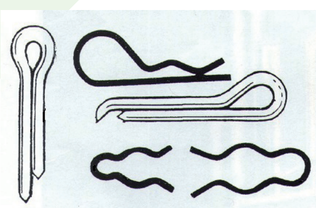
Unthreaded Fasteners –Pins

by Thomas Doppke

Seldom given thought or consideration, failure of a pin can bring about problems as great as any bolt malfunction. Pins are ancient fasteners but have rarely been looked at closely. They are all around us and date to prehistoric times. Originally made of bone, wood, and in more recent times, metal, they hold together clothing, hair coiffures, wheels to axles, doors and windows and anything else that needs fastening.

Although they look a lot different today, their basic functions are still very similar to their forerunners. They are used as retainers to prevent movement of multi-part components, to hold a position (as a locator), as a stop to fix a set point in a part's travel, and as shear devices (to allow pin failure at a point before the failure of other, expensive components). A second family of usages is to act as pivots, to allow rotational movement about itself (hinges, etc.).

Pins differ from their look-alike cousins, the rivet, in that the pin is used as manufactured and without further working of its shape. Pins can be grouped into several classifications, based loosely on shape. These are wire form pins (cotter, hair hitch, etc.); alignment pins (dowel and taper); spring pins (slotted and coiled); grooved pins (groove and barbed); rotational pins (hinge and various types with serrations, knurls, etc.); and the usual unclassifiable miscellaneous groups like clevis, keys, and so on.

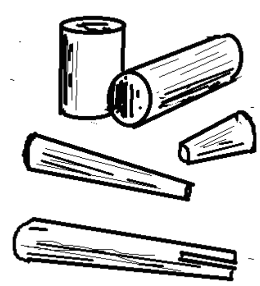


WIRE FORM PINS

Wire form pins consist of cotter pins, hairpins, lynch pins and hitch pins. They all function in a similar manner. They go through a hole in a part to prevent it from losing its position and causing disassembly. Cotter pins are used where great accuracy is not required. Typical usages are with slotted and castle nuts, clevis pins and roller chain connecting links. Cotter pins come in two styles- the extended prong square cut and the hammer lock. The extended prong is the most familiar pin, passing through a hole and the extended prong portion being easily bent apart to prevent removal. The hammer lock style is designed with a lipped end which is hit with a hammer to open the pin. It is used where space or time considerations restrict the installation.

They are made on wire machines using half round wire of steel grade AISI 1015 for carbon steel parts. They are also available in stainless steel and other metals by special order. Length is measured from the point of tangency of the head radius. The recommended hole size is equal to the maximum body diameter plus 0.50mm for sizes up to 4mm and plus 1mm for larger sizes. The cotter pin is a shear fastener but is limited by the softness of the material it is made of. Some typical values are shown in the charts at the end of this article. Reuse is possible but too much bending will fatigue fail the part.

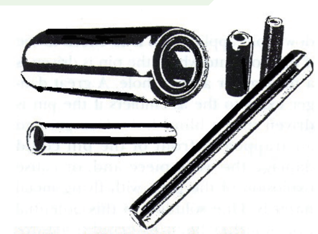
Hair pins look similar to the beauty devices that ladies use for their coiffures, hence the name. They are designed to be placed in a groove on the outside of a shaft. Originally designed as a substitute for "C" and "E" rings, they are easily installed and removed (unintentionally as well). The spring-like properties of this pin are derived from the high carbon steel that they are made of. This also makes them susceptible to hydrogen embrittlement failures. Because they can be easily dislodged they should not be used in areas of vibration or axial loading. Hitch /Lynch pins are designed to have one leg pass through a hole in the shaft and the other pass around the outside of the shaft. The detent action prevents accidental loosening and disassembly. Used where quick assembly and disassembly are required.



Dowel and Taper Pins

Alignment pin, also called dowel and taper pins, as used, as their names imply, for the alignment of other components. Used where is no significant end loading, they retain other parts in a fixed position. The pins are subject to shear loads at the interfaces of the parts being joined. The parts work by the interference fit of the entire circumference of the pin when pressed in the hole. Dowel pins are straight cylinders with a slight chamfer on one or both ends for ease of starting. Taper pins, obviously, are tapered towards one end. Dowel pins are used for permanent assemblies or those which will be taken apart rarely. Taper pins are used in similar assemblies except that they are usable in frequently disassembled components. The parts require accurate placement. Dowel pins could possibly be driven slightly off angle, causing a microscopic error. This happens when the material into which the pin is being driven is softer (iron, aluminum, etc.). The taper pin works by interference action of taper being pressed into the hole. Since the taper sides are self-aligning it allows for a very accurate placement. Reuse is very high with repeatable accuracy. Dowel pins are not serviceable easily as removal and re-installation cause wear on the hole surfaces, while taper pins can be easily driven out and re-inserted. This is also a disadvantage as they can be easily removed well. A short axial movement can cause complete dislodgment of the taper pin.

Dowel pins require accurate hole tolerances. Reaming of the holes is often necessary. In soft materials the hole should be 0.025mm (0.001") smaller than the hardened pin. In hard materials the hole should be ground to 0.005-0.0075mm undersize (0.0002-0.0003"). For small size dowel holes, the hole diameter should be equal to the maximum dowel wire diameter. The pin should be designed to allow 1 1/2 to 2 diameters of engagement.



Coil and Slotted Spring Pins

Caution should be used when installing a dowel pin so that the hole into which it is being driven is not a blind hole. In driving into blind holes the pin can compress the air in the hole and could damage the work piece (cracking) or even cause an explosion. One solution to this has been to grind a groove down the side of the pin to allow air to escape. Spiral grooved pins are also used for this reason.

Taper pins are available in the same materials and hardnesses as dowel pins. The usual taper is 1 in 48. Some taper pins are designed with a split in the end for ease of insertion.

Coiled and slotted spring pins are generally made in high carbon spring steel although various other metals are available. The coiled version consists of a sheet of very thin metal rolled about 2 ½ times on a diameter.

The coil pin has excellent vibrational resistance due to its ability to coil up when a load is applied and rebound when the load is relieved. The damping action of the coiling and uncoiling keeps the load from being transmitted to the hole walls where such forces would cause elongation and enlargement of the hole diameters. This is one of the prime causes of failures in shock and vibrational loaded pinned joints. As the hole becomes larger, the rate of damage and loosening increases and results in increased fatigue forces on the pin. Since the coil pin flexes throughout its entire engaged length, stresses are evenly distributed with no one single point showing any undue concentration.

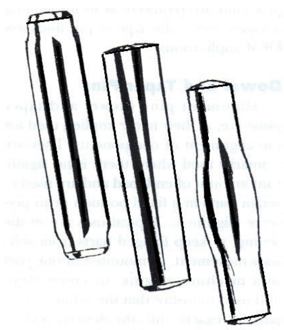
Coiled pins can be used with out of round and tapered holes without affecting performance, provided that the holes are not oversized. Since the pin is larger than the hole diameter, regular drilled holes with plus and minus tolerances can be used. They can be used in soft materials without fear of hole enlargement. However, to control radial tension in thin metal, near edges, and in brittle materials such as plastics and magnesium, some control of the hole diameter is necessary.

Coil pins cost less than screws, the labor to install is minimal, and the tooling required is of the lowest technological state. It is important to have the correct flex-to-strength ratio. A pin too strong will not flex, transmitting loads to the hole walls and causing damage. Too weak and it will flex too much and lead to fatigue of the pin or other components. Pins come in light, medium and heavy series .The varying factor is the thickness of the sheet metal of the coils. The pins are highly functional, economical and reusable, a good choice for a shear joint. End loading, if it exceeds the retention strength of the pin, may cause axial movement.

The slotted pin is made of a single coil of sheet metal, usually high carbon steel, coiled into a tube. There is an open slot running the length of the tube. When installed the gap closes and the radial tension of the material forces the pin walls apart, trying to open. This force is against the inner walls of the hole. The highest stresses are concentrated at the area opposite the gap. If the loading is very high the gap can close completely and the pin becomes a solid tube. If this condition occurs the hole can become enlarged and damage will result. The hole size needs to be carefully controlled for optimum attaching conditions.

Both versions of spring pins are not especially precision fasteners. The hole diameters are usually dimensioned as the nominal diameter of the pin to nominal plus 0.075mm (0.003") for the smallest diameters pins up to 0.15mm (0.006") for M6 pins to 0.25mm (0.010") for pins of M12 and above. The slotted pins are about 40% lighter than the coiled versions.

Groove pins are cylindrical pins with longitudinal grooves rolled or pressed into the body to deform the body material



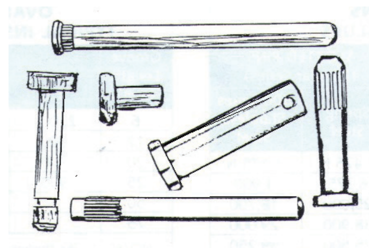
Groove Pins

outwards. When forced into the hole the raised sections are compressed, causing radial pressure against the hole walls. Although some scoring and embedment occurs, the primary holding action is the compressed groove material's reaction against the hole diameter. These pins only require straight drilled holes and reaming is usually not necessary. They are moderately resistant to shock and vibration. They are removable and reusable. Available in six types of configuration their designations are confusing with various vendors having varying systems and numbers/letters. A quick description on the types is as follows. The first has three tapered grooves running the length of the part. This is most commonly encountered type. It has excellent locking ability and is easily installed. The second type is grooved only in the middle section with parallel sided groove impressions. It is found mainly in handles and where some extension beyond the locking area is required. The third and fourth types show the grooves only extending partway from one edge. The tapers may be forward or rearward extended, depending upon which way is the greatest removal force. Other types show piloted ends for hopper feeding, chamfers for ease of installation, annular grooves at one end for a retainer ring.

The expanded diameter of the pins is usually +/- 0.055mm for pins M3-6 in diameter and +/-0.075mm for pins M7-12. Hole diameters are never to be less than the pin diameter. DIN standards specify 0.5% of nominal for oval and tapered grooves and 1% for straight and parallel grooves. Tight hole tolerances provide consistent values. Groove pins require considerable force to seat. The force to install increases in direct ratio to the depth of the installation. Conversely, the force to remove is in proportion to the depth of installation. However, small amounts of axial movement do not cause much loss of function. Some actual values are listed in the tables at the end of this article.

Groove pins withstand shear, shock and vibration well. They do not need special hole preparation and their use reduces the numbers of operations in many assemblies. They can be installed manually, automatically and hopper fed.

Barbed pins are grooved pins with the raised portion arranged circumferentially around the shank. Usually made with a head to prevent end movement and provide a positive stop they are found in many plastic applications, holding knobs, name plates and such. Since the barb is only a few thousands of an inch over the nominal diameter an exact hole size is necessary. They do not really possess any strength and their use is in mainly no-load applications.



Straight, Knurled, Clevis Pins

Rotational pins are seen every day. They hold door hinges together and a vast multitude of things at swing open and close. Often they are just a modification of a straight shaft. Making a "D" shape section prevent movement and twisting. Knurls are often added to secure the position. A secondary feature may be added to further secure the pin such as a through hole for a cotter, hair or lynch pin in a clevis pin. Used for rotational pivoting in the operation of multiple part equipment, a clevis pin has the ability to be quickly disconnected and reassembled, making it an excellent fastener for construction and other field conditions.

Keys are pins that are generally not round. Designed to slide into a groove in a shaft and gear that keep the parts together under rotational forces. While not really made of wire for the most part, they serve in a similar manner but we will leave them off this discussion for now.

The variety of shapes and applications of pins are only limited by the imagination. Pins cover a wide range of shapes, functions, and materials. They replace bolts, rivets, special shouldered parts and locator devices in many applications.

TECHNICAL DATA

The charts and data listed here are from testing, actual applications, and various literature. The values may vary from your actual usage and exemplar testing should be your final answer.

Hole Tolerance

As the pin diameter increases the tolerance of the mating hole must also increase. The chart shows the relative amounts of tolerance needed as the pin diameter increases. As can be seen, the spring coil pin can be used in relatively large tolerance (sloppy) holes while the dowel pin requires an extremely tight hole to function.

The following group of charts lists various forces and properties of the various pins.

SOLID AND SLOTTED PINS TYPICAL DOUBLE SHEAR VALUES					
Nom. Pin Dia.(mm)	SOLID PINS (Dowel, etc.)			SLOTTED PINS (Regular Series)	
	Low Carbon Steel	Hardened Steel	400 Series Stainless Steel	Spring Steel	300 Series Stainless Steel
1.5	1,780N	3,200N	3,825N	1,475N	1,175N
3.0	7,100	12,500	9,800	6,375	4,900
6.0	26,200	51,500	37,500	25,000	18,700
8.0	34,000	79,500	56,500	38,900	29,000
10.0	66,000	156,000	110,000	75,500	59,250

NOTES: Parts tested per ASTM standard for double shear. Values given are typical; actual shear strengths should be determined on actual applications.

OVAL AND TAPERED GROOVES TYPICAL INSTALLATION & REMOVAL FORCES					
Groove Length (mm)	Nominal Pin Diameter (mm)				
	1.5	3.0	6.0	8.0	10.0
6	220N	625N	2,200N	-	-
12	500	1,250	4,100	6,000N	8,000N
20	700	1,850	5,900	8,500	11,400
25	900	2,500	7,500	11,000	14,700
50	-	-	13,000	18,800	25,000
75	-	-	-	28,000	37,000

NOTES: 1. The thickness of the plate has a linear effect on the values.
2. The installation and removal values are the same for these types of pins, see below.

GROOVE PINS TYPICAL DOUBLE SHEAR VALUES				
Nom. Pin Dia. (mm)	Low Carbon Steel	Hardened Steel	300 Series Stainless Steel	Brass
1.5	155N	375N	225N	100N
2.5	450	1000	600	275
3.0	650	1500	900	400
4.0	1150	2700	1600	700
5.0	1800	4000	2500	1100
6.0	2500	6000	3600	1500
4.0	4500	11000	6500	2500
10.0	7000	16500	10000	4250
12.0	10000	24000	14000	6500

NOTES: Parts tested per ASTM standard for double shear. Values given are typical; actual shear strengths should be determined on actual applications.

STRAIGHT GROOVE PINS REMOVAL FORCES

The force to remove a straight groove pin is proportional to the length in contact with the hole walls (interference length). The values for various diameter pins, expressed in Newtons, are as follows.

Pin Dia. (mm) 1.5 3.0 6.0 8.0 10.0
Force (N) 2,200 4,150 9,500 13,100 17,000

NOTES: Values vary with hole tolerances, material, and softness. Tests show that tight hole tolerances yield higher removal than installation values. Variances can be as high as 10-20% for pins as small as M6 diameter with a hole tolerance variance of +0.13mm.

SERRATED STRAIGHT PINS TYPICAL INSTALLATION & REMOVAL VALUES

Actual values vary with panel thickness, type and style of serration or knurl, hardness, material, etc. The values shown here are for comparison only. The serrations used in this test are on a M8 diameter pin and are 3° raised tapered knurl, 32-34 serrations on the diameter, 27 TPI x 110° .

Material	Push In		Push Out	
	Avg.	Range	Avg.	Range
Stainless Steel	925N	250 – 1600N	315N	50 – 800N
(300 Series) Steel	-	2000 Max.	-	135 Min.

COIL SPRING PINS TYPICAL INSERTION FORCES		
Nom. Pin Dia. (mm)	Spring Steel 400 Series Stainless Steel	300 Series Stainless Steel
1.5	1,780N	1,350N
3.0	2,225	1,675
6.0	3,100	2,350
8.0	3,575	2,675
10.0	4,600	3,700

NOTES: Insertion forces for 25mm interference length. Values given are typical for regular series of coil pins. Light and heavy series values vary by as much as ±100%.

COMPARATIVE PROPERTIES OF PINS												
Pin Type	Cost (Piece)	Cost (labor*)	Reuse	Hole Size Sensitive	Locking Effect	Locating Ability	Use as Pivot	Prevents Loosening	Resistance To			
									Vibration	Shear	End Load	Fatigue
Coil Spring	4	3	5	NO	E	G	F	E	E	E	F	E
Slotted Spring	3	3	4	NO	E	G	F	E	G	E	F	E
Dowel	5	5	2	VERY	P	E	P	P	P	E	G	E
Taper	4	2	4	YES	F	E	P	F	P	E	P	E
Cotter	1	4	3	NO	G	P	P	G	G	G	F	F
Hair	1	4	3	YES	P	P	P	P	P	P	P	P
Hitch	1	4	5	NO	G	P	P	G	G	F	G	G
Clevis	3	4	5	NO	P	P	F	P	G	E	F	E
Groove	3	2	3	YES	G	G	G	G	G	E	G	G
Solid Plain	2	2	5	NO	P	P	E	P	P	E	P	E
Solid Serrated	3	2	4	YES	P	P	E	G	G	E	G	E

NOTES: Scales used are: Letters from 1(low) to 5(high) and Alphabetical terms P (poor), F (fair), G (good), E (excellent). *Includes hole preparation (reaming, boring, etc.), special tooling, and labor to install. Results shown are for entire family of parts. Some styles of each family and special modifications may vary from values listed.