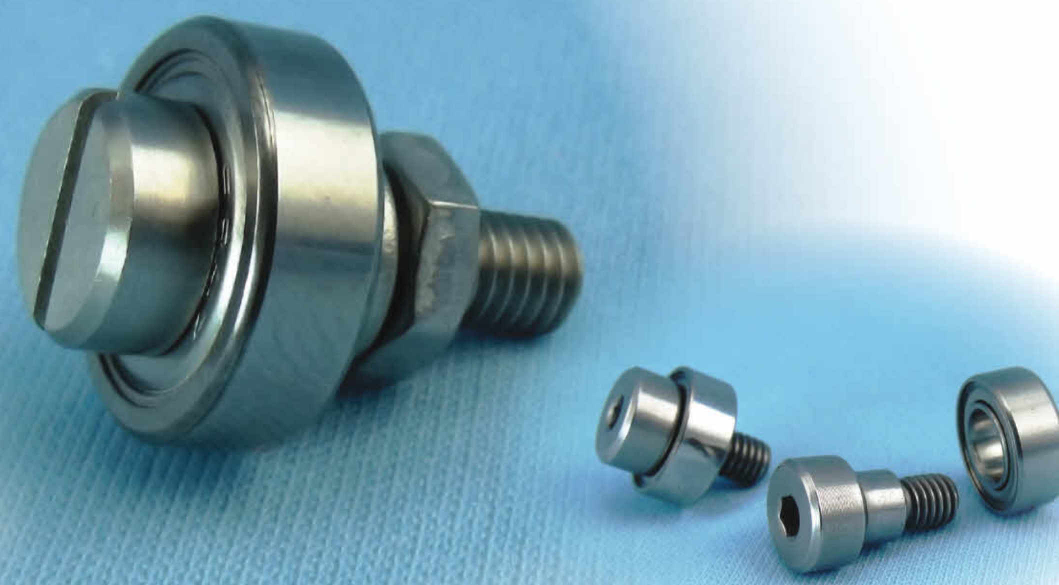
Know your **shoulder** screws

The basics of shoulder-screw grades, dimensions, materials, and options can help designers get the best product for their applications.



Shoulder screws, also known as shoulder bolts and stripper bolts, are machine screws with an integral shoulder or journal between the head and thread. Although they are not readily available in local hardware stores, shoulder screws are used extensively in industries from aerospace to consumer products because of their versatility and unique attributes when installed.

Shoulder screws have three main sections: head, shoulder, and thread. The head has the largest diameter, the shoulder is described by its diameter and length, and the thread has a major diameter slightly smaller than the shoulder diameter.

When the thread of the shoulder screw is fully installed, the unthreaded shoulder extends beyond the surface into which the thread embeds. The shoulders give the screws their versatility by acting as shafts or dowels for rotating items such as bearings and bushings, axles for rolling parts, guides for sliding elements, and pivot points or mounting pins.

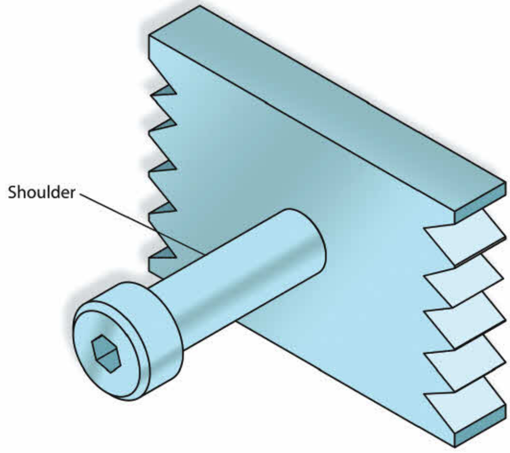
Shoulder screws are often used in punch-and-die mechanisms or plastic-injection-mold sets. The screws act as linear slides to accurately align the die or mold halves as they open or close. In these applications, they are commonly called stripper bolts.

What makes shoulder screws unique is the mechanical components the shoulders can accommodate. Bearings mounted on shoulders create simple cam followers. Pulleys, gears, and sprockets can rotate at moderate speeds on shoulders. Shoulder-mounted springs can preload components traveling axially along the length of the shoulder.

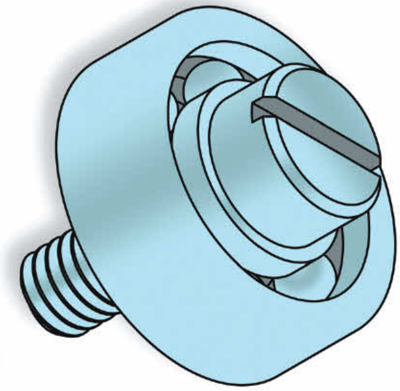
Specifying shoulder screws

Shoulder screws are specified by shoulder diameter and then by shoulder length. For instance, a ¼ × 1-in. shoulder screw has a shoulder diameter of ¼ in. and a 1-in.-long shoulder. This differs from machine screws, where the same specification yields a screw with a threaded section ¼ in. in diameter and 1-in. long. The overall length of the shoulder screw includes the head height, the 1-in. shoulder length and the thread length.

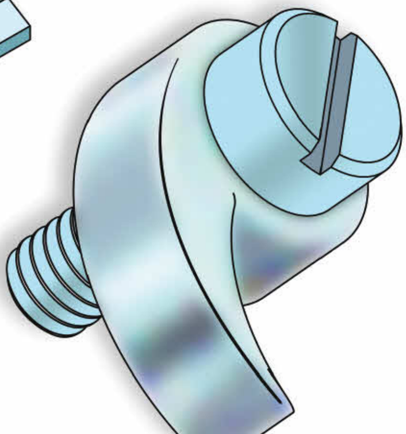
The screws come in a wide range of shoulder diameters and lengths in both inch and metric sizes. Many



When the thread of a shoulder screw is fully installed, the unthreaded shoulder stands proud of the surface. It can work as journal for rotating parts or a guide for sliding parts, among many other possibilities.



To create a simple cam follower, mount a ball bearing on a shoulder screw. With proper shoulder length and tolerances, the screw can fix the inner race of the ball bearing while still allowing the outer race to spin freely.



Shoulder screws can also create a pivot points. Here, the pawl of a ratchet-and-pawl assembly is installed on the shoulder.

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Key points:

- Shoulder screws' unthreaded sections can act as journals, pins, or siding-element guides.
- Commercial-grade shoulder screws are widely available in standard configurations that meet ASME specifications.
- Precision-grade shoulder screws can be custom designed to fit the dimensional, material, and drive-type requirements of an application.

Resources:

Ondrives.us Corp., *www.ondrives.us*

For an expanded version of this report with a comparison chart see: *www.ondrives.us/shlscrew.htm*

ASME B18.3 Standards, *tinyurl.com/MDShldrScrews, tinyurl.com/MDShldrScrwIn*

manufacturers offer custom or made-to-order screws.

Commercial-grade shoulder screws in standard sizes — as specified by ASME B18.3 for inch sizes and ASME B18.3.3M for metric sizes — are available from most fastener and bearing distributors. Most are produced by a cold-heading method that is most economical in quantities on the order of tens of thousands. For that reason, nonstandard sizes can be cost prohibitive.

While commercial-grade shoulder screws used to be the industry standard, they are now being replaced in many applications by precision-grade screws. These have tighter shoulder-diameter and shoulder-length tolerances than commercial-grade screws, making them ideal for use with ball bearings and other precision components. Precision-grade screws now come in shoulder diameters from $^3/_{32}$ to ½ in. and lengths as short as $^3/_{32}$ in.

A manufacturer of precision-grade shoulder screws can give engineers more flexibility when it comes to selecting shoulder screws. Engineers can choose the head type, shoulder length, thread length, and other variables that best fit their applications. Custom shoulder screws can be quickly and inexpensively produced by screw machines for small quantities or cold headers for large quantities.

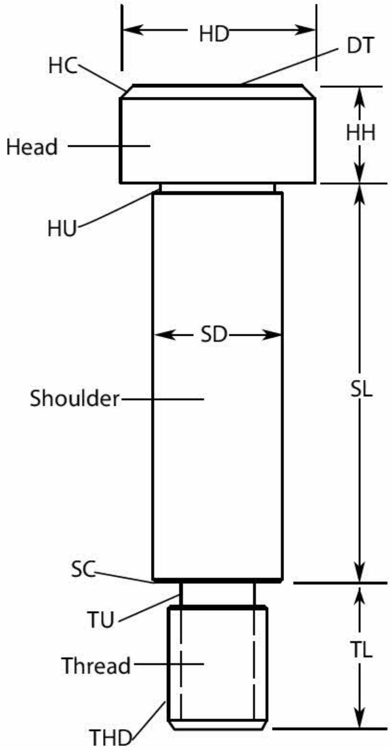
With this flexibility, it's important for engineers to know their options for specifying all the parts of a shoulder screw. The allowable dimensions and tolerances for commercial-grade shoulder screws are spelled out in ASME B18.3 and ASME B18.3.3M. Precision-grade shoulder screws don't have a published standard, but experienced manufacturers can advise engineers on the dimensions and tolerances that will produce the best product.

Head specs

Head type. Typical shoulder screws have modified fillister heads in which the head diameter is approximately twice the head height. But unlike standard fillister-style machine screws, shoulder screws have flat tops with 30 to 50° chamfers on the heads' outer diameters that may be slightly rounded.

Truss heads and low-head fillisters are also available. External hex-head and square-head screws are sometimes made, too. These install with a wrench but have the advantage of an extremely shallow head height.

Some commercial-grade shoulder-screw heads also have an under-the-head chamfer or radius, an optional edge-break on the bottom of the head. Precision-grade shoulder screws usually do not have an under-the-head chamfer or radius.



DIMENSION	DESCRIPTION
HC	Head chamfer
HD	Head diameter
DT	Drive type
HH	Head height
HU	Head undercut
SD	Shoulder diameter
SL	Shoulder length
SC	Shoulder chamfer
TU	Thread undercut
TL	Thread length
THD	Thread

Shoulder screws consist of a head, unthreaded shoulder, and threaded portion. The head has the largest diameter, and the major diameter of the thread must be smaller than the shoulder diameter.

Head diameter. The head diameter is the largest diameter of the screw, typically twice the head height and 30 to 50% larger than the shoulder diameter. Head-diameter tolerances run ±0.005 in. for inch screws and ±0.127 mm for metric sizes. For commercial-grade screws, manufacturers or users sometimes add a straight knurl on the head diameter.

Head height. Both commercial and precision-grade standard shoulder screws have head heights equal to half the head diameter and use the same tolerances as head diameter.

Special low-head shoulder screws have head heights just thick enough to accommodate a flat screwdriver slot or are made with external square or hex shapes. Phillips and hex-socket drives are not appropriate for low-head shoulder screws because the drive socket closely approaches the head undercut, creating a potential fracture point.

Head undercut. Also called shoulder-neck diameter, the head undercut is a decrease in the diameter of the shoulder just below the head that lets mating components mount flush against the head. Some shoulder screws have a full head radius — a smooth radius between the shoulder diameter and the bottom of the head in place of the undercut — but this can prevent a component mounted on the shoulder from seating or rotating properly.

The head undercut width is the maximum length of the undercut. It is included when measuring shoulder length.

Precision-grade shoulder screws don't have standard head-undercut dimensions; most manufacturers keep head-undercut depth to 0.006 to 0.015 in. smaller than the shoulder diameter and head-undercut width to 0.025 in. for small screws and 0.042 in. or greater for large screws. Commercial-grade shoulder screws have standard undercut dimensions established in ASME B18.3 and ASME B18.3.3M.

Head-fillet radius. The high point of the radius of the fillet where the head undercut meets the head may not exceed the shoulder diameter. A related dimension is the fillet-transition diameter, the maximum diameter created by the head-fillet radius. Head-fillet radii are not generally used to specify precision-grade shoulder screws.

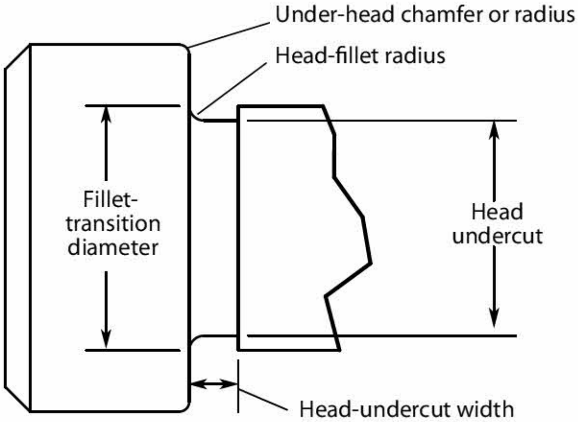
Drive types. Commercial-grade, alloy-steel shoulder screws come almost exclusively with hex-socket drives. These drives' hexagon-shaped cavities accept a hex key for driving the screw into place. Standard hex-socket sizes are based on the shoulder diameter, and key engagement — the minimum amount the hex key engages in the socket cavity — is at least 75% of the hex-socket size.

Precision-grade shoulder screws are readily available with hex-socket drives and with slotted drives — the kind driven by a flat-head screwdriver. To a lesser degree, cross-recess or Phillips drives are also standard in this grade.

Users can special order Torx, star, tamperproof, square-head, and hex-head drives for both commercial and precision grades of shoulder screws.

Shoulder specs

Shoulder diameter. Standard commercial-grade shoulder screws come in diameters from ¼ to 2 in. and 6 to 24 mm. Precision-grade shoulder screws range from $^{3}/_{32}$ to ½ in. and 6.5 to 12 mm in diameter. Any diameter can be made as a custom part.



The head is the widest part of a shoulder screw. An undercut under the head permits a stress-relieving fillet while allowing components on the shoulder to mate cleanly with the head.

Precision-grade shoulder diameters have a tolerance of 0.0005 to 0.0015 in. below the nominal size for inch-size screws and 0.013 to 0.038 mm below nominal for metric sizes. These tolerances accommodate a close but free fit with nominal-sized components such as bearings and pulleys.

Commercial grade screws have a larger tolerance range. They are 0.002 to 0.004 in. below nominal diameter for all inch-size screws. In metric sizes, tolerance scales with diameter: Shoulders 6.5 to 10 mm in diameter have tolerances 0.013 to 0.036 mm below nominal, shoulders 13 to 16 mm in diameter have tolerances 0.016 to 0.043 mm below nominal, and shoulders 20 to 25 mm in diameter have tolerances 0.020 to 0.052 mm below nominal.

Shoulder length. Shoulder screws come in a range of incremental shoulder lengths as measured from under the head to the bottom of the shoulder, including the head-undercut dimension.

Precision-grade shoulder lengths have tolerances 0.0005 to 0.0025 in. above the nominal length, and metric screws are 0.013 to 0.063 mm over nominal allowing for a free fit with nominal-sized mating components.

Commercial-grade shoulder screws can have shoulders ¼ to 10 in. or 6.5 to 120 mm long. Shoulder-length tolerances are ±0.005 in. or ±0.125 mm from nominal. This loose tolerance means a full-width component can bind on a shoulder at the short end of the allowable tolerance, so designers must exercise caution when sizing the mating component.

Thread specs

Threads. The major thread diameter of a shoulder screw must not exceed the shoulder diameter. Commercial-grade shoulder screws have UNC class 3A threads. So, a commercial-grade screw with a ¼-in.-diameter shoulder has #10-24 threads. Precision-grade shoulder screws have UNC class 2A threads as standard, so a ¼-in.-diameter shoulder gives rise to #10-32 threads. Precision-shoulder screws with class 3A threads are common custom-made parts.

Thread length. This dimension is the distance from under the shoulder to the end of the thread, including the thread undercut. Most shoulder screws have relatively short thread lengths but can be produced to any required dimension. As in machine screws, thread lengths are always held to a tolerance below the nominal length. However, tolerances vary slightly among manufacturers.

Thread neck. The thread neck is the region between the shoulder and the thread. This undercut is necessary for manufacturing and lets the shoulder seat flush with the threaded component. Because the thread undercut is a reduction in diameter, it is the weakest point of the screw; an overtorqued shoulder screw is most likely to fracture at this point.

Users can specify the thread-neck diameter (the undercut depth), its maximum width (or length), and its fillet dimensions. The thread-neck diameter and thread-neck width together are often referred to as the thread undercut. Maximum fillet diameter can't exceed the major thread diameter if the shoulder is to fit flush against the mating component.

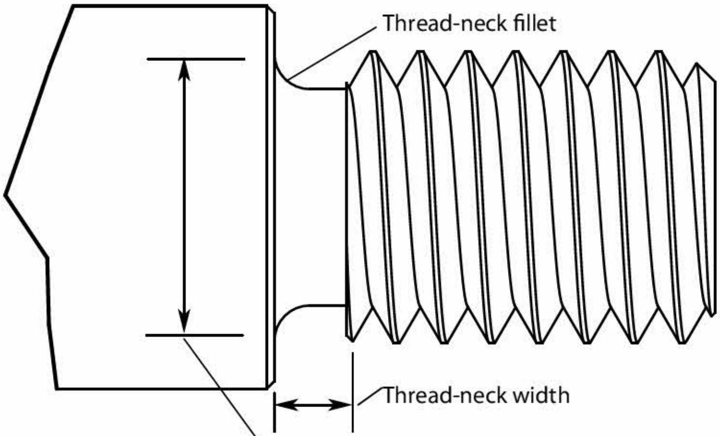
The depth of this undercut is not standardized on precision-grade shoulder screws, although the thread neck diameter is generally 0.002 to 0.005 in. less than the minor thread diameter. Thread-neck width for this class of screws is equal to the width of 1.5 threads.

Thread-neck dimensions in commercial-grade shoulder screws are established in ASME B18.3 and ASME B18.3.3M.

Materials

Shoulder screws can be made from a variety of materials including hardened alloy steel, mild steel, stainless steels, brasses, and plastics. Here are a few of the most common:

303 stainless steel. In its cold-drawn condition, 303 stainless is the most commonly used material in precision-grade shoulder screws. This austenitic material has good corrosion resistance, 75 to 90-ksi tensile strength, and Rockwell B 83 hardness. It can't be further hardened by heat treatment, but work hardening may make it slightly magnetic.



Shoulder screws' threaded regions are usually fairly short. An undercut or neck slightly smaller than the thread minor diameter joins the threaded region to the shoulder.

316 stainless steel. This grade has similar properties to 303 stainless but may be slightly harder. It also has better corrosion resistance, making it ideal for marine applications. Shoulder screws made from 316 are only available by special order, and they are considerably more expensive than those made from 303 because they are harder to machine.

17-4 PH stainless steel. This martensitic, precipitation-hardening material can be heat treated to bring its hardness up after machining. When 17-4 PH stainless steel is heat treated to an H900 condition, its hardness reaches or exceeds Rockwell C 40, its tensile strength climbs to at least 150 ksi, and it becomes brown and nonmagnetic.

416 stainless steel. This highly magnetic stainless steel is stronger and harder than the 300-Series stainless steels. However, it is prone to surface corrosion. Shoulder screws made from this material are generally machined in a prehardened condition where they have a Rockwell C hardness of at least 26, and a minimum tensile strength of 123 ksi.

Alloy steel. This is the original, and most commonly used, material for commercial-grade shoulder screws. Most screws use high-strength alloys like 4140 with Rockwell C hardnesses 32 to 43 and minimum tensile strengths of 144 ksi. The hardening process turns the screw black but the shoulder is ground after hardening which leaves this surface bare steel. Alloy screws are heat treated by oil quenching from above the transformation temperature and then tempered at 650°F or higher.

Mild steel. Any number of mild steels can be used to manufacture shoulder screws. These steels have a range of hardnesses and tensile strengths, are magnetic, and are frequently plated to improve corrosion resistance or appearance. Unhardened mild-steel shoulder screws are a less-expensive alternative to stainless or hardened-steel screws in light-duty applications.

Brass. Brass is a soft material for light-duty applications. Its natural lubricity means it works well with rotating or sliding components. It is also nonmagnetic, an advantage in many applications.

Plastics. Shoulder screws are made from a variety of plastics. Plastic screws have lower surface hardness and tensile strength than their metal counterparts, and they do not conduct electricity. Large quantities of injection-molded plastic shoulder screws can cost considerably less than metal models. However, most plastics can't hold the tolerances required of precision-grade shoulder screws; plastic screws, whether molded or machined, are considered commercial grade.

Verification. Reputable shoulder-screw manufacturers can supply raw-material certifications with their products on request. Engineers can also perform a few simple checks to verify whether a screw is made from 300-Series stainless steels, 400-Series stainless steels, mild steels, unhardened alloys steels, or plated brass, which can all look alike.

For instance, 300-Series stainless steel parts are nonmagnetic or very slightly magnetic due to work hardening; they can't hold the weight of a decent-sized magnet. All the other steels mentioned above are highly magnetic.

Quickly dipping a sample screw in a saturation solution of cupric sulfate will instantly show which magnetic parts are stainless steel. Cupric sulfate discolors nonstainless-steel parts copper, brown, or black but doesn't affect stainless steels.

And simply grinding away a small area of the surface will confirm whether a nonmagnetic part that looks like stainless steel is indeed 300-Series stainless or brass with chrome plating. Just look for the brass color beneath the surface. **MD**