Fastener Engineering

December 2019

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2019 Fastener Handbook

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The significance of small choices

Years ago, during a high-school woodworking course, our instructor would walk through the shop, repeating: "It's the nuts and bolts that count!" Students would laugh or roll their eyes. Interestingly, he rarely questioned students about the type of wood selected for a project (though I still have the chestnut bench I made back then) but he would frequently ask about the type of bolt or screw used ("Hex or flat-headed...coarse or fine-threaded?"). He even taught us about threadlocker though we never used it.

Little did I know that class was my first introduction to fasteners, or that I'd work as an editor decades later for a new *Fastener Engineering* publication. What his lesson taught, which is still critical in the fastener industry, is small choices matter — greatly.

The "nuts and bolts," though too-often overlooked at the design stage of an application, typically provide structural integrity, reliability, and safety. This means the choice of fastener (including the type, material, and quality) is significant. So, too, is the tool used for its installation. For example, thanks to that high-school elective, I learned over-driving may lead to excess pressure on the fastener, resulting in a compressed washer or damaged screw. The use of an incorrect tool or setting for an application can also ruin fasteners and result in structural failures.

Of course, the fastener market is ubiquitous, reaching far beyond woodworking. These devices are small but provide a significant role in nearly every industry (just try naming a sector that exists without the use of fasteners in some capacity). Despite challenges, such as tariffs or foreign manufacturing, it's still a growing market according to several reports.

This is undoubtedly a tribute to the people in the industry, many of whom are longtime co-workers or a part of a family business. At the 2019 Fastener Expo, my first industry trade show, I was impressed by the openness, kindness, knowledge, and friendships shared by the fastener community.

Women In The Fastener Industry (WIFI), for instance, recently celebrated its 10-year-anniversary supporting women in the industry through education and mentorship. Education is also available for those who are new or veterans to the sector, including basic, advanced, and certified training courses to ensure workplace safety and success.

In the pages that follow, we also hope to offer insight, providing information on several standard products available, including adhesives, bolts, latches, levers, rivets, sockets, screws, washers, and other components. You may be familiar with some of the topics and we hope others offer new information.

So, welcome to the inaugural issue of the *Fastener Engineering Handbook*, which aims to share insight into the broad range of tools and components that connect parts together.

Thank you for reading!

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Fastener Engineering

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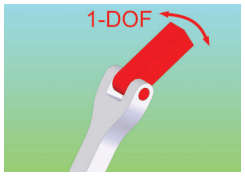
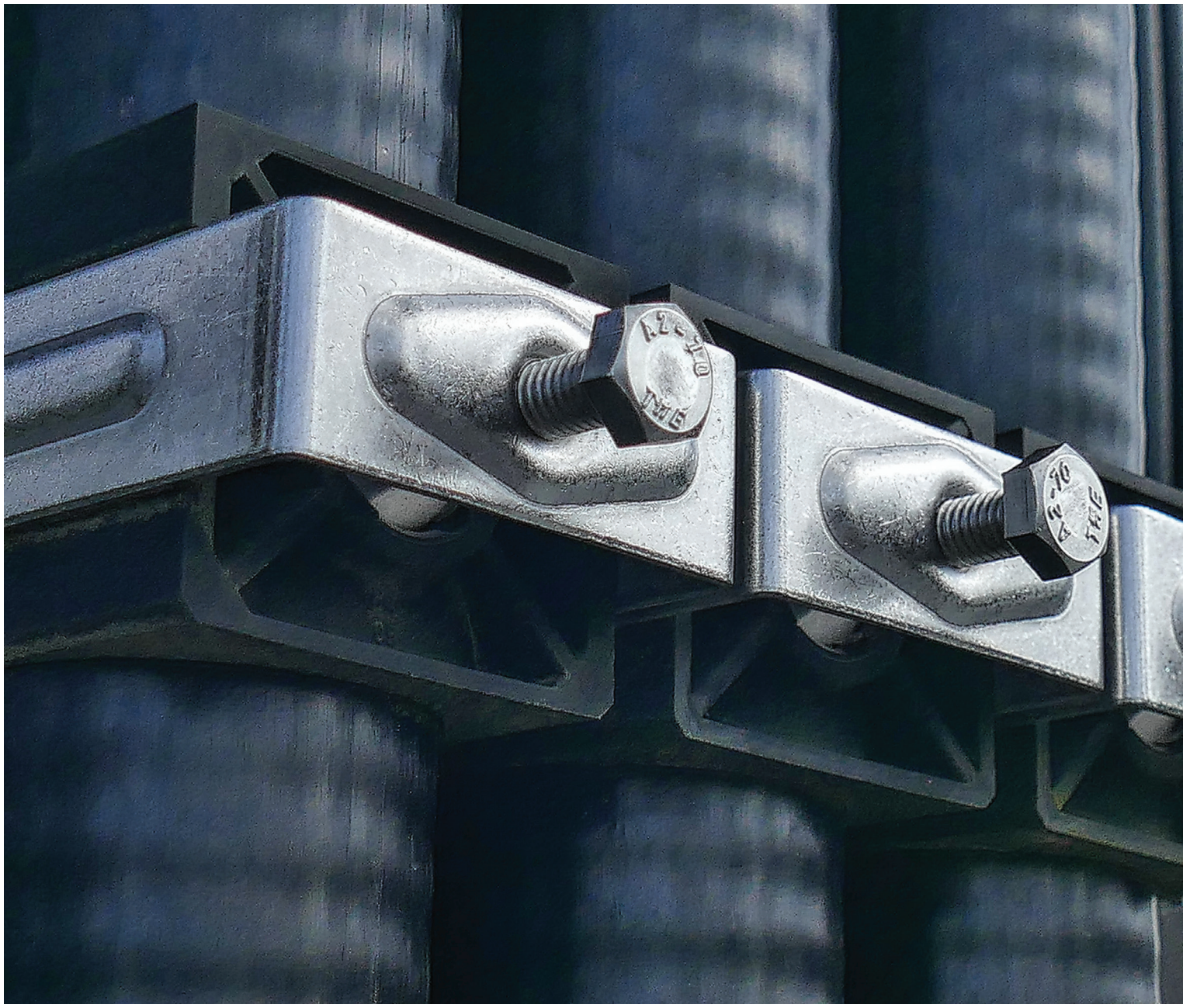




What are industrial fasteners?

A fastener is a hardware device that joins two or more objects together.

Industrial fasteners are a broad category of devices and tools that are used to connect parts together, typically in a permanent or semi-permanent way. The majority of these components are mechanical and familiar to anyone who's a homeowner, such as nuts, bolts, hinges, studs, handles, knobs flanges, rivets, and screws.

Several of these devices, such as screws, can be further broken down into multiple subcategories: thumbscrews, self-drilling, shoulder, captive, jackscrews, security, and others.

In addition to these basics, a few other products in the fastener industry include:

- Adhesives and sealants
- Assembly and processes
- Eyebolts, rod ends, strap clamps
- Gaskets and seals
- Hinges
- Levers
- Pins
- Spacers and standoffs
- Springs
- Sockets, washers, and stampings
- Thread repair kits, thread lockers
- U-clips, U-nuts, J-nuts, twin nuts, flat nuts, ring clips
- Welding

Fastener products also include the tools, assembly equipment, and related supplies required for installation.

Nearly every type of fastener is used in nearly every industry. For example, this is true for consumer devices (such as smartphones and computers), equipment (such as robotics, medical adhesives or machines) to industrial products (such as electric motors and the automotive or construction industries). You'll also find them in everyday life and used in furniture, lighting, vehicles, streetlamps, or even the intricate staging that's designed for a rock concert.

Although safety and quality are important in nearly every application, in some industries where fasteners are used, safety is critical. Examples include automotive manufacturing and aerospace applications. As such, it is essential to weigh the options for each project and give particular consideration to the type of fastener required because each one (say, from a standard flat-head to a hex-head screw) serves a specific function. Every fastener also has an ideal installation process. This is especially important in those critical industries, which usually adhere to strict safety standards for the application and use of fasteners.

When selecting the ideal components for an application, it's also important to consider the material. Although steel or stainless steel are typically used, brass, bronze, and aluminum fasteners are also options for highly corrosive environments. In certain cases, coatings are added to increase durability and corrosion resistance. These include zinc, hot-dip galvanizing, or chrome. Occasionally, coatings are added for appearance and a more polished or finished look in applications.

Cost is, of course, a key consideration. When deciding on fasteners for a project, however, the quality should outweigh any price concerns. This is significant for critical applications.

However, in some cases, it's possible to save on costs. Pre-planning at the design phase of applications, rather than during the installation process, can make a big difference. A reputable manufacturer or distributor may also offer suggestions for choosing the ideal fastener at the ideal cost. So, be sure to do your research and ask for a second opinion if uncertain. **FE**

How are thermoset adhesives used?

Thermoset adhesives are polymeric resins that are cured using heat, or heat and pressure.

Thermoset adhesives are thermosetting polymers or plastics that are used as adhesives. They are supplied in an uncured state consisting of unlinked monomers. Chemical hardeners may be used to instill hardening, or curing may be induced by the application of a stimulus, such as heat or light. Thermoset adhesives offer high strength and an excellent gap-filling ability. They also resist moisture and heat. Examples include epoxy and polyester resins.

Most thermoset adhesives are two-component systems, though one-part adhesives are also available. Two-component adhesives are typically made up of a resin and hardener in liquid or gel form, which are mixed together to initiate the curing process. Curing typically takes between 10 minutes and a few hours.

Two-component adhesives often provide the highest quality bonds, combined with easy storage and relatively simple processing. One-component systems are usually supplied as pastes, which are heat-cured and then cold-stored to delay curing. One-part resins are also used in

The most widely used class of thermoset adhesives are epoxies. Unmodified, an epoxy is a hard and brittle solid that can be useful in a variety of high solids or for protective coatings.

pre-impregnated (prepreg) composites. For certain applications, one-component systems can offer process advantages.

The most widely used class of thermoset adhesives are epoxies. They offer distinct benefits for several applications. When used to bond wood, epoxy provides better moisture resistance and gap-filling than alternatives such as polyurethane adhesives. Epoxy resin is unique because of its ability to create strong bonds on metals and glass.

An unmodified epoxy is a hard and brittle solid that can be useful in a variety of high solids or for protective coatings. Typically, modifiers are added to improve toughness, flexibility, and fatigue-resistance.

Other thermoset adhesives include:

- Polyester resin, which is often used as a lower-cost alternative to epoxy resin for composite structures and fiberglass. However, it does not cure well as a thin film, limiting its use as an adhesive for gap-filling applications. Its bond strength is lower than epoxy, so it's less resistant to moisture and it off-gasses VOCs.
- Phenol formaldehyde resins or phenolic resins are one of the earliest forms of plastic. They're typically used as an adhesive for laminating materials, such as paper and wood, or plywood for external use.
- Polyimide adhesives can resist extremely high temperatures of up to 500° C (930° F) and are sometimes used to bond metal aerospace components. FE

What is the best method for storing adhesives?

The correct storage of adhesives is essential. When not properly stored, some adhesives may dry out or cure, making them impossible to use. What's more: structural adhesives may appear to function correctly but will fail to achieve their specified bond strength. Storage requirements vary considerably between adhesives. Some can be stored indefinitely without any special requirements, while others require refrigeration and only last a few weeks.

Always check the manufacturer's recommended storage for a specific adhesive by reading the label on the container.

Two-part epoxy resin is supplied in two containers — one for resin and the other for the hardener. It's vital when mixing a batch that zero hardeners enter the resin container. The containers should be properly sealed and stored at room temperature. Also, exposure to low temperatures, below about 13° C (55° F), should be avoided.

One-part epoxy resin is supplied as a paste or within a prepreg fiber mat. It requires heat for effective curing that's usually applied in an autoclave. One-part epoxy and prepreg must be cold-stored to delay curing and, generally, only has a shelf life of a few weeks.

Polyurethane adhesive also cures when exposed to humidity and should be stored in a tightly sealed container with as little air as possible. Once opened, it will only last a few weeks.

What are the key factors in selecting an assembly method?

Branson GSX E-1 ultrasonic welder is designed to weld small and intricate plastic parts.

courtesy of Emerson

When choosing or re-evaluating a product assembly method, it's critical to consider the materials or volume production mix to ensure reliability. However, other factors, such as costs and production time, may also affect the fastening method selected. For example, to join or assemble parts made from plastic components, there are three "permanent" fastening methods typically used and discussed below: adhesives, mechanical fasteners, and welding.

Adhesives may be a good choice when:

- Capital investment for assembly equipment is limited.
- Products are assembled in limited volumes or at low speeds.
- Plastic parts are incompatible with plastic welding. Major costs in adhesive assembly include consumable adhesives, labor, applicators, and fixturing to hold parts during adhesive application and setup/bonding time.

Mechanical joining methods include snap and press-fit joints, screws, and rivets. Mechanical joining is ideal for products such as appliances that are subject to disassembly for repair or replacement (bulbs, batteries, switches, or moving parts), for low-volume or initial-run products, or when capital equipment costs for assembly exceed the labor, fastener, and tool costs for the expected production volume.

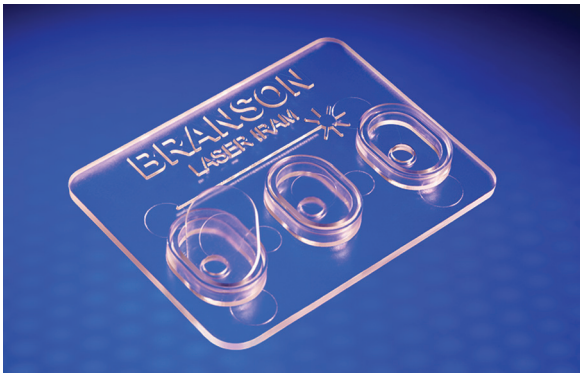
When choosing or re-evaluating a product assembly method, it's critical to consider the materials or volume production mix to ensure reliability. However, other factors, such as costs and production time, may also affect the fastening method selected.

Plastic welding is ideal when plastic parts materials are compatible with each other and the process, production volumes are high, and applications demand permanent bonding, hermetic sealing, and high consistency.

Technically, plastic welding refers to a range of joining technologies, including:

- Ultrasonic welding
- Vibration welding
- Laser welding
- Infrared welding

Ultrasonic welding systems deliver high-frequency mechanical vibration (typically 20, 30, or 40 kHz) and downforce to gently join relatively small plastic parts. The vibration generates friction and heat at the part interface, melting the plastic, which is then permanently bonded under actuator pressure. The key benefits of ultrasonic assembly are speed (most weld cycles > 1 second), zero consumables, no part setup times, low capital equipment cost, and easy integration with automated production processes.



Simultaneous Through-Transmission Infrared and laser absorber enables laser welding of clear-on-clear applications.

courtesy of Emerson

Vibration welding is used to bond larger and more robust plastic parts. This process holds one part in place, then vibrates the other against it while under pressure, using a reciprocating linear motion. Friction melts the adjoining surfaces while downward pressure bonds them. Vibration welding uses lower frequencies (typically 100 to 240 Hz) but higher amplitudes, than ultrasonic welding.

Laser welding is a gentle, clean, and precise joining process that can weld complex geometries and materials. Part interfaces are heated by an infrared laser-light source, then compressed together to form a bond. Weld alignment and part-to-part sealing are precise because there's no movement between the parts. Because welds are clean, with zero particulate or flash, laser welding is an excellent choice for assembling high-purity products such as medical devices.

Infrared welding places contoured, metal-foil emitters between the mating surfaces of large parts. After heating the surfaces, emitters are removed and the surfaces are compressed, bonded, and briefly cooled to produce a strong, airtight, and flash-free welds.

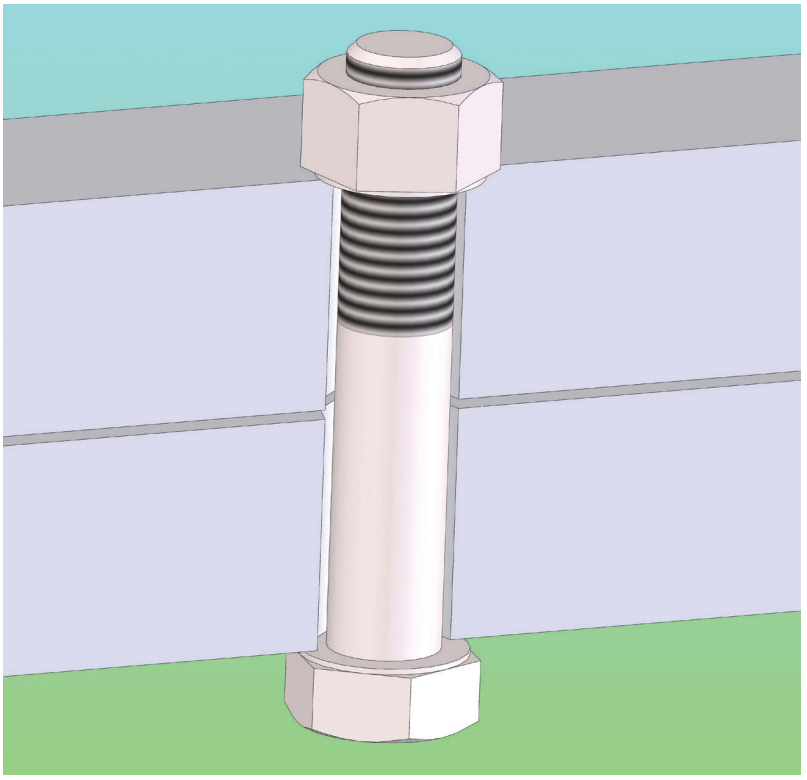
Infrared welding can be used on parts that are too large for laser welding and too complicated for vibratory welding methods. Infrared is quite versatile and capable of joining a wide array of plastics, including high-temperature thermoplastics and semi-crystalline resins such as polyethylene and polypropylene.

When product assembly demands a plastic joining solution, consider the application requirements, part sizes and material compatibilities, anticipated product volume and speed of production (high versus low), the need for disassembly versus permanence, and the cost of labor and consumables versus capital investment. FE

Written by Matt Jones, Sales Engineer for Assembly Technologies at Emerson

emerson.com/en-us/automation-solutions

How do bolts differ from screws?



A nut and bolt clamping two parts together.

A bolt is a mechanical fastener with a threaded shaft. These components are closely related to screws, which are also mechanical fasteners with threaded shafts. Whether a fastener is labeled as a bolt or screw, however, typically depends on how it is used.

Generally, a bolt is inserted through parts that each have unthreaded holes. A nut is then screwed onto the bolt, providing a clamping force and preventing axial movement. A screw, on the other hand, may first pass through a clearance hole but then it threads directly into the parts being fastened, requiring no nut. A screw may cut its threads or mate with a threaded part.

In practice, a bolt is used for a fastener that has only part of its shaft threaded. Fasteners with their entire shaft threaded are generally called screws. The unthreaded part of a bolt shaft is referred to as the shank. The shaft of the bolt prevents the radial movement of the parts, while the head of the bolt and the nut (if fitted) prevents axial movement. The unthreaded shank

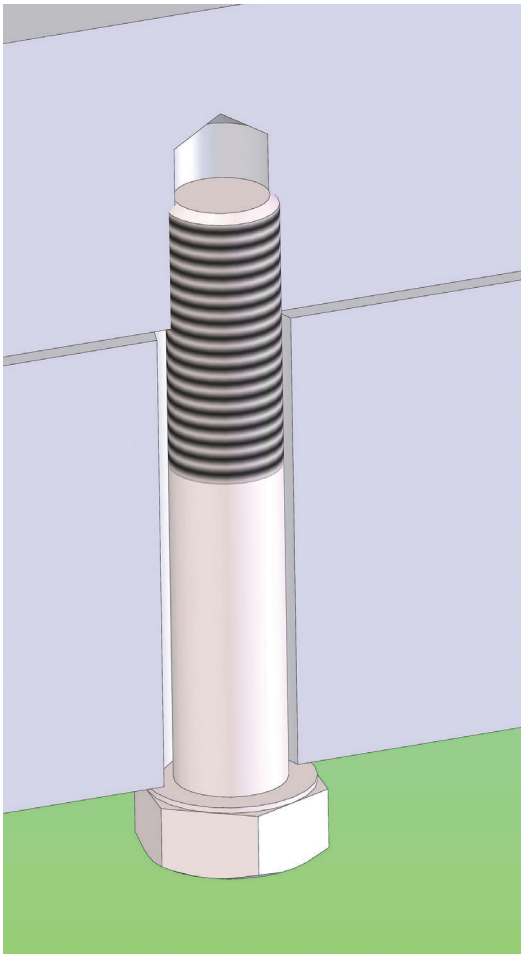
provides an interface with the parts that are typically precise and non-abrasive.

The shank is designed without stress concentrations that could lead to failure. But this means that it's important for the shank to extend past the interface between parts to withstand any significant shear force placed on the bolt. To remain in place, bolts rely on an axial force that causes sufficient friction at the threads. A torque is applied to the head to generate this axial force. The force acts between the bolt head and the object it's screwed into, whether that's a nut or one of the parts being fastened. This results in elongation of the bolt and compression of the parts containing clearance holes. Alternatively, some form of locking nut or threadlocking adhesive may be used to prevent the bolt from loosening.

Bolts are graded according to their strength, using two numbers separated by a point. This grade is usually stamped on the head. The point is not a decimal but serves as a separator.

The first number is the ultimate tensile strength (UTS) in MPa divided by 100. The second number is the ratio of yield strength to the UTS. Common classes are 5.8, 8.8, and 10.9. For example, a grade 8.8 bolt has a UTS of 800 MPa — the load at which it would fail — and will yield at 80% of this value (640 MPa).

The most common type of bolt is a hex bolt. This has a hexagonally shaped head and provides flat surfaces for tools to apply torque when fastening. A simpler to manufacture square head was routinely used for older bolts and this is sometimes still used today — particularly for applications where very high torque must be applied using a spanner.

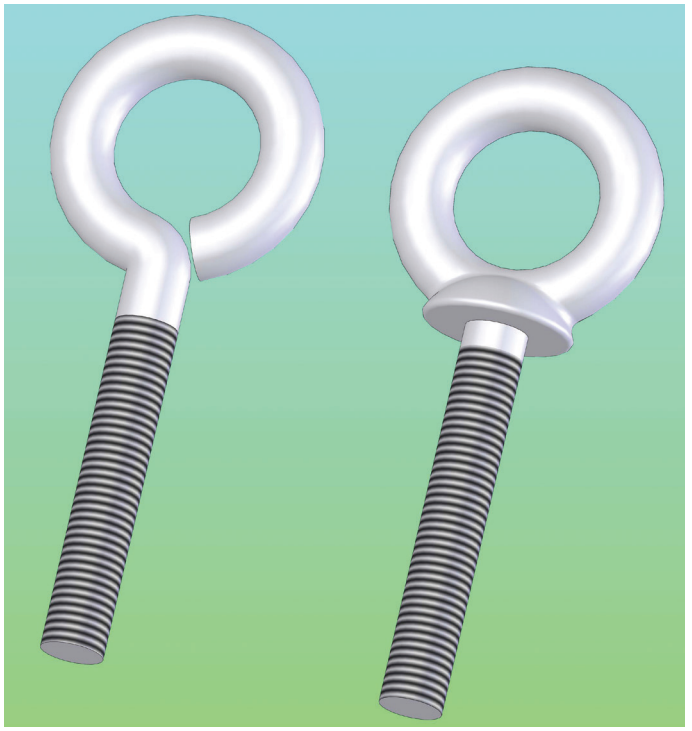


A bolt fastening a part to another part with a threaded hole. Technically, in this application, the bolt is used as a screw.

There are several types of bolts available, depending on the application. Here are a few examples:

- **Carriage bolt:** The head is rounded with a square section of shank immediately beneath it, which locks into the part. This allows a nut to be tightened without holding the bolt.
- **Shoulder bolt:** The shank has a significantly larger diameter right beneath the head and then "steps down" to the threaded diameter.
- **J-bolt:** The head is replaced by a hook formed from the shank.
- **Sex bolt:** A type of elongated nut with an elongated body that's designed to fit inside the hole of a part, acting as the shank of a bolt. FE

What are eyebolts?



Two common types of eyebolts, but the one on the left is a low-strength eyebolt that's been formed from a length of bar. The one on the right is a high-strength forged eyebolt with a shoulder that can support off-axis loads.

An eyebolt is a mechanical fastener with a threaded shaft and head that forms a ring. Eyebolts are used to attach an eye to a structure, through which rope, cable, or shackles are secured. One common use is for vertical lifting devices. For example, a lifting eye lets a crane securely attach machinery within a safe working load. Rated eyebolts are certified to ensure performance and mechanical compliance with governing standards, ensuring product quality and stated lifting capacities.

Low-strength eyebolts are typically formed from a length of bar with the diameter of the nominal thread size. The head is simply bent into a ring from an unthreaded section of the bar. These types of eyebolts can carry axial loads reasonably well but should avoid off-axis loads. This is because the opening (where the end of the bar is closed to complete the ring) is a potential point of weakness or failure, even if welded together.

High-strength eyebolts are a better choice for off-axis loads because these fasteners have forged heads that usually include a substantial shoulder. This shoulder is what enables these eyebolts to support significant off-axis loads. This is particularly helpful when lifting slings with multiple legs are used to attach to multiple lifting eyes.

Typically, an eyebolt is screwed directly into a tapped hole of the structure when used for lifting machinery. In such cases, it's important that the eyebolt is fully threaded all the way up to the shoulder. If an eyebolt is to be inserted through a hole and fastened by a nut on the other side, a shank is ideal. A shank is an unthreaded section of the shaft, below the shoulder, which provides a better transfer of load into the surface of the hole, meaning it is less likely to crack under a fatigue loading.

Special types of eyebolts include:

- **Anchor eyebolts.** These eyebolts include a type of anchor bolt that enables fastening into masonry structures.

- **Eye nut.** A nut that serves the same purpose as an eyebolt. However, they are sometimes identified as eyebolts in catalogs.

- **Pigtail eyebolts.** These are formed from a length of bar, similar to ordinary low-strength eyebolts, but the head is bent into a helix so that it fails to fully close on itself. However, it can continue past 360 degrees. This allows the middle of a rope to be threaded into the eye without requiring access to an end.

- **Ring bolt.** An eyebolt with a captive ring that passes through the eye of the head, effectively forming two chain links. This can reduce bending forces on an eyebolt.

- **Roller eyebolt.** This type of eyebolt is designed to guide a rope or cable so that it can pass smoothly and with minimal friction. The head is an assembly with four rollers, retaining the rope that passes through it.

- **Screw eyes (or eye screws)**. Similar to an eyebolt, but with a wood screw in place of a machine screw. They are used for attaching an eye to wood or plastic structures. Small screw eyes are used to hang picture frames and curtain wire. **FE**

What functions do handles provide?

A selection of handles (from left to right): A fixed door handle, a door handle that operates a latch, a crank handle designed to tighten a screw, and a hand wheel designed to operate a lead screw.

There are many types of handles, but they are all designed to transmit a force between a person's hand and an object. Handles are installed on many types of tools, packages, furniture, and machinery — typically to help open, close, tighten, hold, or safely use an object. Buildings and vehicles may also be fitted with safety handles that a person can hold onto to prevent falling.

An adequately designed handle should be:

- Sufficiently sized for users and its required purpose
- Strong enough to support a user's grip
- Able to support sufficient friction to reliably transfer a force
- Ergonomic and comfortable to use
- Safe

Machinery

Several types of handles are used in machinery. Examples include:

- Moving slideways and lead screws
- Tightening clamps
- Opening of covers and guards
- Operating electrical switches

Some standard types of handles used for building machinery include:

Clamping levers: These levers are essentially a machine screw with an attached spanner. A threaded bar with a serrated head is attached to the handle, which can then engage with the serrated head. Sliding the handle axially lets the serrated head engage and disengage to tighten a screw within confined spaces.

Crank handles: These handles have a detachable part that temporarily fits into a shaft to enable actuation or the tightening of a screw. They typically have a square hole that allows high torque for transferring into a shaft.

Hand wheels: These provide a means for continuously rotating a shaft by hand. They are often used to actuate lead screws, such as on lathes and milling machines.

Knobs: Rounded handles that are used for holding firmly onto a piece of machinery. They may be spherical or T-shaped. (Elongated bars are typically referred to as "handles," whereas spherical-shaped handles are called "knobs.")

Lever arms: A simple bar with a rounded handle at one end and a screw thread for installation at the other end.

Ratchet handles: These are similar to clamping levers but use a ratchet to make tightening easier.

Building fixtures and furniture

Building fixtures (such as doors and windows) and furniture (such as cabinets and draws) use handles. Some handles are fixed and are used to pull such items open or push them closed. Other handles move, actuating a latch to lock a door or window in the closed position.

Tools

A handle is an integral part of hand tools, providing the interface for users to properly hold and operate the tool. Ergonomics are critical in ensuring that tools can safely operate with comfort and precision over prolonged periods.

Some handles (for tools or other objects) may offer a sheath or coating for added friction against the user's hand. This reduces the gripping force required for safer and more comfortable use.

The handles of most tools differ from typical ones because they are frequently an integral part of a tool's structure, rather than an addition. Most handles are intended to appear as discrete parts, which are fastened to some other object.

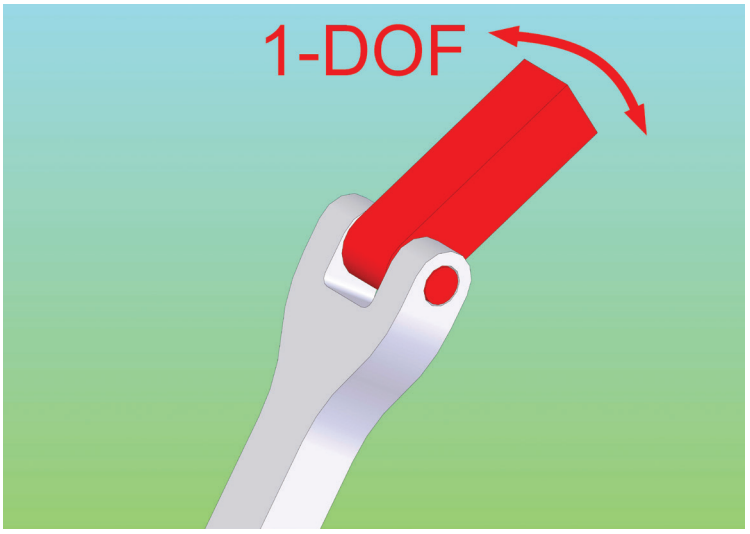
Packages and carrying handles

Packages often include handles for easy carrying. These may be integral to the structure, such as cut-outs in the sides of a cardboard box, or they may be additional parts added to the package.

Separate standard hardware carrying handles are also available, which can be fitted to cases and machinery based on a user's preference.

FE

What is a pin joint?



Pin joints can transfer axial loads but are unable to transmit torque.

A pin joint is a connection between two objects that allows relative rotation within a single axis. The joint only has one degree of freedom (1-DOF) so that all translations or rotations about any other axis are prevented. This means a pin join transfers vertical and horizontal shear loads but is unable to resist bending or rotational forces.

A type of kinematic pair, the pin joint is a somewhat idealized description of the motion constraints within a machine that allows motion analysis. In kinematics, it is formally labeled a revolute joint. Though, occasionally, the pin joint is referred to as a pivot point when analyzing motion in two dimensions, or as a hinge.

There are many ways pin joints are constructed, such as hinges and roller bearings. Three surface contacts are typically involved in constraining motion. A cylindrical surface contact constrains four degrees of freedom (including translation in the two radial directions and rotations about the allowed axis). Additionally, two planar surface contacts are typically required to constrain the single degree of freedom of axial translation — with each surface contact resisting surface penetration but not separation.

Kinematic pairs are classified as either a higher pair or a lower pair. Higher pairs relate to point or line contact. Examples include a ball or cylinder rolling over a surface. So, machines may have many higher pairs such as all the ball bearing contacts within roller bearings. Lower pairs generally refer to surface contact.

However, analyzing a complete machine at the level of all of these kinematic pairs would be extremely challenging. Typically, higher pairs are only considered when designing or analyzing the individual machine elements, such as the bearings and gears. When considering the machine as a whole, these elements are modeled as lower pairs — meaning, for example, that a roller bearing would be treated like a pin joint.

Other types of lower pair are:

- **Prismatic joint (1-DOF):** A joint that only allows linear motion along a single axis.
- **Revolute joint (1-DOF):** A joint that only offers rotational motion about a single axis (a pin joint).
- **Cylindrical joint (2-DOF):** A combination of a prismatic and a revolute joint. This joint only provides linear motion along an axis and rotation about that axis.
- **Spherical joint (3-DOF):** A joint that ensures two bodies remain connected at a common point, preventing any linear translation. However, rotation about an axis can occur. A ball and socket joint is an example of a spherical joint.

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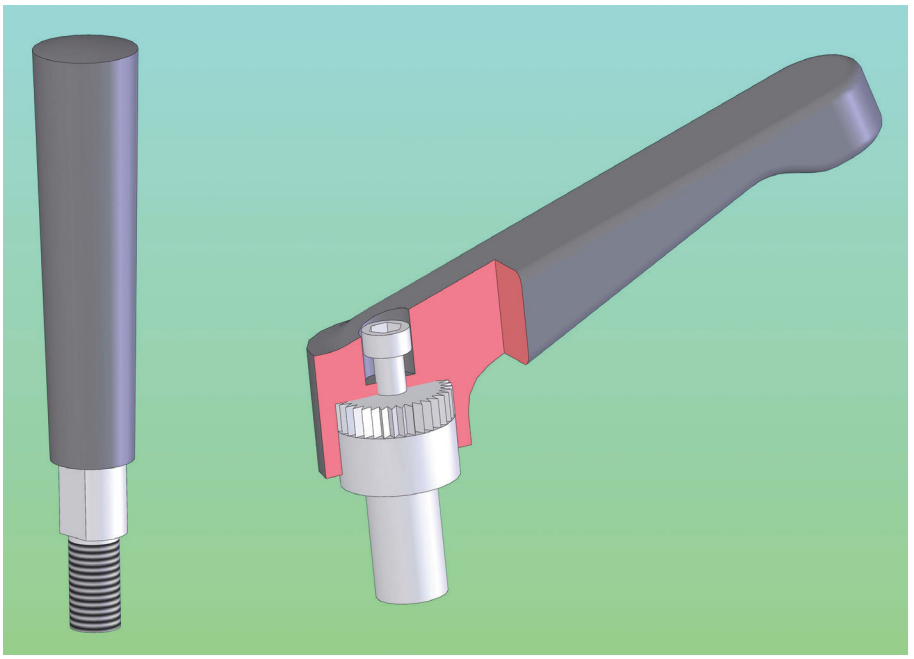
What are adjustable levers?



Levers are used on machines to turn screws and clamps for position adjustments or clamping. Two types of standard levers available for machine building: a lever arm (left) and a clamping handle (right).

Levers serve as an extended handle, typically with a threaded shaft or hole at one end to enable secure fastening to a machine. They are used to increase mechanical advantage, which is an advantage gained by the use of a mechanism in transmitting force. Generally, levers allow for hand operation to exert considerable force, often in conjunction with a screw that multiplies that advantage.

Typically, levers are ideal for applications that require more torque than provided by a basic knob or standard handle. These clamping components are also user-friendly and useful in tight spaces.

In classical mechanics, a lever is a beam that pivots about a fulcrum (typically, a bar that's supported at one end) to apply a load through the use of effort. The fulcrum, load, and effort must all act at different points along the length of the beam for it to function as a lever. If the load is applied closer to the fulcrum than the effort, the lever offers a mechanical advantage — or, more simply, it provides leverage.

However, usually the closely spaced forces — made up of the fulcrum and load — are not considered part of the lever. Typically, only the long beam extending from the couple is considered the lever. For example, if the jaws of a spanner exert a couple of forces on the head of a bolt, it is the handle (that extends from the jaws) that's referred to as the lever.

Some levers are available as standard components for machine building and include:

- **Lever arm:** A straight bar with a threaded shaft or hole at one end and a rounded handle at the other — all arranged along a single axis.

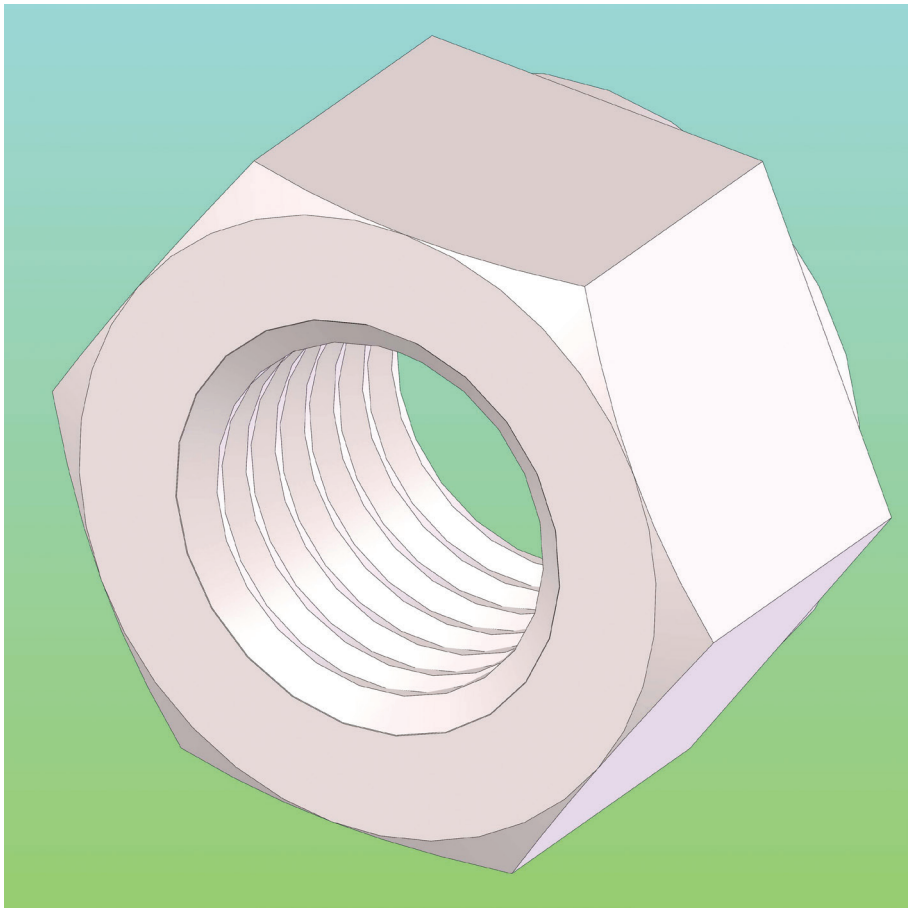
- **Clamping lever:** A small assembly consisting of a machine screw with a captive handle that fits over its head and protrudes perpendicular to the screw. This effectively acts as a screw with a permanently attached spanner. Typically, the head of the screw has a serrated section, a plane shaft, and a tapped hole in the top.

  The tapped hole is used to fit a smaller retaining screw to keep the handle in place. The handle can slide axially along the head, either engaging with the serrations to tighten the screw or moving freely around the plain shaft. This allows the screw to be tightened within a confined space.

- **Ratchet handles:** Similar to clamping levers but with a ratchet mechanism. This allows tightening, by backward and forward motion, to occur without manually sliding the handle up and down the head of the screw.

- **Crank handles:** Similar to the handle part of a clamping lever but without the screw. They usually have a square hole that allows them to fit easily with machined screw heads made for specific machines, or standard clamping screws that offer high torque. FE

What is a nut?



A nut is a mechanical fastener with a threaded hole.

A nut is a mechanical fastener with a threaded hole. It's typically used in conjunction with a mating bolt, screw, or stud to provide a clamping force and prevent axial movement. For example, a bolt is inserted through two parts, with aligned holes, and a nut is then screwed onto the bolt. The shaft of the bolt prevents the radial movement of the parts, and both the head of the bolt and nut prevent axial movement.

The most common type of nut is a hex nut. It has a hexagonal shape and the six sides provide tools enough grip for fastening or loosening. To ensure secure fastening, hex nuts typically rely on torque to generate the axial force. This axial force is needed to provide sufficient friction at the threads to prevent the nut from unscrewing. The force may act between the bolt head and nut, resulting in compression of the parts being fastened.

Alternatively, it may act between a pair of adjacent nuts, allowing parts to fasten more loosely. Unlike hex nuts, most older nuts were manufactured with

a simpler square head. Occasionally, square nuts are still used as they are ideal for certain tight or blind locations — for example, in the electronics industry where small spaces are typical). This is because they are easy to fasten with basic pliers or a wrench. The square shape can also serve as a quick gauge. It's easy to see if the nut or bolt head is at an incorrect angle and requires further tightening.

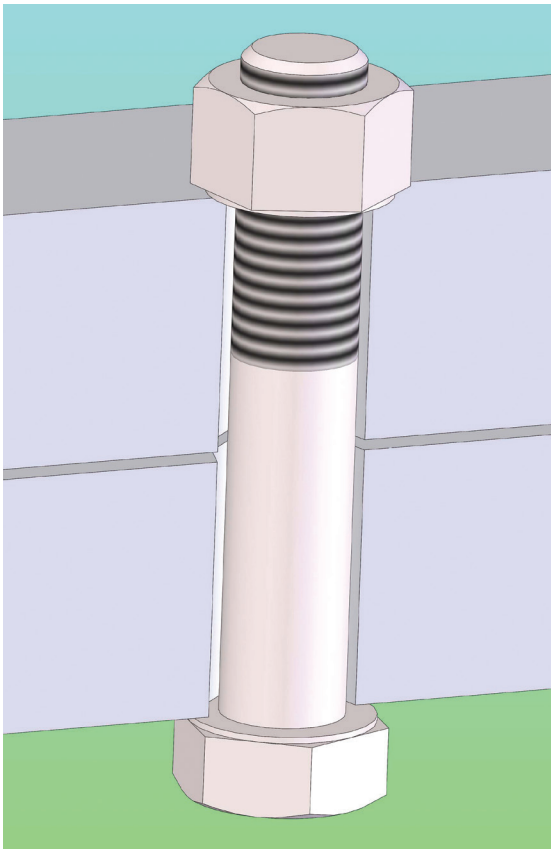
To prevent loosening and corrosion, a threadlocking adhesive can be applied to nuts and bolts. Special locking nuts may also be used that work in conjunction with devices such as pins, lockwire, and nylon inserts to prevent loosening. Locking nuts offer extra resistance from loosening when under torque or vibrations.

There are many more specialized types of nuts. Here are just a few:

- **Barrel nut:** A cylindrical shape that can be inserted into a hole that runs perpendicular to the axis of the bolt. Barrel nuts can provide self-wrenching and self-locking attachment points within thick structural joints. They're used with high-strength bolts in aerospace and sometimes in furniture assembly.

- **Cage nut:** A form of captive nut that can attach to parts, such as sheet metal, letting bolts fastened in inaccessible spaces. Cage nuts are also used in racks and other mounting applications because they have "wings" that assist with bolt insertion, essentially keeping the nut stationary in a square hole.

- **Cap nut:** The hole is only accessible from one side, with a smooth domed surface on the other side. Cap nuts prevent stripping of screws and bolts on machinery, engines, and wood frames, so they can be easily removed and reused. They are also designed to prevent injury.



A nut and bolt clamping two parts together.

- **Coupling nut:** An elongated nut that allows two threaded shafts to be joined co-axially. Also called extension nuts, coupling nuts are typically used to join two threaded rods or pipes.

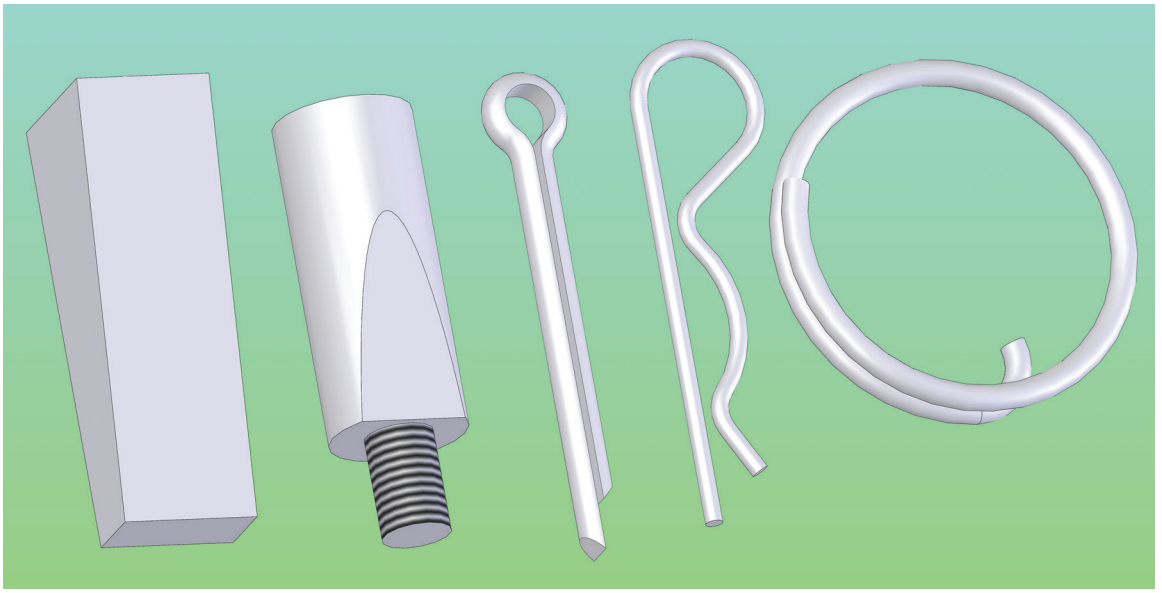
- **Flange nut:** A hex nut with an increased diameter around the base so that a washer is unnecessary.

- **J-nut:** Combines a spring steel retainer with a threaded nut, providing an ideal fastener for heavy-duty applications. J-nuts are commonly used to fasten sheet metal.

- **Swage nut:** A self-clinching nut that attaches to a sheet metal part when tightened, by swaging the material around the hole.

- **Speed nut:** A type of locking nut with two sheet metal prongs that act as one thread. Speed nuts serve the functions of a lock washer and a nut. **FE**

How are dowel and cotter pins used?



Cotter pins prevent axial movement along a shaft. From left to right: Traditional tapered cotter, a cotter with a threaded section, a split pin, and an R-clip and a split ring.

Several types of pins used as fasteners, including dowel and cotter pins. At its simplest, a dowel pin is a solid cylinder of material, which is inserted through a hole. When inserted through concentric holes in two or more components, a dowel pin can locate and hold them together. A slight interference or transitional fit is typically used, which compresses the pin and generates significant friction to hold the pin securely in place.

Steel dowel pins are used in precision engineering applications for accurate location and alignment. These dowels have chamfers at each end to enable insertion and guide alignment. This type of dowel is also available in other metals and engineering-grade polymers.

Wooden dowels are widely used within joinery, conventional timber-frame construction, and shipbuilding. They're available in "dowel rod" lengths, from which individual dowels can then be pre-cut or cut as needed. The pre-cut dowels typically have chamfers at each end for easier insertion. If a smooth, wooden dowel is driven into a tight interference-fit hole, it can form an air-tight seal and particularly if it is coated in a layer of glue.

If driving dowels into blind holes, air and glue may become trapped in the hole, creating significant pressure. This can prevent dowel insertion or split wooden parts. When cutting dowels from a smooth dowel rod, plane a flat on one side to relieve the pressure.

Biscuit or mortise and tenon joints may be used as an alternative to wooden dowels. One advantage of using dowels: drilling a simple round hole is all that's required.

As alternatives to steel, dowel pins are available as roll (slotted or spiral), grooved, and cotter pins. Cotter pins are typically used to prevent axial movement along a shaft.

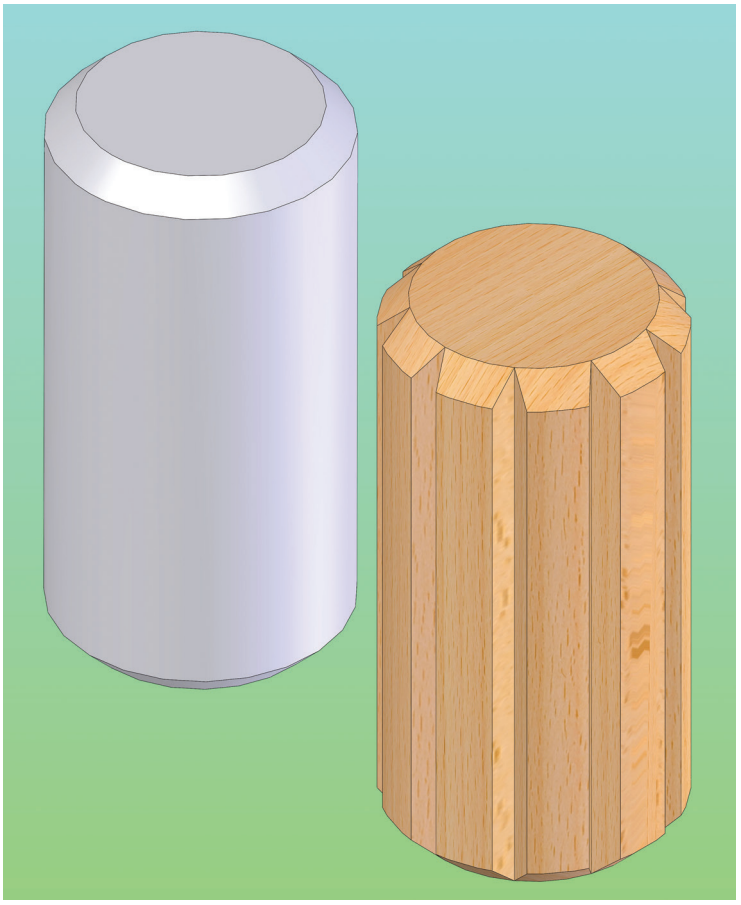
However, cotter pins can refer to several different types of fasteners:

- **Cotter:** a wedge that's driven or drawn into a hole. Historically, cotter pins have been used to attach cranks onto the shafts of bicycles and steam engines. Cotters may have a threaded shaft protruding from the narrower end of the taper, which is used to draw the cotter into the hole and hold it in position. This type of cotter has been largely replaced by splines and square shafts.

- **Split pins:** often referred to as cotter pins. This pin is bent in half so that both ends can be inserted through the same hole. Split pins are typically manufactured from a half-circular profile so that the two ends form a circle together, which then fits into the hole. The bent end is formed into an enlarged end and the double end can bend outwards to prevent the pin from unwanted removal.

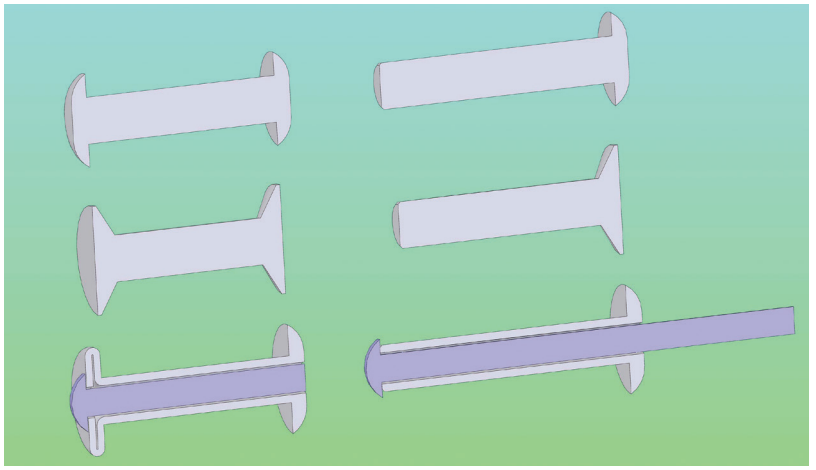
- **R-clips or R-pins:** sometimes called hairpin cotters. These are sprung pins with a straight section, which then bends to form a ring at the head and reverts back with a curved section offset from the straight pin. The straight section may be pushed through a hole in a shaft, while the curved section clips around the outside of the shaft, retaining the pin in place. A finger can be inserted through the ring at the head to pull the pin out of the hole.

- **Split ring:** also referred to as a circle cotter or cotter ring. This is a wire loop that extends past 360 degrees so it can thread through a hole. Keyrings are a common application for this type of fastener, although they may also be used to retain pins and shafts. FE



Dowel pins (left) are straight solid pins that typically have chamfered ends to aid insertion and alignment. **Wooden dowels (right)** may have flutes or flats to relieve pressure.

How do rivets work?



A selection of rivets, which are shown after installation on the left and as supplied on the right. From top to bottom: Solid rivet with universal head, solid rivet with countersunk head, and blind rivet.

A rivet is a mechanical fastener with a plane unthreaded shaft that's inserted through holes to join two or more parts together. A permanently formed head at each end prevents the rivet from removal from the hole. The shaft prevents any radial movements of the components. Depending on the type of rivet and its ability to support shear load, it can resist considerable forces. The heads prevent axial movements of the parts, although less force is supported in this way.

The function of a rivet is similar to that of a nut and bolt. However, while nuts can readily unscrew for disassembly and reassembly, typically rivets are broken or damaged before removal. They are, therefore, designed for permanent or semi-permanent joints, fulfilling the same role as structural adhesives or welding. The benefits of using rivets include the ability to resist vibration and secure joints with short clamp lengths.

A rivet has a pre-formed head at one head, called the factory head. Another head is formed after insertion and it's referred to as the shop head. The factory head is similar to the head at one end of a bolt while the shop head is like a nut, which forms a temporary head at the other end of a bolt.

The end of a rivet's shaft, which is formed into the shop head is called the tail. The process for forming the tail into a head is known as upsetting or bucking, which means it is deformed. By doing so, the tail expands, allowing it to securely hold the rivet in place. The two heads on each end of an installed rivet let it support tension loads (two forces pulling on opposite directions) and shear loads (the force is parallel to the surface or axis of the shaft).

Solid rivets

Solid rivets are one of the oldest and most commonly used types of fasteners. They are highly safe and reliable fasteners, with proven effectiveness in critical applications.

For these reasons, they are widely used in the construction of aircraft. In such cases, a form of hammer and anvil are required to form the factory head of a solid rivet. Both sides of the hole also require access for installation, so that the anvil is against one end of the rivet and the hammer strikes the other end.

Hand hammers are rarely used for this process. Instead, modern manual riveting operations use hand-held air hammers. Automated drilling and riveting machines are also typical in aerospace manufacturing.

Blind rivets

Blind rivets are hollow with a mandrel on a stem that runs through a central hole. By drawing the mandrel back through the rivet's body, the factory head can be formed from the opposite side. This means it's possible to install them from one side — or into a blind hole.

However, special-purpose riveting tools are required to install blind rivets. Manual tools are divided into plier-type riveters, which tend to be less costly and more compact, and lazy tong rivet tools. FE

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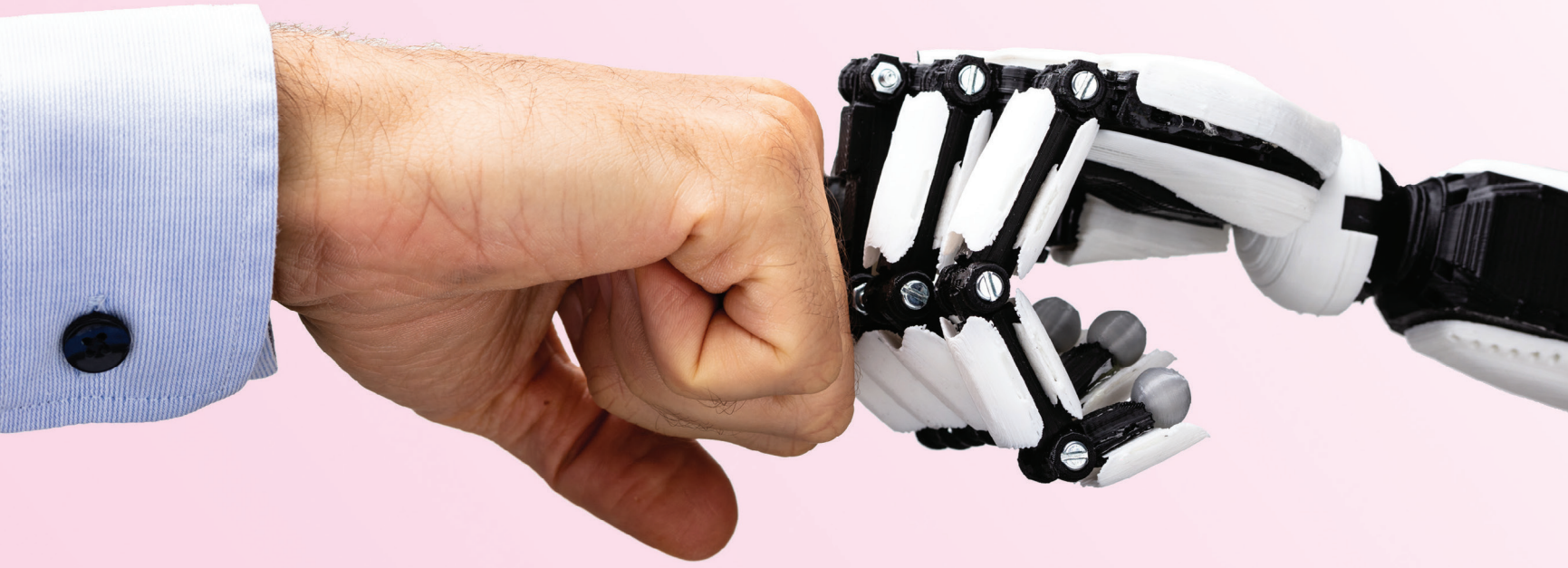

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What are security screws?

The main use of security fasteners is to stop theft and vandalism.

Security or tamper-proof screws are, for the most part, standard screws — but with one unique feature. They are inordinately difficult to remove with the typical tools, such as screwdrivers or extractors. Such a secure design helps reduce the risk of vandalism or disassembly in several applications.

For example, security screws are useful to retain high-cost, portable equipment such as electronics. These components may also be used in industrial infrastructure, at medical and correctional facilities, in the aerospace and automotive industries, and at financial institutions, government sites, and others. Even hotels might use security screws to deter guests from tampering with furnishings or fixtures and classic auto collectors commonly use them to attach license plates to valuable cars.

It's easy to identify security screws by their unique drive style. Rather than a traditional screw head that might engage a flat or Phillips screwdriver or bit, security screws have unconventional drives that correspond with specialized fastening tools.

Some examples include:

- Screws that feature a six-lobe or star drive with a central pin
- Spanner or snake eye security screws that have two drive holes
- Custom keyed screws that are designed to fit one (and only one) proprietary driver bit that's supplied by the manufacturer

The customized screws are typically protected with additional backstops, such as serial numbers or a level of security clearance when ordering.

Another option for tamper-proof screws is one-way or irreversible screws. These can be fastened with a conventional screwdriver but cannot be removed the same way. Curves on the screw head allow the screwdriver to "grip" in the driving direction, but not in the removing direction.

However, security screws are rarely 100 percent tamper-proof (although some come close). The majority of security screws are only considered "tamper-resistant." Although the average individual might not own Torx or spanner bits to remove these components, the bits are fairly easy to obtain. Locking pliers, vice grips, and bolt extractor tools can also sometimes be used to remove or destroy security screws.

But, in general, tamper-resistant security screws impede opportunistic breaches more so than deliberate intentions. Removal can be time-consuming, which serves as a deterrent to casual theft and vandalism. Engineers are wise to take into consideration the level of security required for each application and thoroughly evaluate the different security components available to find the ideal fit.

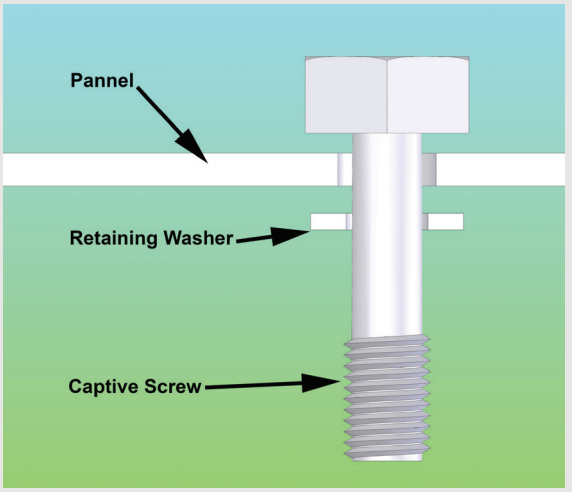
Also, pay close attention to component branding. Typically, tamper-resistant screws are relatively difficult to remove, whereas tamper-proof screws are nearly impossible to remove without the right tool.

Additionally, security nuts are available, which feature a tapered diameter, making these components resistant to most gripping devices. They are typically labeled as tri-groove, T-groove, trident drive, or cone trident drive nuts.

When selecting security screws, designers must also evaluate the long-term product or project needs. Some applications might require the option for assemblers to later remove the security screws with the corresponding drive. In such cases, labor costs should be weighed against the risks and need for tamper-resistance. Overall, consider the security level and strength level required for the application, whether the screw must be removed in the future, and the final appearance of the fastener and product. FE

How do captive screws work?

Captive screws are fasteners designed to remain attached to guards or equipment. A conventional screw typically passes through a clearance hole in one part and then screws into a threaded hole in a second part — so the first part is clamped to the second. However, when the fastener is unscrewed from the threaded hole in the second component, it can easily separate from the first one.



Captive screws have the typical thread but then a reduced diameter for the remaining screw length.

A captive screw is designed to prevent this from occurring. It can freely rotate within the first component, with some axial movement, but it's unable to separate from it. Captive screws are used when fasteners must remain attached to equipment, such as in cover panels. They are a requirement for several machinery safety standards.

Captive screws have a normal thread and a reduced diameter for the rest of the screw length. A captive screw is usually used with a retaining washer or a retaining flange. These have a hole with a short-threaded length. The threaded portion of the captive screw is screwed through this hole until the reduced diameter can pass freely through it. The washer or flange is then captive on the screw.

To install a captive screw on a panel using a retaining washer, the screw is first passed through a hole in the panel. The washer is then screwed onto the captive screw, until the reduced diameter section is reached, retaining the screw on the panel.

Other forms of captive screw are also available that have pre-fitted caps in place of a retaining washer or flange. These caps can be pressed, bonded, or screwed into the panel or equipment to which the screw is to be retained.

How are sockets used?

A socket attaches to a turning tool to tighten or loosen fasteners, such as a nut or bolt. Sockets are typically sold in sets with a drive tool.

Sockets are tools used to tighten mechanical fasteners. They fit over the head of the fastener to provide torque. Typically, sockets have a hexagonal hole at one end that's designed to fit over a hex-head bolt or screw. On the other end of the socket is a square hole that fits over the square drive of a socket wrench.

However, the term socket also refers to a hole designed to accept some other part. For example, a mechanical fastener may include a socket in its head that accepts a male tool.

Tool sockets

A socket is a cylindrical tool with a different shaped socket at each end. At one end there's a prismatic hole that fits over the head of a fastener. This hole is most commonly hexagonal to fit the head of a hex-head bolt or hexagonal nut. However, several types of sockets are available to fit a variety of fasteners.

On the opposite end of the socket is a square hole that engages with another tool to drive the socket. The square drive is either 1/4, 3/8, 1/2 or 3/4-in. Metric sockets still use these sizes for the drive.

Sockets are unable to generate torque alone. Rather, they provide an interface between a torque-generating tool or driver and the fastener. Examples of tools used to drive sockets are wrenches (including socket, pneumatic impact, and hydraulic torque wrenches), as well as torque multipliers and breaker bars.

One advantage of sockets is that a single driver can be used for several different sizes and types of fasteners. This includes short, long, and narrow sockets that reach various workspaces. Standard sockets are designed to fit over fasteners with good access and offer strength to apply significant torque. These tools can also drive hex tools or male bits, which fit into socket head fasteners.

What's more is that sockets are typically less costly and require less space than spanners. Also, if necessary, an extension bar can be used to access hard-to-reach fasteners, which is not an option with spanners.

Socket sets are ideal because they offer a large selection of sockets and male bits with drive tools in one case.

Fastener sockets

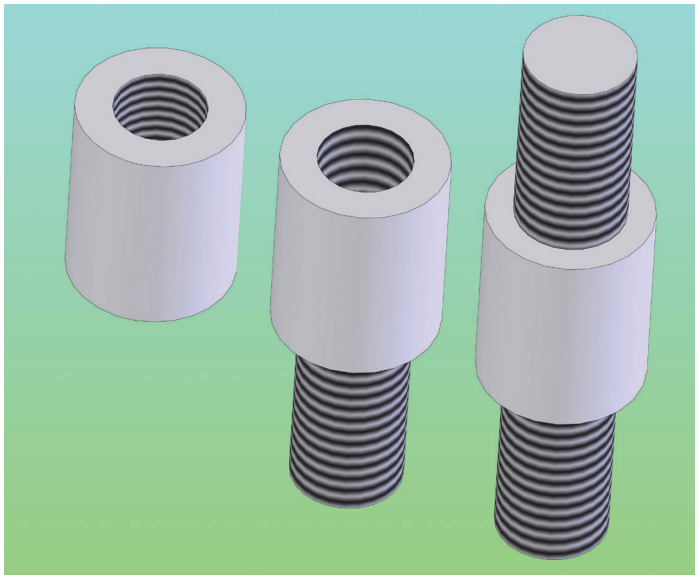
Fasteners may have sockets within their heads through which torque is applied. Socket fasteners include screws, set screws, bolts, and shoulder bolts.

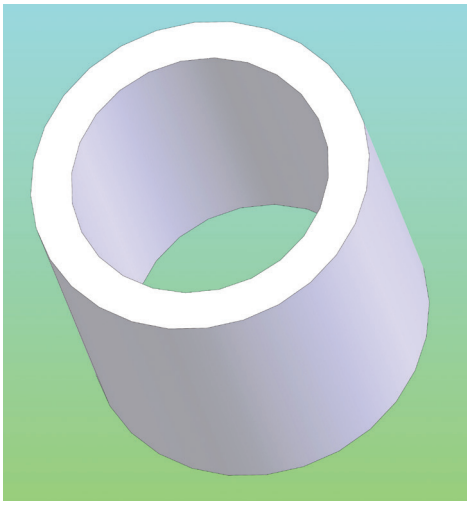
A few common socket shapes used in the heads of such fasteners include:

- **Cross, Philips, or Pozidriv.** Cross-shaped holes that taper toward a point at the bottom, these sockets are used for wood and self-tapping screws, or small countersunk machine screws.
- **Hexagon socket.** A prismatic hexagonal hole that's mostly used in machine screws, such as socket head cap screws.
- **Slot or flat head.** A rectangular slot that runs the length of the head and is typically found on wood screws
- **Socket bits.** A combination of a screwdriver bit and a hex socket that can be made of one solid piece of metal or two separate parts that are fixed together.
- **Torx.** A six-pointed star that's typically used in machine screws for the automotive and consumer goods industries. FE

One advantage of sockets is that a single driver can be used for several different sizes and types of fasteners. This includes short, long, and narrow sockets that reach various workspaces.

How do spacers differ from standoffs?





As shown above, a spacer is typically a simple length of tubing that increases the distance between parts, allowing a bolt to pass through the center. A standoff is a double-ended threaded fastener that's used to set a distance between two parts. Typical standoffs examples are shown in the image to the left (and from left to right): female/female, male/female, and male/male.

A spacer is used to properly align or increase the distance between two fastened parts. Typically, spacers are a length of tube through which a fastener is inserted. A short spacer may, therefore, resemble a thick washer. Or, occasionally, washers are used as spacers.

Spacers are similar to standoffs, but standoffs include a threaded shaft (male) or hole (female), enabling them to be fitted without an additional fastener. This means standoffs may be designated as male/male, male/female, or female/female. However, these distinctions between spacers and standoffs are rarely strictly applied so it is possible to find threaded standoffs referred to as spacers in many catalogs.

Both spacers and standoffs are commonly used in electronic assemblies, such as printed circuit boards (PCB). They're used to provide space for cooling airflow and electrical insulation. For example, insulating standoffs may be installed to keep two parts from touching each other, thereby preventing electrical shorts. Spacers may also be used between electronics (such as a computer case and its circuit board) to ensure airflow and provide some protection. They're often referred to as PCB Spacers. Common materials for such spacers are brass, stainless steel, nylon polyoxymethylene (POM), polyvinyl chloride (PVC), and ceramics.

The majority of spacers have a clearance hole through which a bolt is inserted. This means the spacer is unable to engage with the threads of the bolt and, since it's impossible to directly tighten the spacer, a round outer profile is most common.

However, there are spacers with a hexagonal profile, which is combined with a plain hole. These are typically constructed from a relatively soft material, such as nylon or brass. They can be used in the same way as a conventional spacer but offer added flexibility because they can be threaded onto a stud or self-tapping screw. This is done by using the external flats of their hexagonal profile to apply torque. As a result, this type of spacer can essentially be turned into a female/female standoff.

Spacers are also frequently used in furniture or when hanging art. For example, spacers may sit between a glass tabletop and its legs (to protect the glass from scratching). Picture frame spacers are small pieces of plastic that sit between the glazing and the art.

Snap-in spacers are also available, which have a sprung push-fit fastener at one end and a threaded hole at the other end. They're designed for easy attachment and removal but are technically a type of standoff. **FE**

What are extension springs?

Extension springs are coiled springs that are designed to resist a force.

Extension springs, also known as tension springs, are springs that can stretch and increase in length. However, when extended, these springs are under tension. Typically, each end of the extension spring is attached to a different component and, when the components are pulled apart, the spring pulls them back together.

Similar to compression springs — which are the most commonly used spring — most extension springs are coiled springs manufactured from sprung steel spring wire. In fact, both of these springs exhibit elasticity and strength, but that's where their likeness ends. Extension springs are designed to hold two things together, while compression springs keep components from coming together.

For this reason, extension springs are wound quite tightly. They usually come with a hook or an eye at each end to facilitate fastening. Variations on the ends include open hooks, extended hooks, side hooks, and double full loops. These are typically used to create a restoring force in devices, such as latches and counterbalances. Also, because extension springs are under tension, they require no support along their length. This is a simpler mechanism than a compression spring.

Hooke's law is often used as an approximation for elastic objects. It states that the force (F) required

Extension springs are designed to hold two things together, while compression springs keep components from coming together. For this reason, extension springs are wound quite tightly. They usually come with a hook or an eye at each end to facilitate fastening.

to extend or compress a spring by some distance "x" is proportional to that distance. The rate of the force increasing depends on the stiffness of the spring "k."

This can be expressed as: F = kx.

However, since extension springs must resist initial tension (F1) before extension occurs, these springs fail to follow Hooke's Law.

A closer approximation for the force in an extension spring is: F = F1 + kx

This is because the initial tension (F1) is difficult to control and may vary significantly between springs of the same part number.

Generally, the dimensions of an extension spring are given in its relaxed state. This is specified in the outside and inside diameter, or wire diameter. The length of the body coils may be given in addition to the unloaded length inside the hooks and the maximum extended length inside the hooks.

Typically, a sprung steel spring wire is coated with zinc but stainless-steel springs are also available. Rubber bands, elastic bands, or bungee cord provide low-cost alternatives to steel extension springs in simple fastening projects. FE

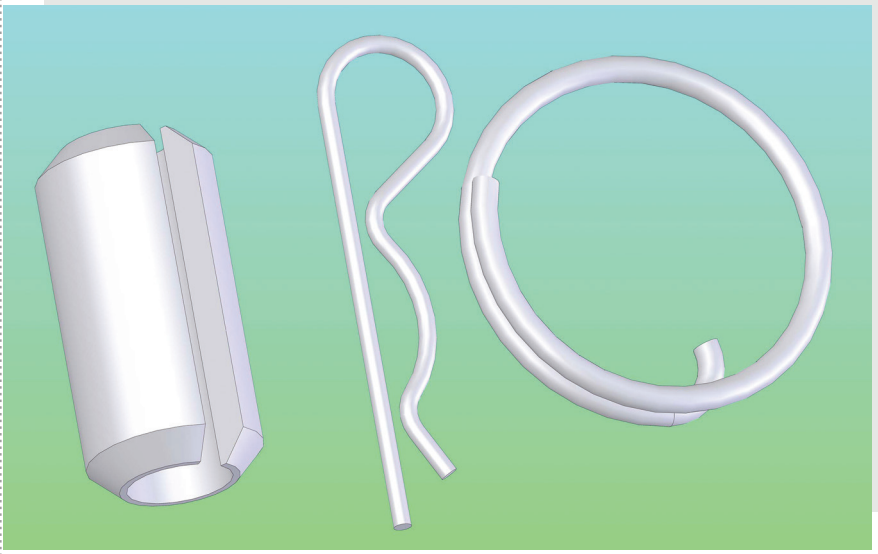
Why elastic deformation is important

Elastic deformation is a critical feature that prevents loosening in the majority of fasteners. This is particularly true of spring pins, clips, and washers. Elastic deformation occurs when a force temporarily changes the shape of an object (such as springs), but when removed, the object reverts to its original shape.

For example, when spring pins — such as roll, slotted, and even dowel pins —are driven into holes smaller than the free diameter of the pin, these pins deform elastically. This is because their diameter is reduced and a radial reaction force acts between the surface of the pin and hole. The resulting friction holds the pin securely in the hole. This is entirely dependent on the pin acting as a spring.

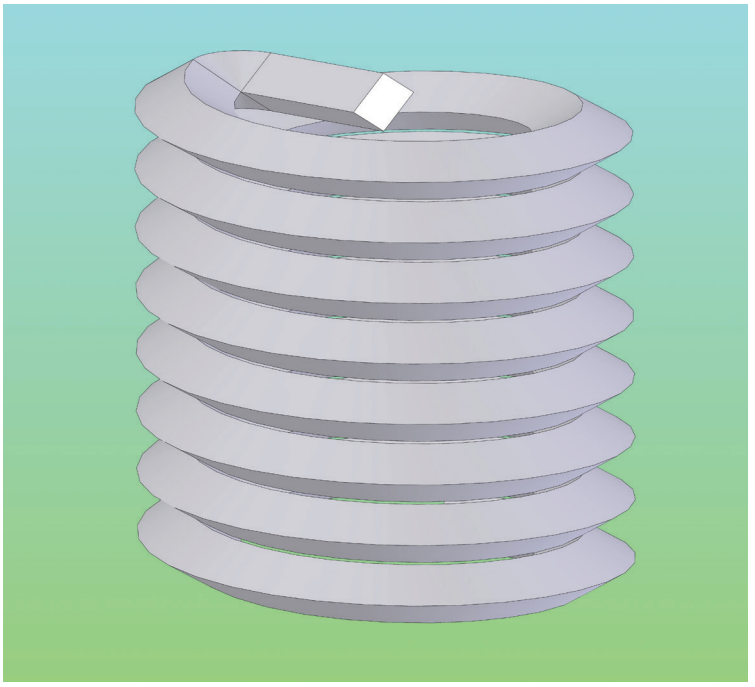
Sprung fasteners such as R-clips (a spring-like fastener resembling an "R") and circle cotters (a wire fastener shaped like a circle) offer quick, tool-less assembly while providing secure connections. They require flexibility to correctly insert into position, which is typically through a radial hole in a shaft.

When the part they secure moves or is in motion, it will act against them in a different direction but has close to zero effect on their sprung property. These types of clips resist vibrations by springing back to their original position.



Sprung fasteners act as springs to provide secure fastening. From left to right: A roll pin, an R-clip, and a circle cotter.

When are thread repair kits required?



A helical insert is screwed into a hole to replace broken threads.

Thread repair kits are used to fix threads by removing the damaged ones in a hole and replacing them with new threads of a similar size. These kits can also provide strong threads in soft materials, such as aluminum. Typically, repair kits contain a tapping tool, an insertion tool, and some type of thread inserts. A drill and a tap wrench are also required, however, not all kits include these tools.

Threads are damaged and repaired in different ways. A repair kit is only sometimes warranted. For example, if a male thread becomes damaged, such as on a bolt or screw, it can often be cleaned up by running a die over it. If threads are only lightly damaged, it may be possible to reform the threads by simply running a nut up and down. However, this method poses a risk the nut will fuse to the thread, a process known as galling. So, it's typically safer to use the die.

If threads are completely stripped out of a hole, there are a few repair options. One idea is to drill out the hole and tap it with a larger diameter thread. This is a good option if there is room for a larger fastener. However, when it's impossible to create a larger tapped hole, a thread repair kit is the ideal choice.

The helical insert, also referred to by the trade name Helicoil, is the most common type of thread insert used in repairs. A helical insert looks like a tightly wound spring and consists of a helix wound from a wire with a diamond cross-section. The helix has a small return at one end that engages with the insertion tool, letting the insert fit in the hole. A small notch in the wire means this return can be snapped off once the insert is fully installed.

The steps to repair the threads in a damaged hole — when using a helical insert — are as follows:

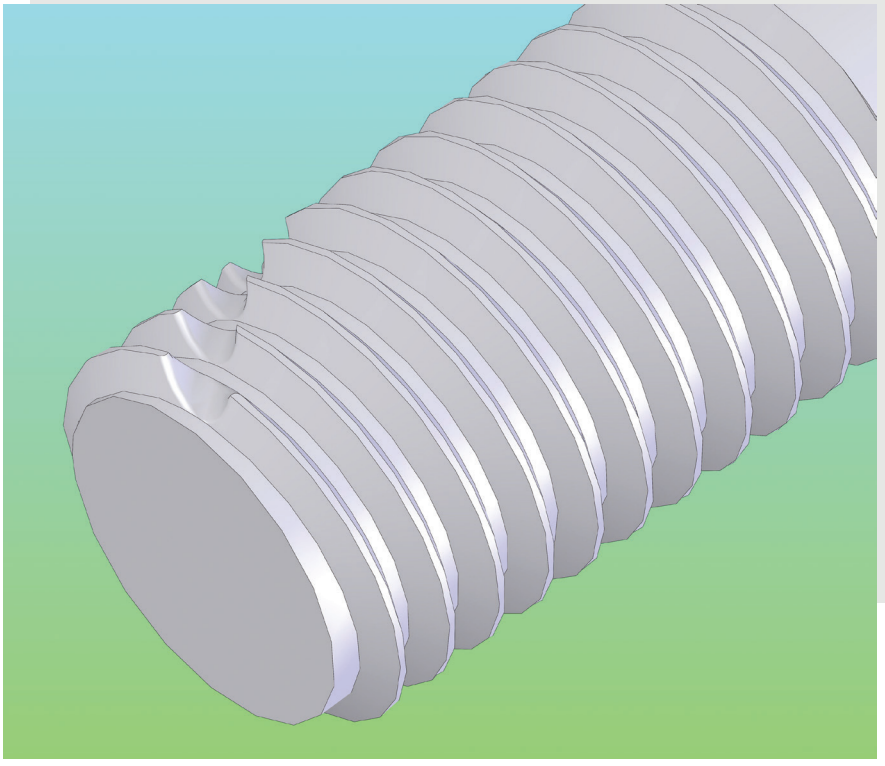
1. Drill out the damaged threads by using the correctly sized drill bit.
2. Tap the hole with a special thread to accept the threaded insert. Typically, the exact tap required is listed with the thread repair kit.
3. Screw the threaded insert into the hole, using the insertion tool, to just below the surface of the part.
4. Next, unscrew the insertion tool. The threaded insert will expand slightly as the torque is released from the insertion tool, causing it to lock.
5. Snap off the tang where the thread insert wire returns across the hole. A punch or hex tool can be inserted through the new thread to rest against the tang and then tap with a hammer to snap it off. **FE**

Why does galling occur?

Galling is a common type of damage that can occur in threads. When galling happens, it appears as though chunks of thread have been torn off. It's caused by excessive friction or adhesion between mating threads. Technically, galling is any transfer of material between metallic surfaces, resulting from friction when they slide past each other.

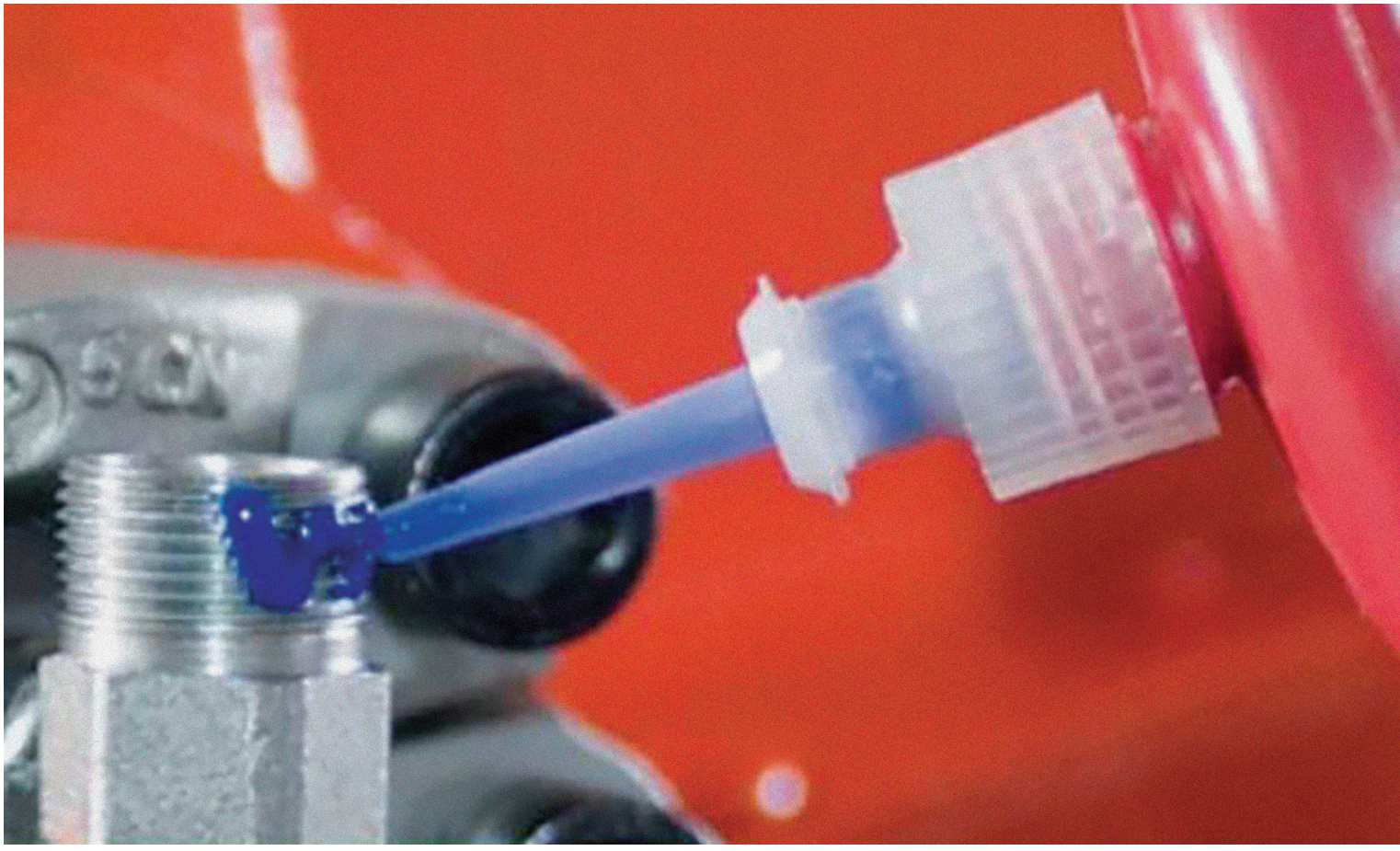
Microscopic galling occurs continuously in sliding contacts. During normal use, however, thread damage is only called galling when it results in visible damage and affects the function of the thread. This is rarely a gradual process and only occurs when a seized or over-tightened thread is unscrewed. As the seized thread breaks free, part of the thread shears off and remains attached to the mating surface.

The resulting lump increases the local friction and, typically, causes further damage as the thread continues to be unscrewed. If the galling is severe enough, it may lockup the thread and break the fastener. It's possible to avoid galling through correct maintenance, such as lubricating threads.

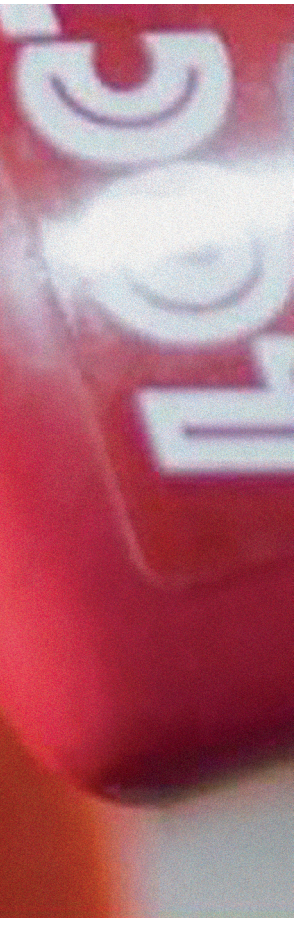


Galling occurs when threads are damaged by material sticking or tearing off.

Why is threadlocker used on fasteners?



Threadlocker is an adhesive used to prevent the loosening of threaded fasteners.



Threadlocker, also known as thread-locking fluid, is an adhesive used to prevent threaded fasteners from loosening. It may also be used to seal threads and prevent corrosion.

Typically referred to as its original brand name Loctite, threadlocker is supplied as a thin fluid in a bottle. The adhesive easily drips onto the threads of fasteners (such as bolts and screws) from a nozzle-top bottle. The fastener can then be tightened into place. The liquid will cure to form a layer of thermoset plastic between the male and female fastener threads.

A color-coded label typically indicates the different strengths of threadlocker available.

For example:

- **Low-strength** threadlocker prevents fasteners from working loose under vibration while providing fairly simple disassembly and reassembly. Loctite's "Purple" is suitable for use on low-strength materials, such as aluminum and brass. It also works on smaller, more delicate fasteners, such as electronic devices.

- **Medium-strength** threadlocker requires a significant force to break the lock — such as by using a mallet on a spanner. Loctite's "Blue" is medium-strength. It fully cures in 24 hours and can be dissembled with hand tools. The brand's "Green" is a wicking threadlocker that can be applied to pre-assembled fasteners, such as electrical connectors and set screws. It provides medium to high-strength adhesion and can be removed with heat and hand tools.

- **High-strength** threadlocker would require a force that could shear off the head of the fastener. It is strong. Generally, heat is used first to soften the adhesive for simpler removal. Loctite's "Red" is high-strength, fully cures in 24 hours, and requires heat for disassembly.

Alternative methods of locking threaded fasteners include locknuts, jam nuts, lock washers, and safety wire. In critical applications, these may be used in conjunction with threadlocker. FE

How to minimize the effects of vibration on fasteners

How to ensure fasteners remain tightly sealed in applications that are prone to vibration is a question engineers frequently attempt to solve. Eventually, vibration loosens fasteners by creating relative motion between the threads. Loose fasteners are certainly a maintenance nuisance but also a hazard in several applications, including in power generation, transportation, manufacturing, and others.

Of course, adequate torque is the first step to ensuring fasteners are properly installed. The use of washers to lengthen the ratio of clamped length is another option for certain applications. The washer may add extra friction to the joint and maintain the clamping force. Threadlockers, used to seal or lock fastener assemblies together, and vibration-proof fasteners are two other alternatives.

Threadlockers Safety wire (or lockwire). These are chemical adhesives applied to a fastener, such as Loctite. However, Loctite acts like a lubricant when wet and can affect torque so it is ineffective in certain applications. It's also not made for high-temperature conditions.

Safety wiring is a locking device that prevents fasteners from loosening. The correct technique is critical for proper installation and the work can be time-consuming. Additionally, it's important to think twice before drilling holes into fasteners, which can significantly reduce their reliability over time.

Vibration-proof fasteners. Some fasteners are better designed to cope with vibration than others. For example, consider bolts and screws with pre-installed nylon patches, which typically hold up for about five cycles of removal and reuse.

There are also vibration-proof fasteners that are engineered to prevent self-loosening due to vibration. These include hex nuts with nylon inserts, jam nuts, lock nuts, slotted hex nuts, tooth lock washers, lock washers, and spring washers. Such fasteners may have a unique thread design that distributes stressed more evenly or an extra clamping system that reduces rotation.

Unfortunately, there is no failsafe solution. The efficacy of vibration-proof fasteners will depend on the application, so maintenance checks are essential.

Article courtesy of J.W. Winco | jwwinco.com

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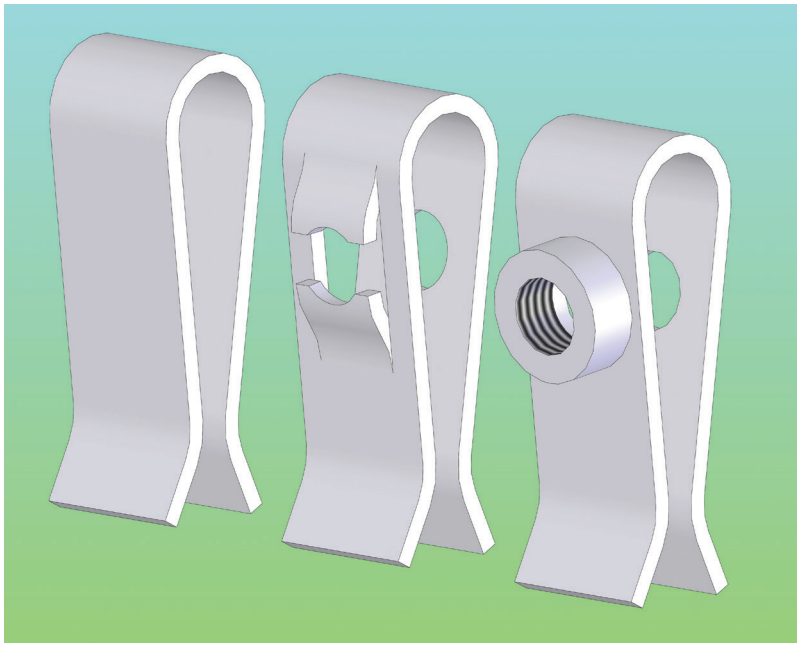
What are U-clips?



U-clips are designed to clip onto panels or sheet metal parts. From left to right: A simple U-clip, a U-clip designed to accept a self-tapping screw, and a U-nut.

U-clips are an easy-to-assemble mechanical fastener. They are typically formed from a single strip of sprung steel and bent into a "U" shape to form two legs. One or both of the legs often have turned-up lead lips, which easily push over panels or sheet components, allowing for fast assembly. The sprung legs exert a light clamping force that secures the clip into place. Some spring clips are also equipped with barbs to provide a more secure fastening connection.

U-clips can be used to clamp panels together, retain cables and insulation, or provide for a spring catch. They are typically made from zinc-plated sprung steel but are also available in stainless steel, copper, and bronze. U-clips are economical, easy-to-use, and reusable fastening devices that work without tools. This means they require zero holes, welds, screws, or rivets, allowing for a quick and simple installation.

These fasteners can, however, also be used as a form of captive nut, providing a threaded hole for the attachment of a bolt or self-tapping screw. To serve in this way, a U-clip is fitted at a slight angle to the panel, with its legs over the edge. The clip is then pushed in so it fits squarely against the edge of the panel.

Additionally, U-clips can form part of a captive or clip-on nut with a nut. This is to accept a bolt or machine screw that's then welded to the U-clip. When a U-clip incorporates a preformed thread in this way, it's referred to as a U-nut or a chimney nut. A U-nuts is known for its self-retaining property, which prevents the nut from moving when a screw is driven into place.

Many U-clips are designed without preformed thread but can still accept a self-tapping screw. In this case, one leg typically has a clearance hole while the other leg has a smaller hole or bent tabs for thread from a self-tapping screw. When U-clips are designed to accept self-tapping screws, they are also referred to as U-nuts — but, typically, these are still called U-clips. FE

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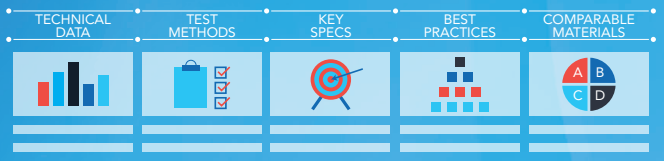

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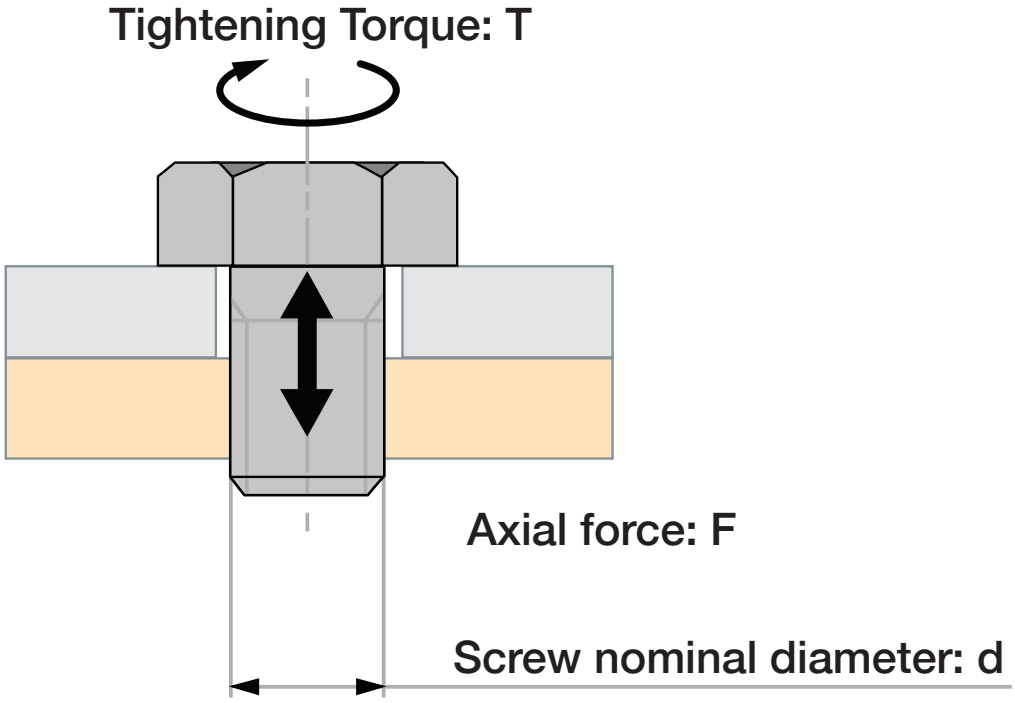
What are the key terms when working with screws?



Screws are a mechanical fastener with a threaded shaft that's designed to screw into a part. They typically rely on friction at the threads to remain securely fastened. Although there are several terms one should understand when working with screws, here are the basics:

Tightening torque: the force required to rotate a screw. The relation between tightening torque and axial force in the elastic region is expressed by the following formula:

T=kdF
T: Tightening torque (N·m)
k: Torque coefficient
d: Screw nominal diameter
F: Axial force (N)

The torque method refers to managing tightening torque with a torque wrench, for example, to control the axial force on the screw. Since this can be done with a tool and is a relatively simple way of managing axial force, it's used quite regularly. However, the torque coefficient varies, which means that the axial force also varies more than with other methods and must be considered for proper installation.

Torque coefficient: the value determined by the friction coefficient of the screw portion and the seating surface. Typically, this is about 0.15 to 0.25 but may vary depending on the material, surface roughness, and if plating or oil is used.

Axial force: the tightening force generated in the axial direction when a screw is tightened.

Yield load (or yield stress): the load at which material deforms beyond return to its original state. When load and stretch are increased linearly in tension testing, the load suddenly decreases while the stretch continues to increase. This is known as the yield phenomenon and the load during this time is known as the yield load. The value of yield load divided by cross-sectional area is the yield stress.

A 0.2% proof load | Plastic strain: the proof load is the load that generates 0.2% plastic strain when an external force is removed from metal material, such as aluminum alloy (which fails to demonstrate the yield phenomenon). It is used in place of yield load.

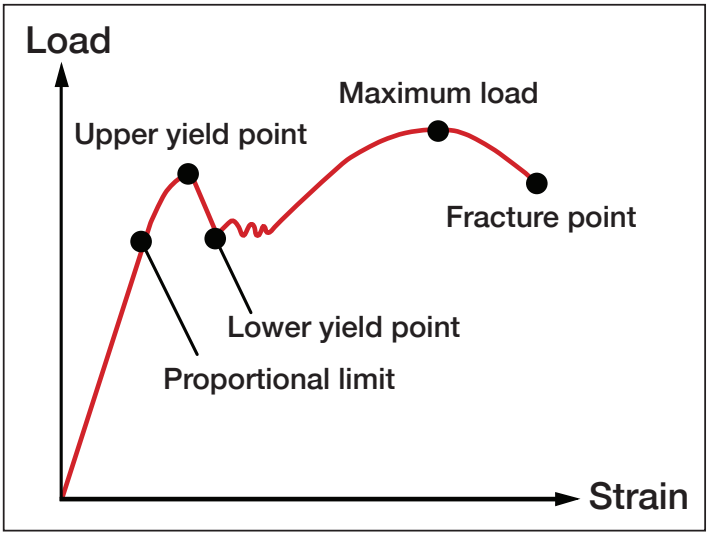
Plastic strain that persists, even after the external force is removed, is known as permanent strain — meaning the material suffers permanent deformation. Conversely, elastic strain is one that decreases to zero when the external force is removed.

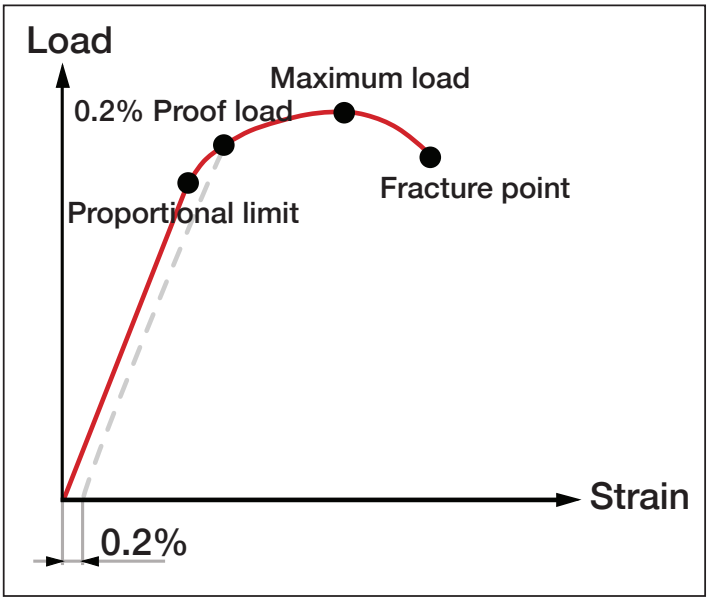
Tensile strength: an index for strength levels, referring to the maximum tensile stress that a material can endure. Given material variance, the value below at which the material will not break is called the minimum tensile strength.

Strength class: an index for screw strength, displayed differently for steel screws and stainless-steel screws. Carbon steel and alloy steel screws are displayed as "10.9" or "12.9," with the ones place showing the 1/100 value of nominal tensile strength and the tenths place showing a value that's 10 times the ratio of nominal lower yield point and nominal tensile strength.

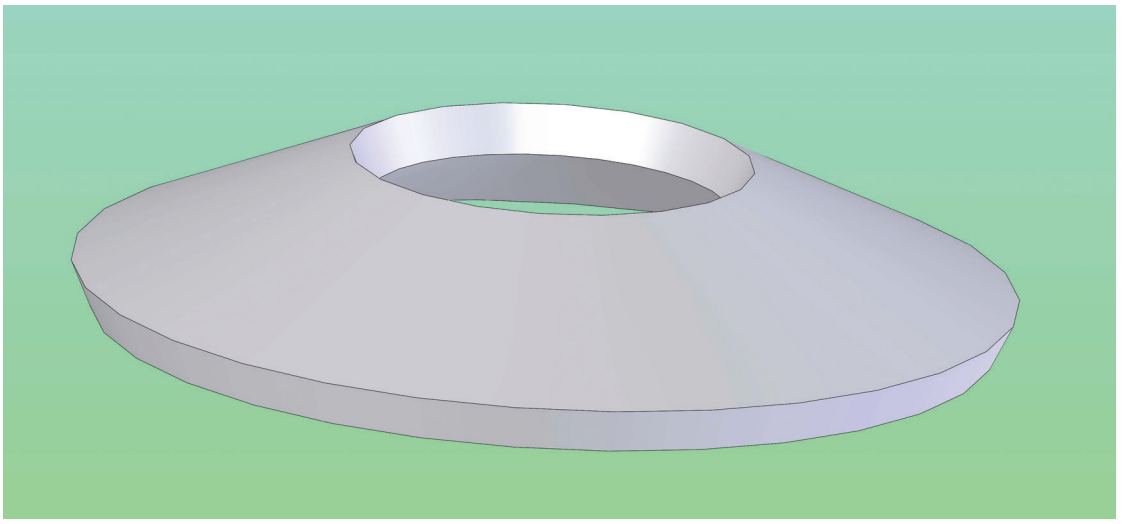
For example, "12.9" shows a nominal tensile strength of 1200 N/mm2, with nominal proof stress of 1200 x 0.9 for 1080 N/mm2. Typically, "A2-70" is displayed for stainless-steel screws, with the numbers before the hyphen representing the type of steel and the numbers after indicating the strength class. In this case, it indicates 1/10 the tensile strength value. For example, "A2-70" has a minimum tensile strength of 700 N/mm2. **FE**

Written by Hiroki Goto, Engineering Specialist with NBK America LLC
nbk1560.com





What functions do washers provide?



A Belleville washer is formed from a flat washer pressed into a conical shell and can be used as a washer or spring.

A washer is a plate with a hole that lets a fastener to pass through it. The most common shape is a flat disk with a concentric hole. Washers are frequently used to distribute the clamping force from threaded fasteners over a larger area. This prevents bolt heads and nuts from indenting the surfaces of the fastened parts, which could loosen the fastener.

Washers can serve as a spacer and are available in serrated or tabbed to prevent unscrewing. Sprung washers offer axial flexibility and are used to prevent fastening or loosening because of vibration, or to indicate correct pre-load. Several different types of washers are available to suit different applications.

For example, Belleville springs are a sprung washer in the shape of a conical shell, which can be loaded along its axis statically or dynamically. They are also called Belleville or conical spring washers. Belleville washers are typically used in conditions of high current loading or cycling. They are used to absorb vibration and can maintain preload in bolted joints, indicating correct preload based on the gap between adjacent washers. They can also help with "bolt creep" or stress relaxation between a bolt and washer.

However, one feature Belleville washers are unable to provide is significant locking capacity in bolted applications because of a lack of serrations. Although this can be beneficial, depending on the application, because serrations can also damage the clamping surface.

Although they resemble a washer, Belleville washers are often used as a spring to actuate mechanisms and provide suspension. They can

be stacked together in different ways to create longer springs with highly configurable spring rates. They have a number of specific advantages for such applications, including:

- Configurability through stacking
- High force within a small or confined space
- Concentric force distribution

Stacks that use a combination of alternating and same direction Belleville springs can achieve particular spring characteristics. For example, when two or more Belleville springs are stacked together, this changes the spring rate. If multiple springs are stacked in the same direction, this is equivalent to arranging springs in parallel. Although the total range of motion remains the same for one spring, the force generated is multiplied by the number of springs.

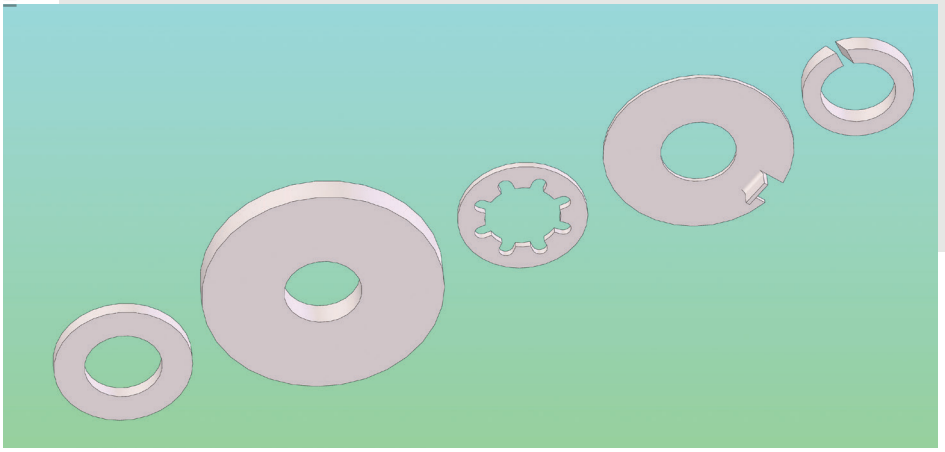
When Belleville springs are arranged in this way there is also significant friction between the mating surfaces. This creates a damping effect that can reduce vibration. **FE**

Washer types

Many types of washers are available for functions such as load distribution, locking, and vibration reduction. Steel washers are typical, although other metals and plastic are also used quite regularly.

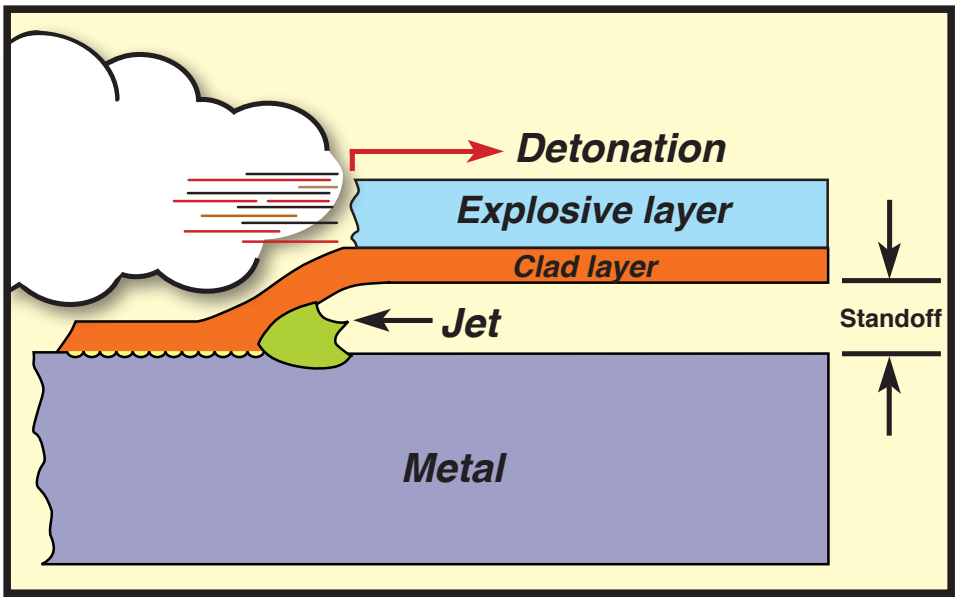
Here are a few of the common types of washers:

- Plain washers are simple flat discs with a concentric hole to accept a fastener. The outer diameter is approximately twice the hole diameter. Plain washers are generally used to distribute load in bolted connections.
- Extra-large plain washers are used to spread load over a larger area when fastening flexible or weak materials, such as thin sheet metal. They may also be used where a hole has been enlarged or suffered damaged. For these reasons, they are often referred to as repair washers.
- Toothed lock washers are designed with serrations around their inner or outer edge to prevent rotation.
- Tab washers have a rectangular tab or recess that fits a mating feature on the part requiring fastening to prevent rotation.
- Thrust washers are flat discs of low friction material that can be used as simple trust bearings. This is a type of plain bearing designed to transmit axial loads in rotating shafts.



From left to right: Plain washer, extra-large plain washer, lock washer with internal teeth, external tab washer, and spring lock washer.

What is explosion welding?



The explosive welding setup and process.

Explosion welding, also called explosive cladding, joins two metals together by an explosive force. It's typically used to join dissimilar metals that have a significant difference in mechanical properties, thermal expansion coefficients, or melting temperatures — such as a low-cost metal to a more costly corrosion-resistant metal.

A few common clad layers deposited onto steel plates include aluminum, copper, bronze, titanium, monel, nickel alloys, and zirconium.

An explosive weld is made by impelling a cladding plate against a substrate plate material, using significant energy from an explosive discharge. This results in a high-energy rate impact. In fact, extremely high forces at the area of impact (estimated at several hundred thousand lb/in^2) cause the first few atomic layers of each material to form a plasma jet that's ejected out of the impact zone — including contamination and unwanted oxide layers. The impact causes the metals to form a true metallic bond, where the metals share valence electrons. Of particular importance are the characteristics of the explosion weld itself. Explosion welding generally produces a wavy bond zone morphology. This waviness is a function of the different material properties and the welding parameters. The impact angle and detonation velocity (the speed at which the detonation shock wave travels through the explosive) influence the amplitude of the waviness.

When done correctly, an explosion weld is a solid-state bond without a heat-affected zone that's often typical of other heat-dependent welding or joining processes. Such a zone can degrade the strength of a bond.

Explosion welding is ideal for joining large, flat areas, such as for clad-plate manufacturing. A clad plate is a multi-layer plate that combines a carbon or low alloy steel plate with a layer of corrosion-resistant grade (or clad). For more complex components, a bimetal pre-form (consisting of two metals joined together) is typically produced by explosion welding in the plate or tube configuration, followed by hot or cold working.

An explosive weld is made by impelling a cladding plate against a substrate plate material, using significant energy from an explosive discharge. This results in a high-energy rate impact.

Explosion welding

As its name infers, explosion welding requires the use of explosives to fasten or join parts, which means it's a hazardous task. It's important to weigh its advantages against its limitations.

Limitations

- Requires knowledge of explosives and safety regulations
- May require special licensing for high explosives
- Limited to flat surfaces or coaxial cylindrical surfaces

Advantages

- An ideal way to join metals that are typically difficult to bond.
- Large areas can be bonded quickly
- Produces stronger and cleaner bonds than those formed through friction, diffusion welded joints, or melting-based processes

The explosive welding technique is frequently used to clad low-cost plate (typically carbon steel) with more costly corrosion-resistant materials. The clad plate is often used as a tube sheet for heat exchangers in the chemical and petrochemical industries. Other applications include sandwiched metal for coinage and the production of titanium-to-stainless steel transition joints, such as in the Apollo spacecraft.

A broad range of sizes can be explosively welded. For example, this method of welding has been used to join electronic components of widths less than 0.5 mm and for cladding plates up to 5 x 12 m. Cladding metal thicknesses can range from 0.025 to 100 mm (0.001 to 4 in.), and base-metal thickness can range from 0.025 mm (0.001 in.) to over 1 m (40 in.). The size limits are generally mandated by component metal manufacturability and transportation requirements.

Explosion welding is usually performed in isolated facilities by experienced companies because of the unique safety and noise-vibration considerations. Such risks have led to alternatives, such as magnetic pulse welding. This form of welding joins metals through the use of powerful magnetic forces, which create the propulsive power of an explosion without the heat, danger, or waste. FE

PRODUCTS

A built-in, load-monitoring device

Valley Forge & Bolt Mfg. Co.
vfbolts.com

Bolts and fasteners might be small components but faults or failures with these devices can lead to big problems. In critical industries, joint failures are a major safety concern and replacements are typically costly. Work shutdowns required for changeouts can equate to several thousand dollars at a time, adding up to millions over a year.

Maxbolt Load Indicating Fasteners — a patented product of Valley Forge & Bolt Mfg. Co. — can reduce downtime, premature wear, and catastrophic joint failures. This is because Maxbolts provide monitoring to warn users of initial relaxation and loosening during operation, thanks to an extremely accurate and durable load-monitoring device in each fastener.

At a glance, technicians will know when the proper load is achieved. During operation, technicians will also know if load ever falls out of spec on any bolt.

With Maxbolts, measurements are based on tension and the inaccuracies of torque control are eliminated, ensuring optimum initial conditions before an assembly is placed into service. All operators can assemble complex bolted joints with uniform clamp loads within +/-5% of the design specification.

Secure position control hinges

Southco, Inc.
southco.com

Southco, Inc. has expanded its successful line of constant torque position control hinges with a new version that enables secure position control with minimal user effort. The E6 One-Way Constant Torque Hinge lets heavy doors and panels lift easily by removing friction from the hinge in one direction. The E6 also offers high torque that securely holds a door or panel in place without closing on the user.

Sealed for outdoor use and constructed from corrosion-resistant materials, the E6 Hinge offers increased longevity and requires zero maintenance or adjustment over the lifetime of most applications — making it an ideal solution for off-highway access panels, automotive center consoles, and industrial printers.

By ensuring reliable positioning and consistent operation, these hinges eliminate the need for secondary support components, such as gas struts or door stays, to hold doors or panels in position. Southco's position control hinges are available in several torque ranges and sizes.

*For further information about products on these pages visit the **Fastener Engineering** website @* **www.fastenerengineering.com**

Toggle clamps with integrated locking

JW Winco
jwwinco.com

JW Winco has optimized its portfolio of toggle clamps, offering new product versions with integrated safety features. For example, the toggle clamp GN 820.3 is protected by a safety hook that guards against unintended opening and operational errors. However, if necessary, the safety lock can be released with a single hand.

Product version GN 810.3 allows both end positions of the clamp to be secured with this new locking function. This enables the use of longer clamping arms without accidental closure. All Winco toggle clamps are available in steel or stainless steel and manufactured from sheet steel or forged parts, with a galvanized or black-coated surface.

Depending on the application, customers can choose from vertical clamps with a vertically oriented clamping lever, horizontal clamps with a horizontal lever, or locking clamps and push-rod clamps. As a new service, JW Winco also delivers the matching spindle assembly with toggle clamp orders.

Stripped screw removal tools

NBK
nbk1560.com

NBK offers Impact Screwdrivers and Stripped Screw Removal Bits for removing stripped screws or those with damaged recesses, which are unable to loosen with conventional tools. Damage may occur for several reasons, such as when recesses are crushed because of rust or corrosion from long-term exposure to outdoor environments or simply due to incorrect tool use or faulty attempts to forcibly remove stuck screws.

Impact Screwdrivers and Removal Bits can be used together to create grooves in damaged recesses, which can then be turned to safely and effectively remove the screw. These tools can also be used to remove flat-head screws that fail to grip with a wrench or screws in counterbored holes.

Galvanic corrosion prevention

Nylok
nylok.com

Nylok, a provider of resin, adhesive, and lubricant coatings for threaded fastener applications, offers NYSHIELD — a coating that prevents galvanic corrosion between steel fasteners and extremely lightweight materials.

NYSHIELD has minimal tension loss (even up to 150° C), exceptional chemical resistance, and adheres well to most substrates. Simply apply NYSHIELD uniformly to the steel fastener surfaces that contact dissimilar materials and it works to shield and protect the least noble material. It also protects steel fasteners from galvanic corrosion in high-risk material combinations, including carbon fiber, magnesium, aluminum, chrome plating, and others.

NYSHIELD offers excellent adhesion, coating uniformity (typical thickness is 50 to 75 microns), low tension loss at elevated temperatures (150°C), an adjustable coefficient of friction (typically between 0.10 – 0.16), and reliable chemical resistance.

Securing 2H heavy hex nuts

Bryce Security Fasteners
brycefastener.com

If 2H Heavy Hex Nuts in sizes 1/2-13 up to 2-8 are a typical go-to choice for project applications, consider increasing the security level for better peace of mind. Bryce Security Fastener's Key-Rex Structural Nuts provide extra protection from theft and tampering.

Key-Rex Structural Nuts can be installed with standard 2H Nuts. They're certified for the pipeline industry with seven layers of patented security. Bryce Security Fastener recommends installing two Key-Rex Structural Nuts per six 2H Heavy Hex Nuts.

What's more: no extra sockets are required. The same socket is used to torque both 2H Heavy Hex Nuts and Key-Rex Structural Nuts down. The Structural Nuts also exceed pipeline torque requirements. The majority of other large, security nuts are unable to torque as high as Key-Rex, and particularly in larger sizes.

Custom lock and tab washers

Boker's Inc.
bokers.com

Boker's offers complete production of non-standard and customized lock washers and tab washers that provide secure fastening. These types of washers are vital in applications subject to vibration, torque, heat, or corrosion to reduce turning, slipping, or loosening under load.

Lock washers are widely used as a reliable method to secure fastening and include internal or external tooth, or a combination of the two. Lock washers exert a load, partially deform, and lock a fastener into place.

Tab washers are an additional form of lock washer that features one or more internal or external notches (or tabs) to hold a nut in place in relation to the connecting bolt or stud. Tabs may be bent or engage in keyways or slots in connected surfaces to provide a positive locking surface. In some applications, tabs are used along with a flat washer to distribute the load evenly without deforming the assembly that the fastener is secured to.

Tab washer sizes include a complete range of sizes up to 12" in outside diameter, in addition to multiple inside diameter and thickness options, for compatibility with all types of nuts, bolts, or fastening systems.

Bulge control rivet nuts

EFC International
efc-intl.com

EFC International's BCT rivet nut provides a best-practice, light-weighting solution for attaching carbon fiber and composite panels for the automotive industry. The rivet nuts are manufactured by BBA with bulge control technology — or BCT.

BCT rivet nuts are ultra-high-strength and engineered to prevent cracking or delamination of carbon fiber panels. This patented design enables an engineered yield point on the body of the rivet nut, ensuring the bulge formation starts beyond the panel and is drawn back on the panel. This means BCT rivet nuts can be placed near the edge of the panel without inducing a crack in the panel.

These rivet nuts can be fully process-monitored, controlled, and installed in areas that offer limited rear side clearance. An M6 rivet nut needs only 8mm of rear side clearance before installation and only 5mm after installation. This is ideal for use in a thinner version of sandwich (composite) materials, avoiding the need for a through-hole.

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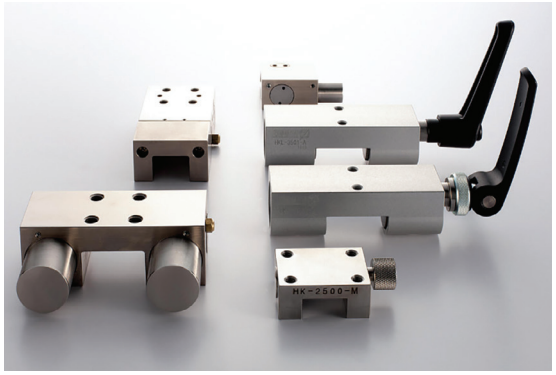

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Ramco

Ramco has been a global supplier and manufacturer of critical threaded and non-threaded fasteners since 1977. Headquartered in Hudson, Ohio, the company also has facilities in Italy.

The company's experienced and knowledgeable staff of product, process, and design engineers partner with customer engineering teams to improve current products and processes.

Ramco is a go-to source for all types of needs, with a long history in lock nuts and weld nuts for the automotive industry. It also manufactures hundreds of other products, including nut and washer assemblies, externally threaded, spacers, rivet nuts, assemblies and engineered components including cold formed, hot formed, stamped and machined.

Quality has always been the hallmark of Ramco's production success. With products manufactured in the USA and produced to exact specifications on materials and measurements, the company confidently stands behind its goal of zero PPM, which is backed by a quality system that is certified to TS 16949 and ISO 14001.

Options like prevailing torque, a variety of platings, and thread masking are always available. In-house processes include cross-functional feasibility reviews, APQP, PFMEA, process flows, control plans, SPC and in-house sorting.

Major manufacturers trust Ramco to meet their objectives. For years, Ramco products have met stringent qualifications to supply products for Ford (Q1), direct GM and Chrysler.

Ramco's completely new, 165,000-square-foot facility has enhanced its longstanding ability to deliver quality, service and efficiency.

When you work with Ramco, you can be confident that parts will meet specifications and will function better than expected. For more information, visit www.ramconut.com or call 330-653-5135.

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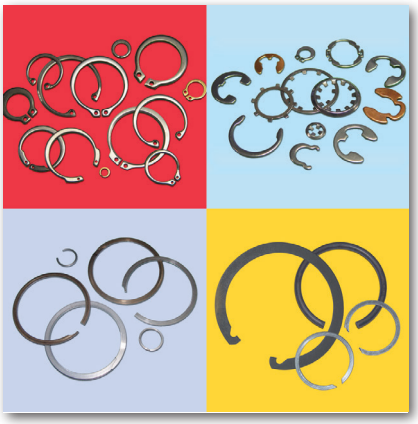
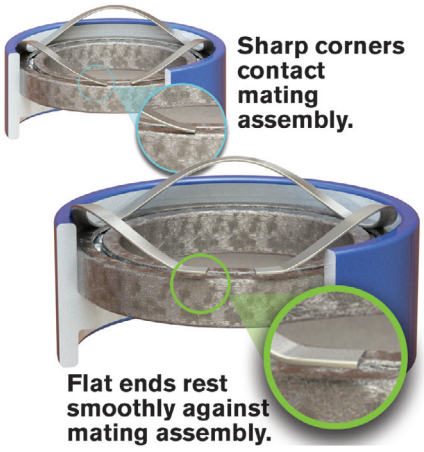
Rotor Clip



Rotor Clip is a global leader in the manufacture of tapered, constant section and spiral retaining rings meeting Inch, DIN, ANSI Metric and JIS standards. This includes the manual and automatic tools needed to install/remove every ring we sell.

Rotor Clip also manufactures wave spring rings as well as self-compensating hose clamps, all produced in a lean environment dedicated to eliminating waste and ensuring quality through IATF 16949, ISO 9001 & ISO 14001 registration, and AS9100C certification.



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Bearing Retention & Preload Solutions through Engineering Expertise.

Rotor Clip TruWave® single-turn wave springs are suited for applications that include connectors, fluid power seals, noise and vibration attenuation, and bearing preload.

The design of standard single turn wave springs with gap typically used for preloading components features sharp corners at the cut off area of the spring ends. These sharp corners can scratch the surface of the bearing as well as the mating parts when the wave form shows a steep incline depending on the load specification.

Rotor Clip's patented single-turn wave spring design solves this problem by flattening the ends of the spring so that they will not create excessive wear that can damage the application.

This new design also offers the potential for cost and weight savings in applications where design engineers would typically choose a multi-turn wave spring with shim ends to prevent wear on mating components. However, multi-turn wave springs with shim ends require more material in their production, which adds to both cost and weight.

As with all of our wave spring designs, there is no charge for tooling on custom designs with this end feature.

Feel free to contact our technical sales staff (tech@rotorclip.com) to find out if your design can benefit from our new single-turn wave spring design. Maybe you have questions about another of our retaining ring, wave spring or hose clamp products. Our technical sales engineers are here to help you find the right solution for your application. **www.rotorclip.com**

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So much happens between issues that even another issue would not be enough to keep up. That's why it makes sense to visit fastenerengineering.com and stay on Twitter, Facebook and Linkedin. It's updated regularly with relevant technical information and other significant news for the design engineering community.

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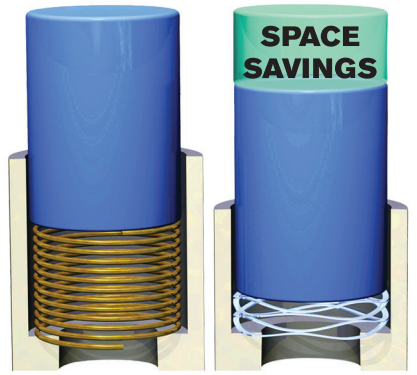

TRUWAVE® wave springs exhibit an excellent force-to-work height ratio.

Well-designed wave springs can produce the same or even greater forces as coil springs while providing up to 50% of space savings.

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