

Friction springs on aerial masts are located between structural elements and attached masses to absorb kinetic energy and prevent damaging swaying.



Quieting impact and vibration

Friction springs consist of radial rings that deform briefly and convert impact energy into frictional heat. They are useful for damping in many applications.



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Spring technology for damping is relatively old. Stagecoaches had leaf springs, early trains had large, crude, coil-spring buffers (to absorb shocks when cars bumped together) and early automobiles made use of simple springs for damping as well. However, these early springs were roughly assembled and packaged, so they generated inconsistent force and unpredictable behavior. Then a tapered ring system was de-

veloped: These *friction springs* (as they are now called) were originally developed for use as primary railway buffers. Engineers stacked these tapered rings and found that they could absorb shock in a fairly controlled manner. Today, they're used in a myriad of applications.

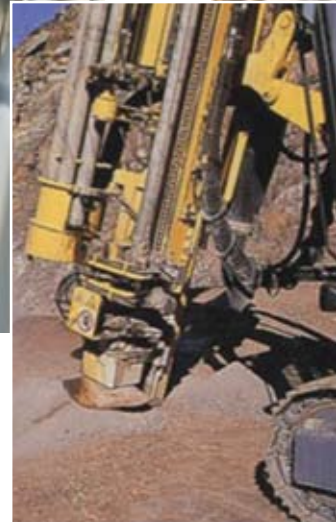
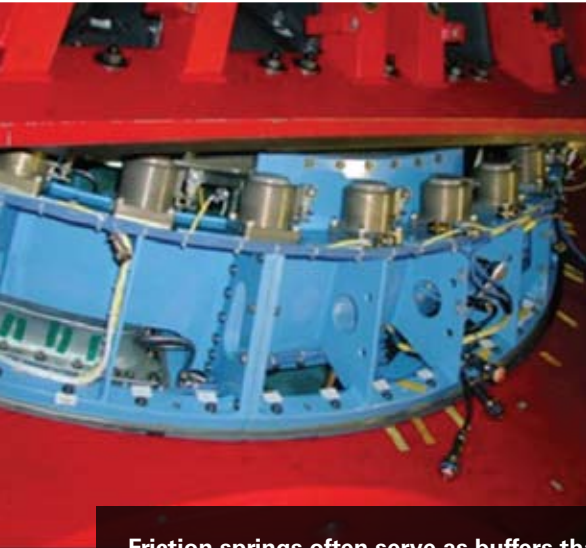
How they work

Friction spring dampers consist of a series of concentrically stacked steel rings with mating taper faces. A stack can include two or 200 rings, depending on how much force and travel the design must absorb. Inner and outer rings alternate down the length of the friction spring; un-

der application of axial load, the wedge action of the taper faces expands the outer rings, contracts the inner rings radially, and allows axial deflection.

When compressed, each solid ring slides on a taper, and these in turn rub against each other and generate heat. For example: If we apply 1,000 lb to a spring, it absorbs about 66% of that force as heat. The material deforms, but compression is within the elastic material limit, so deformation is temporary.

There is recoil — in industrial systems, thousands or tens of thousands of pounds. However, with friction springs, designs can absorb the impact of big press



Friction springs often serve as buffers that absorb kinetic energy of moving mass. Above, the adjusting mechanism of the red and blue telescope built by MAN Technologie AG, Augsburg, Germany, uses a number of aluminium friction-spring buffers and limit-stop dampers. To protect structural components, buffers with high capacity and low terminal force are most suitable.

hammers, jack hammers used in construction, or even cannons, so shock load is not transmitted through frames or structures, and cannot hurt anyone.

During manufacture, the rings are cut from spring steel, rolled or turned, calibrated for size, hardened, and tempered. The rings are then given a final dimensional check. Friction springs can absorb energies from 1 J to more than 100 kJ. For overload protection, absorption of impact energies is 0.1 kN to 10,000 kN. Friction springs make the most of the material from which they are made — so their dimensions and weight are minimal.

During operation, friction springs require lubrication. Specifically, engineered greases are necessary to withstand the shearing friction of tapered ring operation without the degradation or migration that other greases can exhibit. Manufacturer-engineered grease can be tailored to fine tune damping output force generated by friction springs.

Damping technology comparison

Most engineering programs don't cover friction springs, so many U.S. engineers aren't fully aware of their valuable capabilities. Even so, their use grows. Friction springs are replacing coil springs and hydraulic buffers in many applications because these purely mechanical tapered springs require little or zero maintenance, and operate for decades with no problems.

Unless they are overloaded, friction spring rings in most applications do not wear out. German and some Canadian railroad lines remove their springs every 15 or so years, inspect them, relubricate them, and put them back into service. In contrast, friction springs in jackhammers and some machine-gun applications do wear out — so after a certain number of cycles, they must be replaced. However, to reiterate, friction springs in most applications are reused indefinitely.

In comparison, more com-

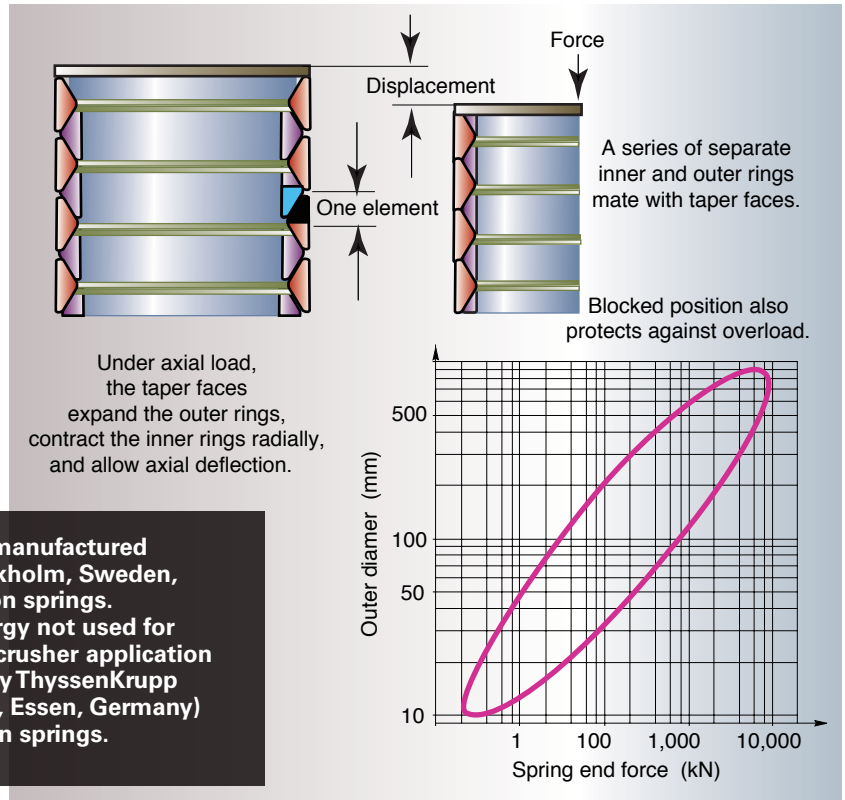
plicated hydraulic dampers can be tuned to give more or less damping, but rely on hydraulic fluid to control their function. So, they're subject to leaking, require maintenance, and (in steel mills, for example) are vulnerable to heat due to their rubber seals and potentially flammable oil. In addition, hydraulic dampers and springs of synthetic material are influenced by temperature fluctuations and inherent temperature rises.

In contrast, the characteristic curve of a friction spring remains independent of these factors within certain limits. Friction springs can be employed in the temperature range of -40° to $+180^{\circ}\text{C}$ without much change in force capacity. Here, allowances must be made for the inherent temperature climb caused by damping. Note: For extreme applications going beyond indi-



Left, a drill hammer manufactured by Atlas Copco, Stockholm, Sweden, is protected by friction springs. They absorb the energy not used for crushing. Above, a crusher application (this blue unit built by ThyssenKrupp Fördertechnik GmbH, Essen, Germany) is common for friction springs.

Elements and force



An effective taper face — one half inner ring and one half outer ring — is defined as one element, so the spring here consists of eight elements. The number of elements determines how much force the design absorbs. The ratio of outer diameter to spring end force varies; several combinations with slit inner rings produce low force on soft stroke.

cated temperature ranges, consult the manufacturer; mounting options can often address heat issues. What's more, friction spring nesting geometry allows optimization of available mounting space with parallel and series spring arrangements.

Typical applications

One place you won't find friction springs is at the bottom of an elevator shaft. Instead, there are usually several long, fat coil springs that don't dampen much. Why? Simple overload protection such as this requires only simple safety devices. In contrast, if a design must protect goods or personnel, it requires more damping.

To illustrate, friction springs are used on tools that machine steel. On tool holders, if there is a jam or the holder impacts a rotating machine part, friction

springs absorb the shock, and can even cause the machine to shut down, so that an operator can investigate. Similarly, in drilling operations (to obtain water or oil, or to cut away at a mountain, for example) friction springs protect equipment from impact when hard or uneven material is struck. Friction springs also reduce the shock level experienced

by jackhammer operators. In bay doors of European cargo planes, friction springs dampen any impact upon closing as well.

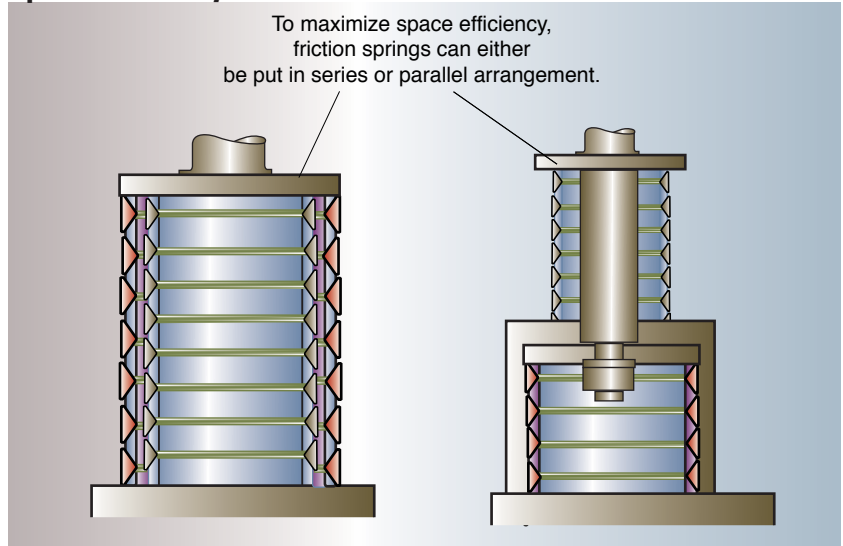
Another use: Blocking

In contrast to velocity-dependent spring systems, friction springs provide full spring work and damping even when load is applied quickly or very slowly.

On the excavator crawler shown here (built by LIEBHERR, with U.S. headquarters in Newport News, Va.) friction-spring buffers (more than 1.6 m long and 1.2 tons in weight) apply pre-stressing of 1,000 kN. The system requires zero maintenance.



Space efficiency



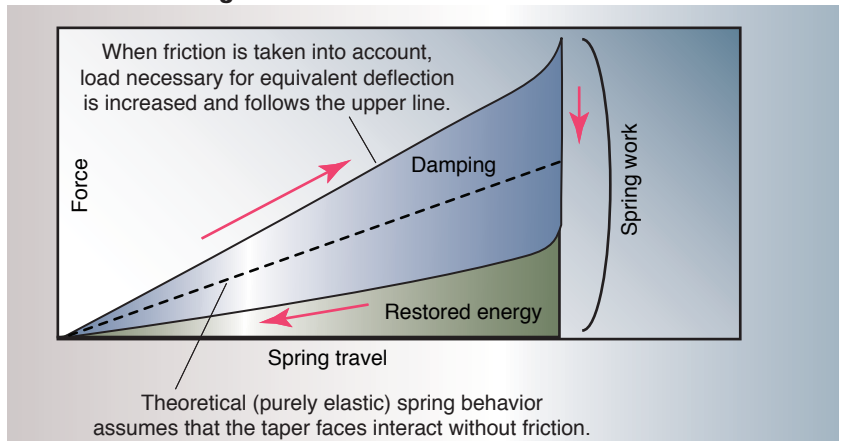
Friction spring geometry optimizes use of mounting space.

Friction springs also block load, so when maximum spring travel is reached, the front surfaces of the inner rings touch and form a rigid column. For this reason, admissible stresses cannot be exceeded and friction springs suffer no damage. Even so, in actual applications such loading condi-

tions should be avoided because the spring is not effective in its “blocked” (or solid) position: High peak forces may result and jeopardize structural components.

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Force-travel diagram



Force increases linearly with spring deflection according to Hooke's Law. During recoil, load is reduced by approximately the same amount and follows the lower line in the diagram, completing a hysteresis loop. The shaded area within the loop represents absorbed energy or damping; this amounts to two thirds of the input energy and is dissipated as frictional heat. Recoil force at any point on the diagram is equal to about one-third the relative compressive force. Total energy absorption can be calculated by multiplying component values (from manufacturer tables) by the number of deforming shock-absorbing elements. Spring capacity is represented by the total area below the load curve.