather than pitch).

**Plain Ends**
End coils of a compression spring having a constant pitch and not squared.

**Poisson's Ratio**
The ratio of the strain in the transverse direction to the strain in the longitudinal direction.

**Preset**
See Remove set.

**Rate (R)**
Change in load per unit deflection, generally given in pounds per inch. (N/mm)

**Remove set**
The process of closing to solid height a compression spring which has been coiled longer than the desired finished length, so as to increase the apparent elastic limit.

**Residual stress**
Stresses mechanically induced by set removal, shot peening, cold working, forming or other means. These stresses may or may not be beneficial, depending on the application of the spring.

**Set**
Permanent distortion in length, height, or position which occurs when a spring is stressed beyond the elastic limit of the material.

**Shot peening**
Blasting the surfaces of the spring with pellets to induce compressive stresses and thereby improve fatigue life.

**Slenderness ratio**
Ratio of spring length (L) to mean coil diameter (D).

**Solid height (H)**
Length of a compression spring when under sufficient load to bring all coils into contact with adjacent coils; no additional deflection is possible.

**Spring index**
Ratio of mean coil diameter (D) to wire diameter (d).

**Squared and ground ends**
See Closed and ground ends.

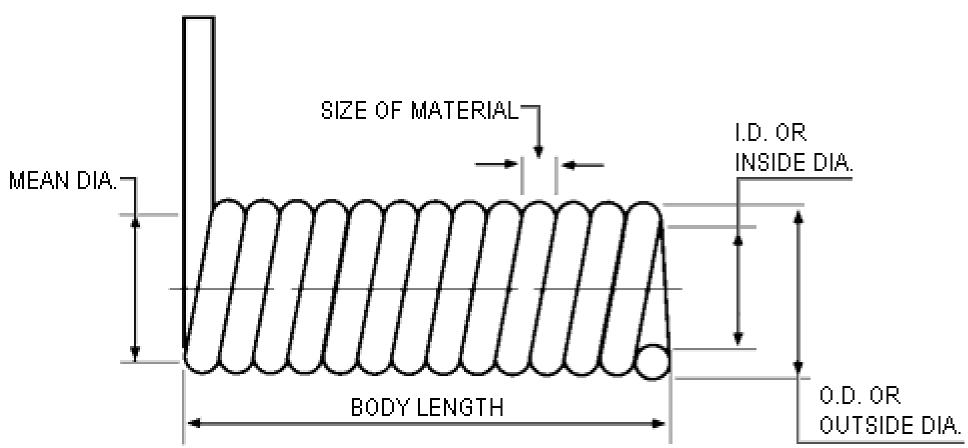
**Squared ends**
See Closed ends.

**Stress range**
The difference in operating stresses at minimum and maximum loads.

**Stress relieve**
To subject springs to low-temperature heat treatment so as to relieve residual stresses.

**Torque (M)**
A product of the distance from the spring axis to the point of load application, and the force component normal to the distance line. A twisting action in torsion springs which tends to produce rotation, equal to the load multiplied by the distance (or moment arm) from the load to the axis of the spring body. Usually expressed in oz./in., lb./in., lb./ft., or in. N/mm.

**Torsion Spring**
A torsion spring provides rotational energy or torque. You can have a single bodied or double bodied torsion spring. You must have three points of support and the body usually sits on a shaft or arbor. Again, the design of the ends or legs of a torsion spring are limitless. The stress in a torsion spring is bending. Round wire is still the preferred material due to the cost of rectangular wire, even though rectangular is more efficient in bending.

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**Total number of coils ($N_t$)**
Number of active coils ($N_a$). For compression springs, active coils (Na) plus the number of dead coils forming the ends.

**Wahl Factor**
A factor to correct stress in helical springs effects of curvature and direct shear.

*Reference: From Wikipedia.com, the free encyclopedia.*