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MECH203, Mechanical Engineering Design

Permanent and Non-Permanent Joints

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Why do we need to have permanent and non permanent joints?

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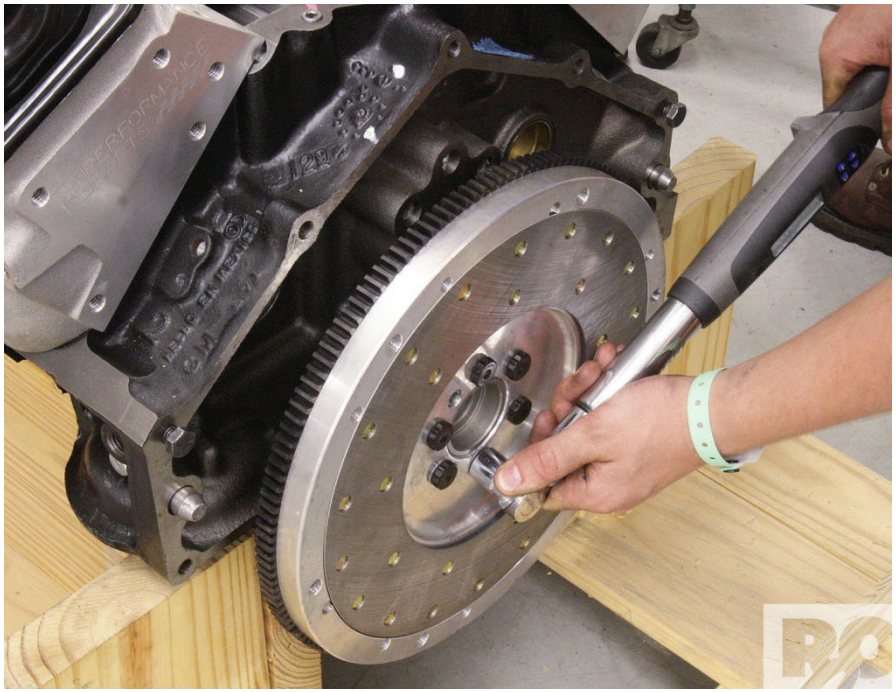
Permanent and Non-Permanent Joints

Why do we need to have permanent and non permanent joints?

We may need to be able to assemble and disassemble components regularly.



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Permanent and Non-Permanent Joints

Why do we need to have permanent and non permanent joints?

It may be expensive or not possible to manufacture components in one single piece.

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Permanent and Non-Permanent Joints

Why do we need to have permanent and non permanent joints?

We may need to join components made of different materials.

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Screws and Bolts

What is the difference between a screw and a bolt?

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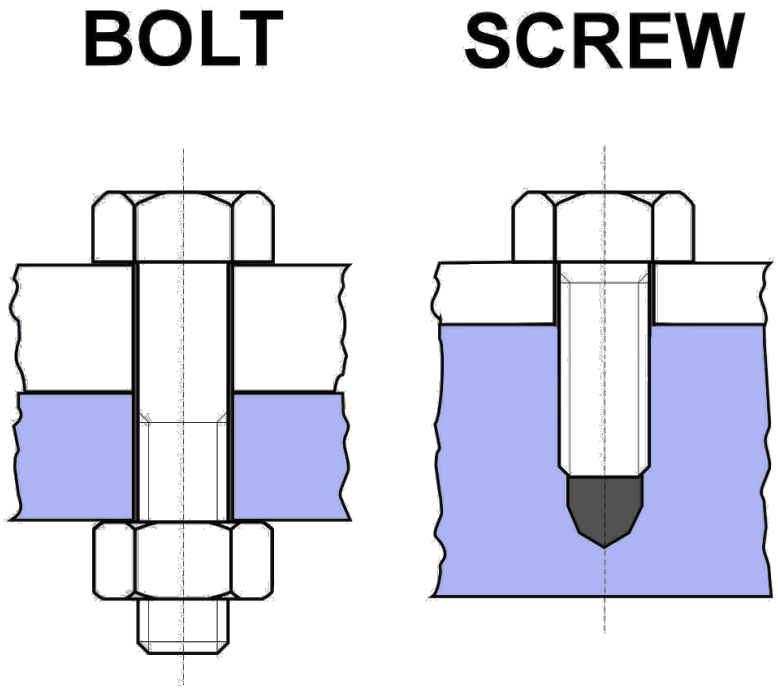
Screws and Bolts

What is the difference between a screw and a bolt?

A bolt is a fastener that is tightened through the use of a nut. A screw is tightened from the head and tightened by the thread in a hole



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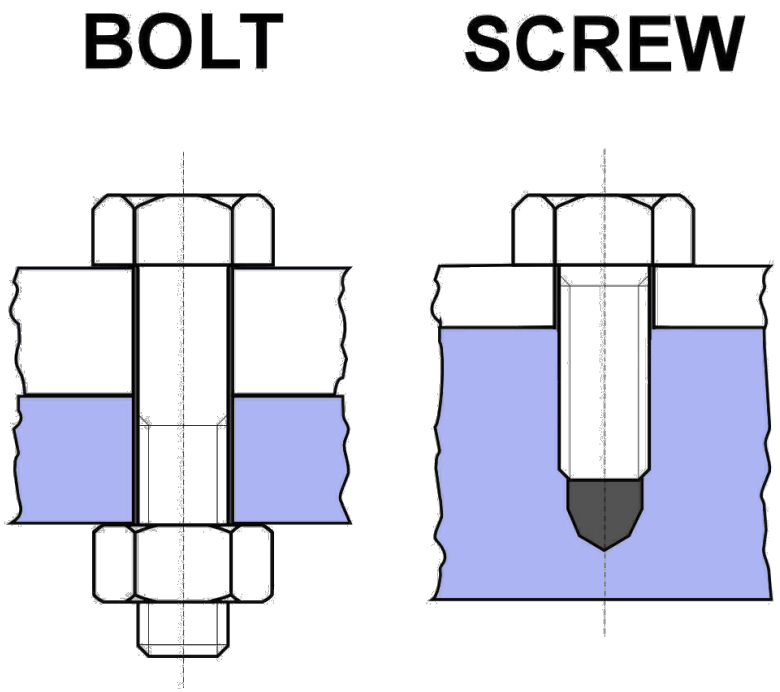
Screws and Bolts

Therefore the difference between a screw and bolt is dependant on its **application**. If a fastener is used with a nut, it is a bolt, if it is with a threaded hole, it is a screw.



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Screws and Bolts

Many bolts can also be used as screws, but some screws like self tapping screws can not be used with nuts making them unique.

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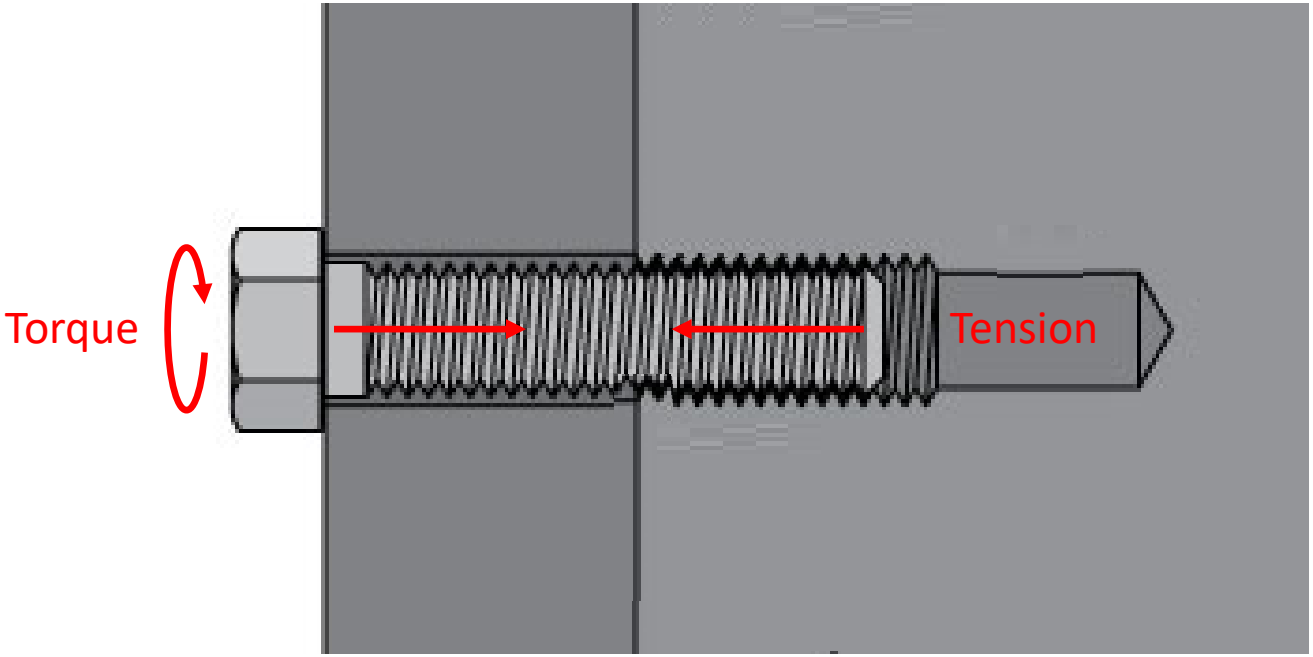
Screws and Bolts

Both screws and bolts operate in the same manner. They have torque applied to them such that the bolt or screw is placed under tension.



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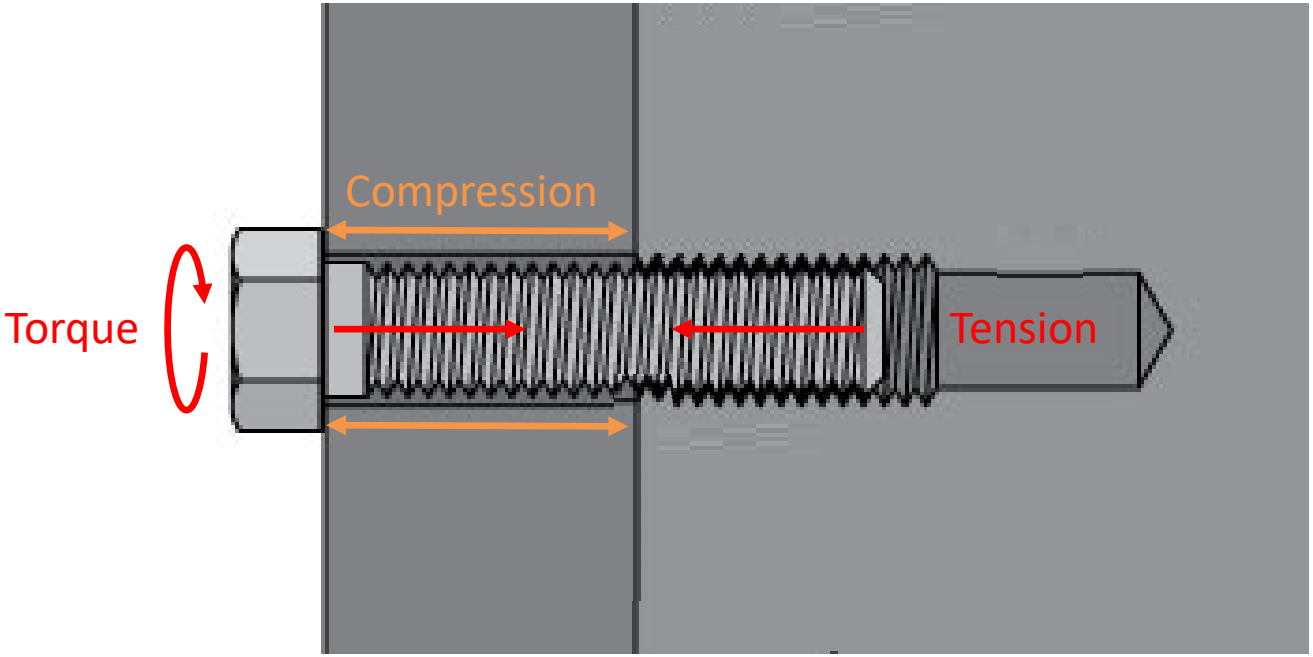
Screws and Bolts

The tension in the bolt or screw clamps the first component applying a compressive force too it and increases the friction between the two components.



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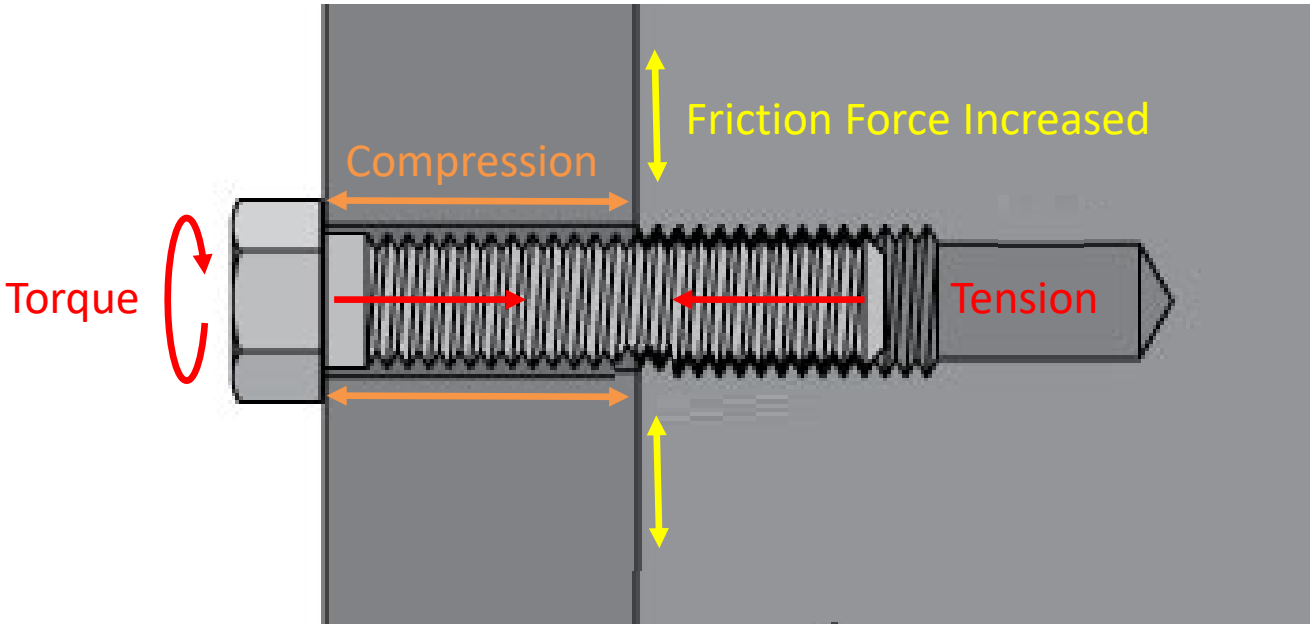
Screws and Bolts

A bolt does not prevent the two components from moving relative to each other directly. The clamping action which increasing the friction between the two allows a stronger joint in shear to be achieved.



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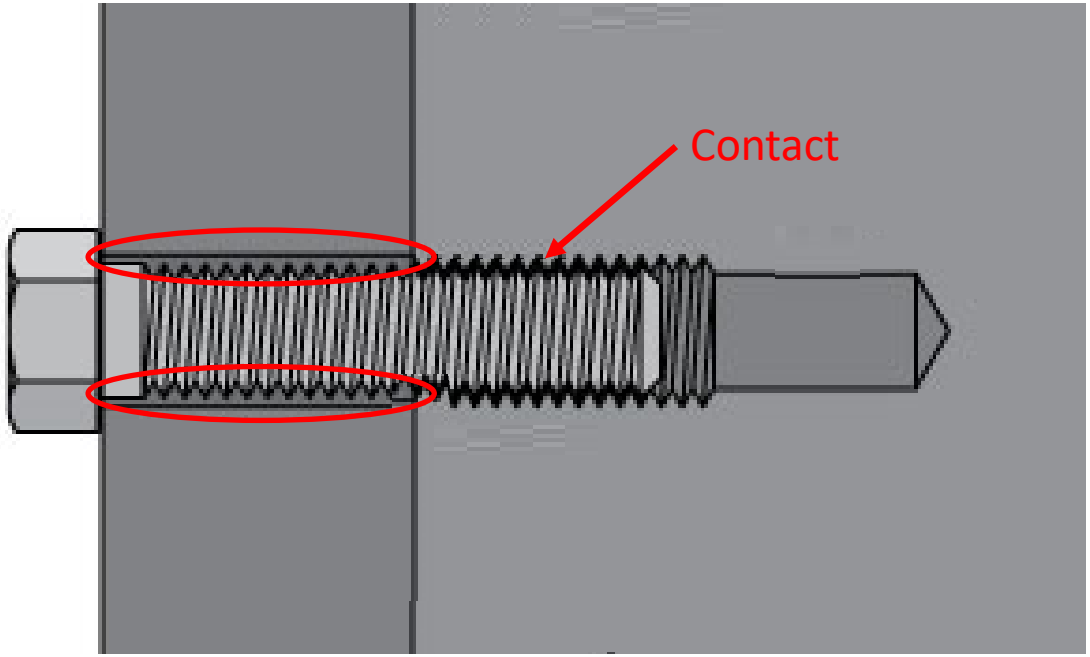
Screws and Bolts

As a result, the shank of a screw or bolt must have clearance through the component being clamped and only be fixed to the far components threads.



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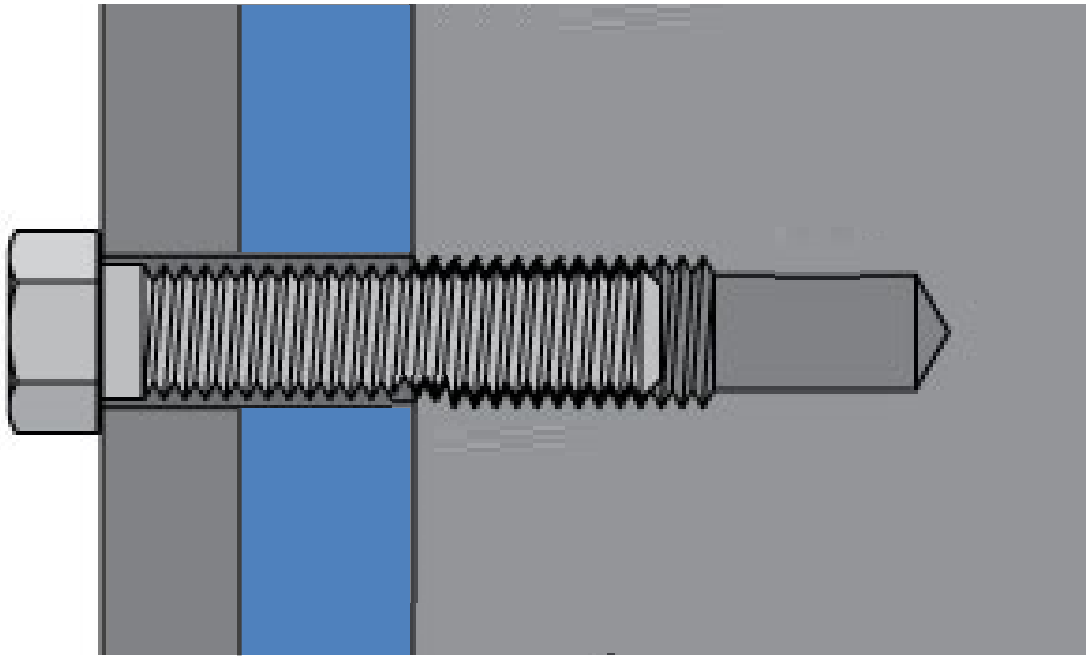
Screws and Bolts – Head Geometry

This process can also be applied with several components being clamped by a single bolt as long as some clearance is provided around the screw or bolt.



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Screws and Bolts – Head Geometry

Screws and bolts come with a variety of different heads depending on the finish required and tools available to apply the necessary torque.

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Screws and Bolts – Head Geometry

Torque can be applied to Hexhead screws through the use of sockets or spanners which have a hexagonal shape head.

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Screws and Bolts – Head Geometry

Cap head and **Domed/Mushroom** head screws can have torque applied through the use of Allan keys. They include a hexagonal recess to insert the Allan key into.

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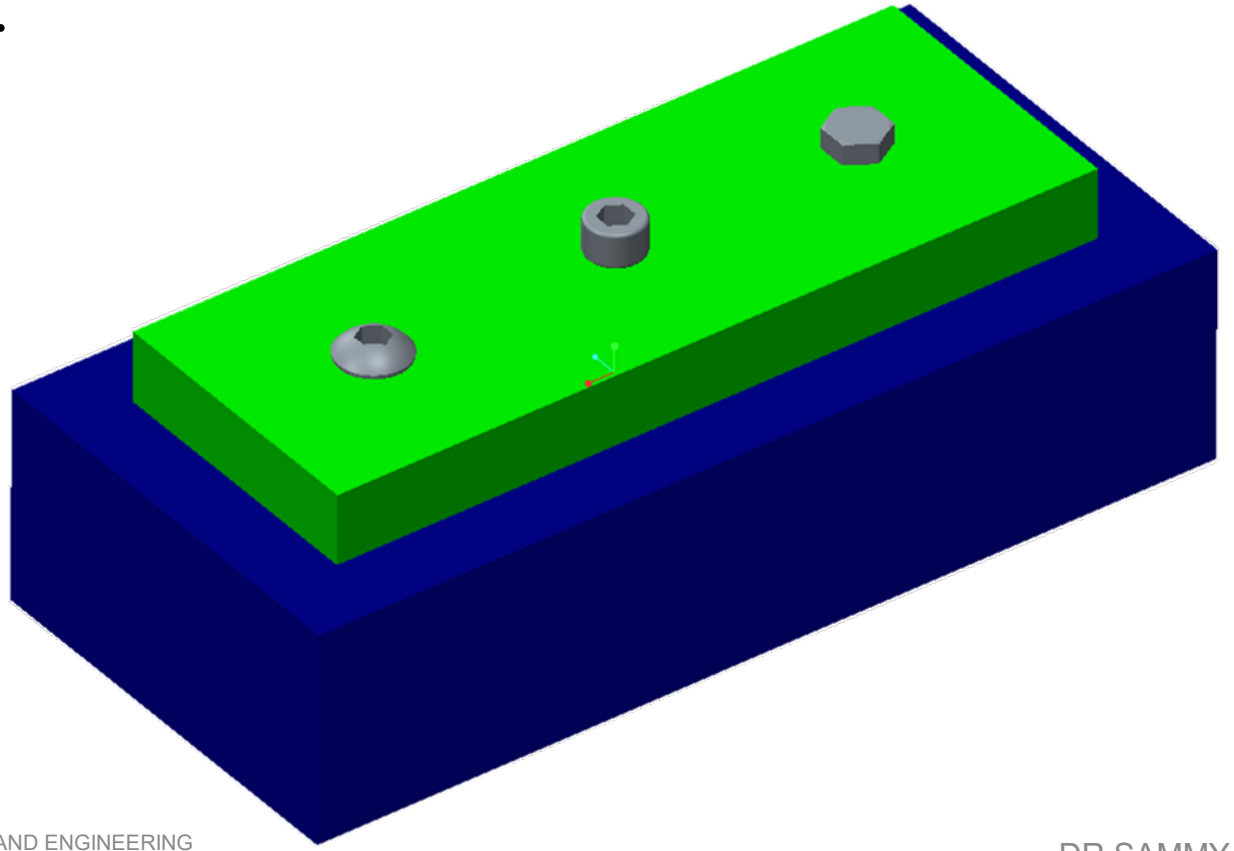
Screws and Bolts – Head Geometry

Hex head, Cap head and **Domed/Mushroom head** screws all protrude above the surface that they are bolting against in an assembly.



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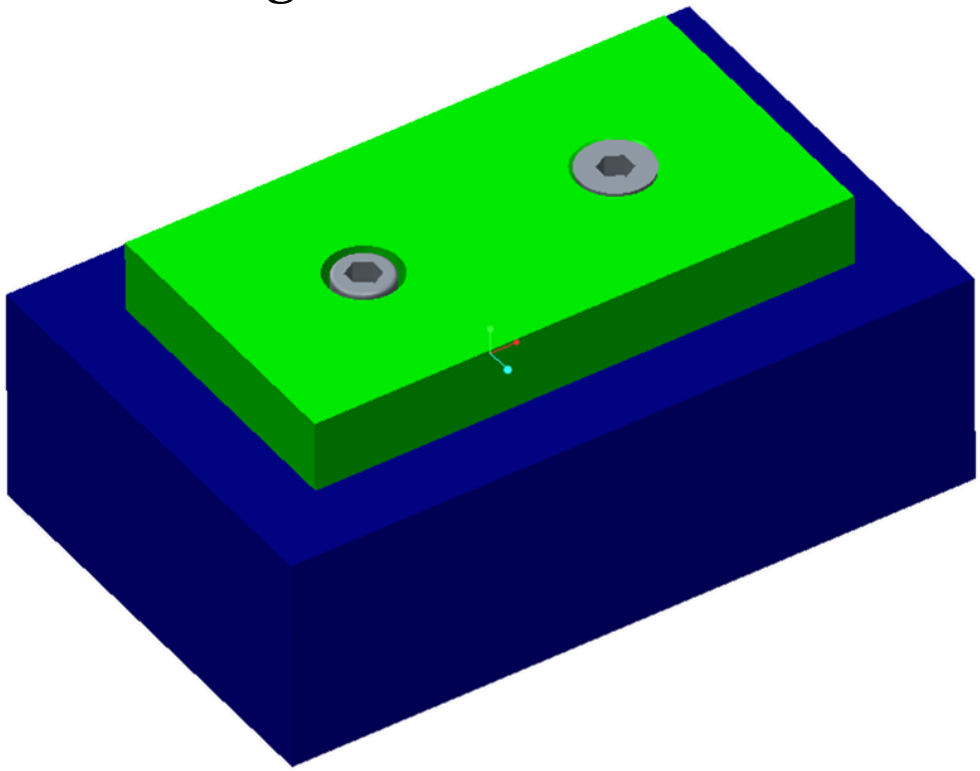
Screws and Bolts – Head Geometry

Countersunk screws fasten against a countersunk hole providing a flush finish. This is only possible when the material is adequately thick enough to accommodate the head.



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Screws and Bolts – Head Geometry

Countersunk screws can have a variety of different recesses in the head including Allan keys as well as Phillip and or flat head screwdrivers.

There are several key dimensions to specify when selecting a screw or bolt. This includes:

- The diameter
- The length
- The thread pitch and type

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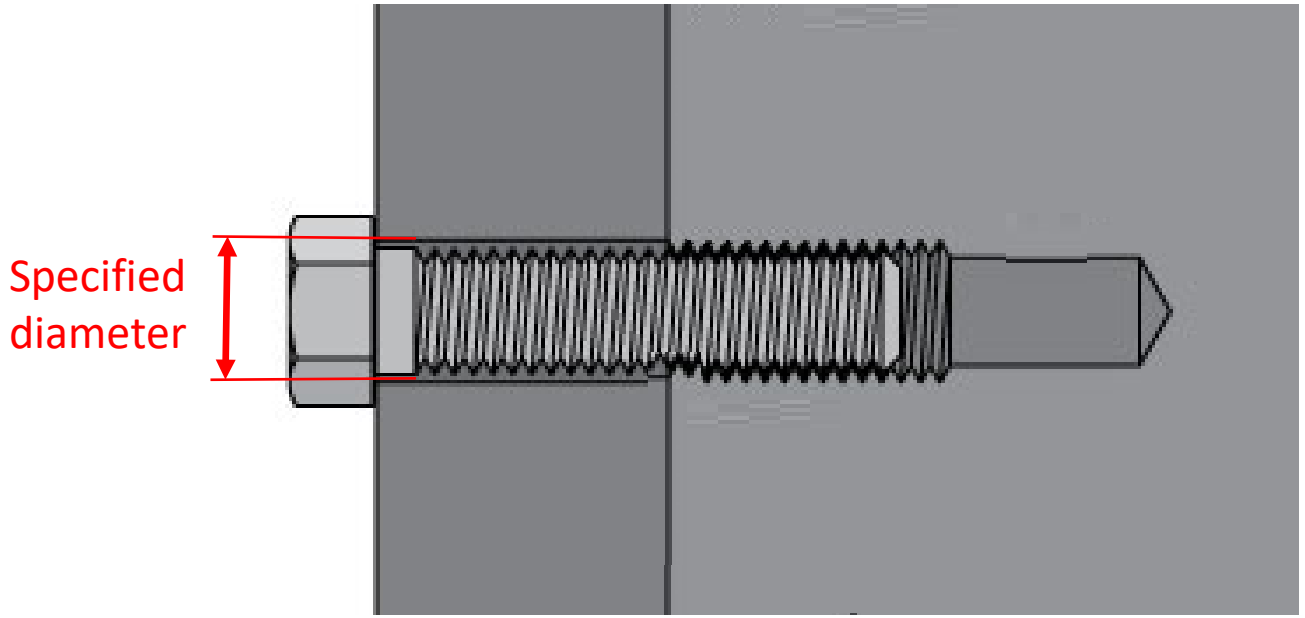
Screws and Bolts – Dimensioning

The diameter of a screw or bolt is specified by the nominal size hole that it will fit into. An M8 screw will fit in an 8mm diameter hole, but it is unlikely that any section of the screw or bolt will have that dimension.



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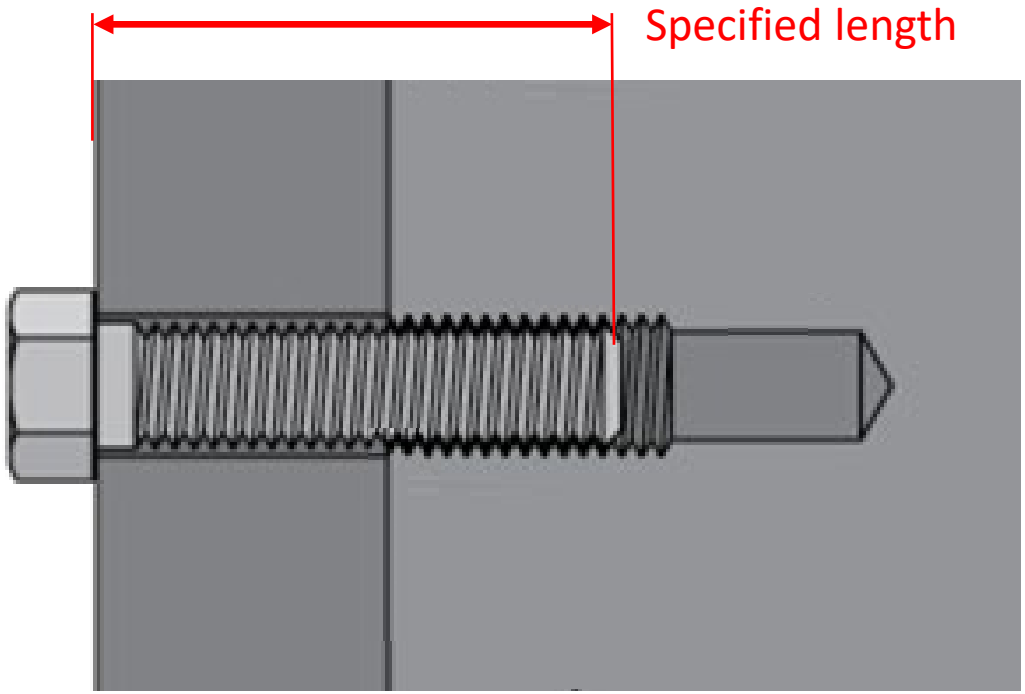
Screws and Bolts – Dimensioning

The length of a screw or bolt is an indication of the combined thickness that the component is required to assemble.



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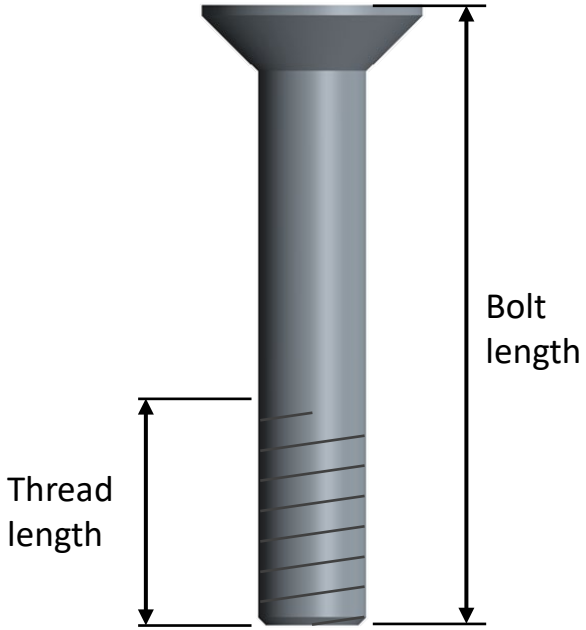
Screws and Bolts – Dimensioning

For this reason the length is specific to the type of head being used. For countersunk screws and bolts, the length is specified as the overall length.



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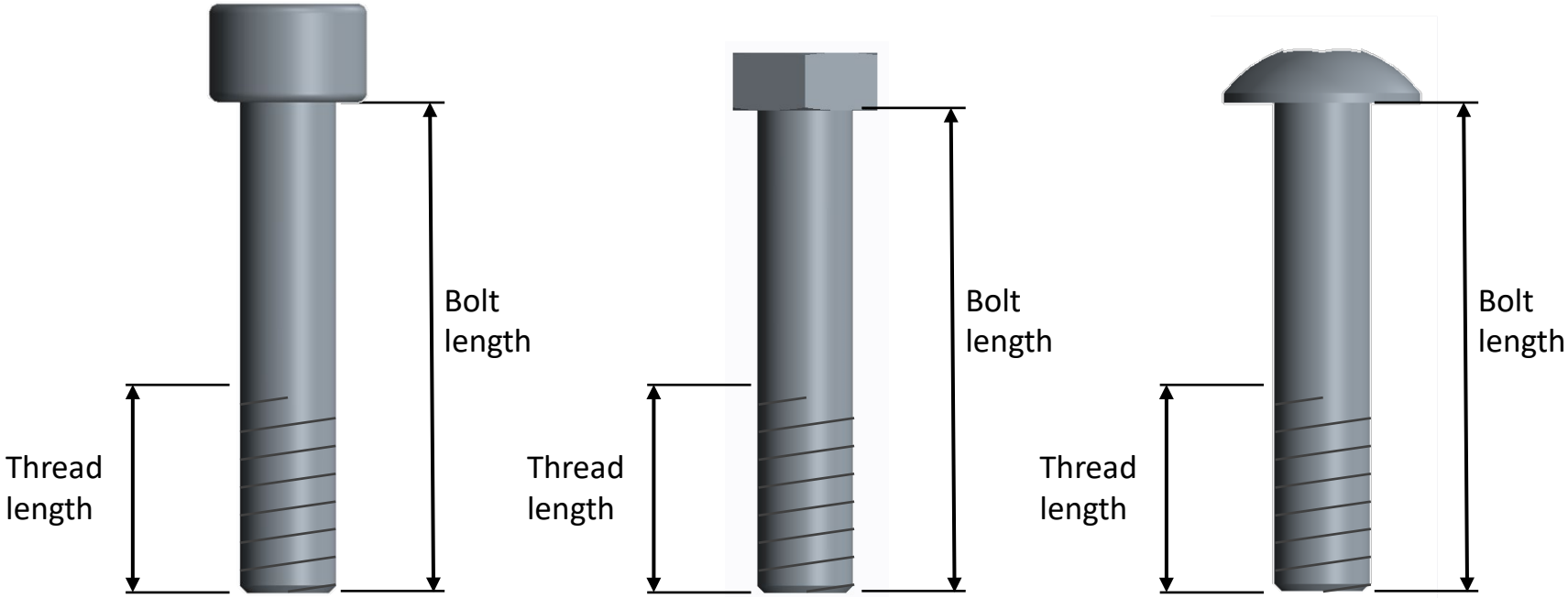
Screws and Bolts – Dimensioning

For all other screws and bolts, the length is measured from the base of the head regardless of what head type it may be.



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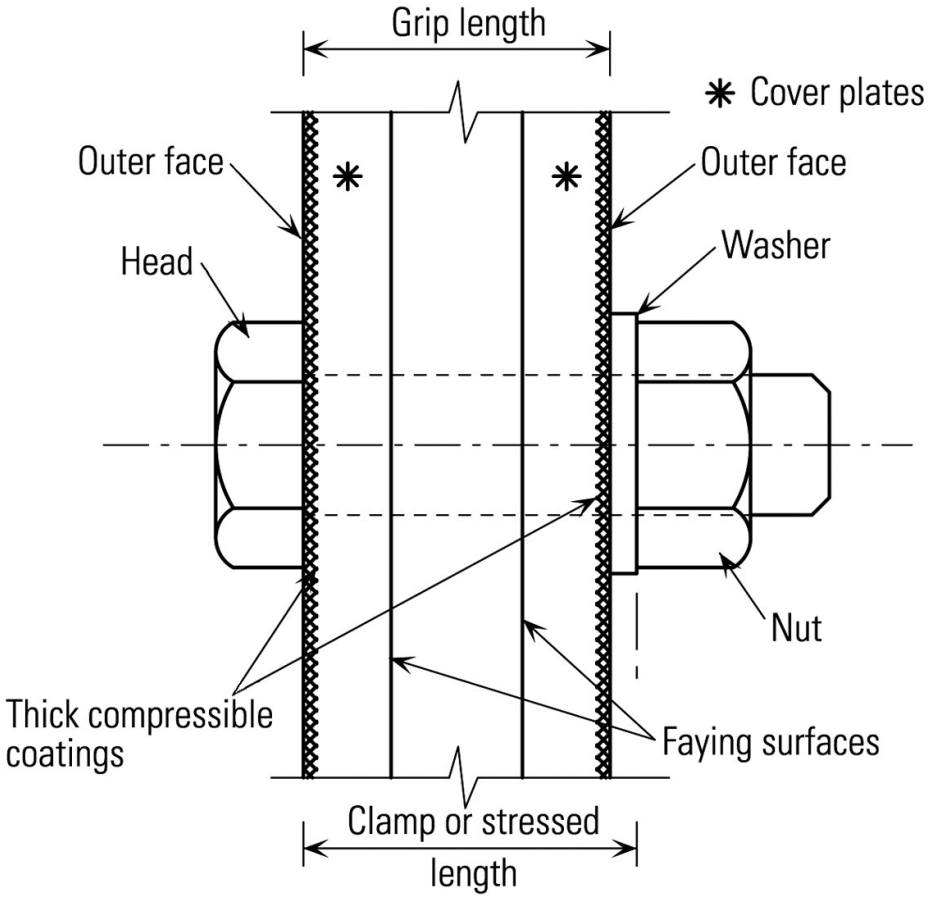
Screws and Bolts – Dimensioning

When selecting screws and bolts, be certain that the length is sufficient to also include the necessary washers and nut. At least two turns of thread should be exposed past the nut once assembly is complete.



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Screws and Bolts – Threads

Metric screws and bolts are available with two different thread sizes, either coarse or fine. Fine threads are typically only available for diameters greater than M6.

Nominal diameter (mm)	Coarse thread (mm)	Fine thread (mm)
1	.25	n/a
1.2	.25	n/a
1.4	.3	n/a
1.6	.35	n/a
1.8	.35	n/a
2	.4	n/a
2.5	.45	n/a
3	.5	n/a
3.5	.6	n/a
4	.7	n/a
5	.8	n/a
6	1	n/a
7	1	n/a
8	1.25	1
10	1.5	1.25 or 1
12	1.75	1.5 or 1.25
14	2	1.5
16	2	1.5
18	2.5	2 or 1.5
20	2.5	2 or 1.5

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Screws and Bolts – Threads

Imperial screws and bolts have a larger variety of threads and great care must be taken that the correct thread is selected.

Nominal Tap Size	Recommended Tapping Drill Size
U.N.C.	
1	1.65 mm
2	1.95 mm
3	2.25 mm
4	2.55 mm
5	2.90 mm
6	3.20 mm
8	3.80 mm
10	4.30 mm
12	5.00 mm
1/4"	5.80 mm
5/16"	7.30 mm
3/8"	8.80 mm

Nominal Tap Size	Recommended Tapping Drill Size
U.N.F.	
0	1.4 mm
1	1.7 mm
2	2.0 mm
3	2.3 mm
4	2.6 mm
5	2.9 mm
6	3.2 mm
8	3.8 mm
10	4.5 mm
12	5.1 mm
1/4"	5.9 mm
5/16"	7.5 mm
3/8"	9.0 mm

B.A.	
0	5.60 mm
1	4.90 mm
2	4.40 mm
3	3.80 mm
4	3.30 mm
5	2.95 mm
6	2.60 mm
7	2.30 mm
8	2.00 mm
10	1.55 mm

B.S.W	
1/8"	2.9 mm
3/16"	4.3 mm
1/4"	5.8 mm
5/16"	7.3 mm
3/8"	8.8 mm

B.S.F	
3/16"	4.4 mm
7/32"	5.2 mm
1/4"	5.9 mm
5/16"	7.4 mm
3/8"	9.0 mm

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Screws and Bolts – Threads

Is anybody familiar with the British Airways flight 5390?

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Screws and Bolts – Threads

Is anybody familiar with the British Airways flight 5390?

Flight where a cockpit window came loose from the plane and the pilot was sucked out, cabin crew hung onto him!

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Screws and Bolts – Threads

Is anybody familiar with the British Airways flight 5390?

He dangled outside the aircraft while his co-pilot nose dived the plane to a safe, breathable altitude and eventually landed.

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Screws and Bolts – Threads

Is anybody familiar with the British Airways flight 5390?

Fortunately the pilot survived and no passengers were harmed!

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Screws and Bolts – Threads

Why did the cockpit window get sucked out?

During maintenance conducted the day before, the aircraft mechanic did not take due care in selecting the correct pitch thread screws!

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Screws and Bolts – Threads

So how can the thread of a bolt be measured?

Thread gauges are used to determine this, they should be located against the screw to ensure pitch is correct.

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Screws and Bolts – Nuts

A large variety of nuts also exist to use in conjunction with bolts. The type of nut that should be used is specific to the application and tools that are being used.

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Screws and Bolts – Nuts

The most common nut to use is hexagonal in shape and approximately 0.8 times the diameter of a bolt. A half nut may also be used as security which usually has a height of 0.5 times the diameter of the bolt.

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Screws and Bolts – Nuts

Wing nuts provide an option that can be tightened or loosened by hand. They do not allow for the same amount of tension to be applied to the bolt as other nuts.

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Screws and Bolts – Nuts

Nylock nuts offer additional security by incorporating a ring of plastic at one end which is cut by the bolt thread preventing it from loosening. Nylocks therefore should only be used once.

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Screws and Bolts – Nuts

Castle nuts are designed to be used with locking wire or split pins. The locking wire or split pins ensures that the nuts can not come loose without cutting and removing the wire.

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DEPARTMENT OF ENGINEERING

DR SAMMY DIASINOS

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Screws and Bolts – Washers

Washers are intended to spread the compressive load supplied by the bolt and prevent the component that is being clamped from being damaged. They are available in a range of materials.

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Screws and Bolts – Washers

Spring washers assist with preventing a nut and bolt from coming loose by constantly applying a force that increases the friction between the bolt and nut thread.

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Screws and Bolts

How many screws or bolts do you think have been used in the Sydney Harbour Bridge?

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Screws and Bolts

How many screws or bolts do you think have been used in the Sydney Harbour Bridge? *- Some people say 16…*

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Screws and Bolts

These photos suggest 592 bolts and that they are only being used at the base to anchor the bridge into the ground.

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Screws and Bolts

Even 592 does not sound like very many bolts for a structure that required 8 years to build and spans over a kilometre to join Sydney with North Sydney…





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Screws and Bolts

So how was such a large structure constructed then?

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Rivets

So how was such a large structure constructed then?

They used over 6 million rivets!

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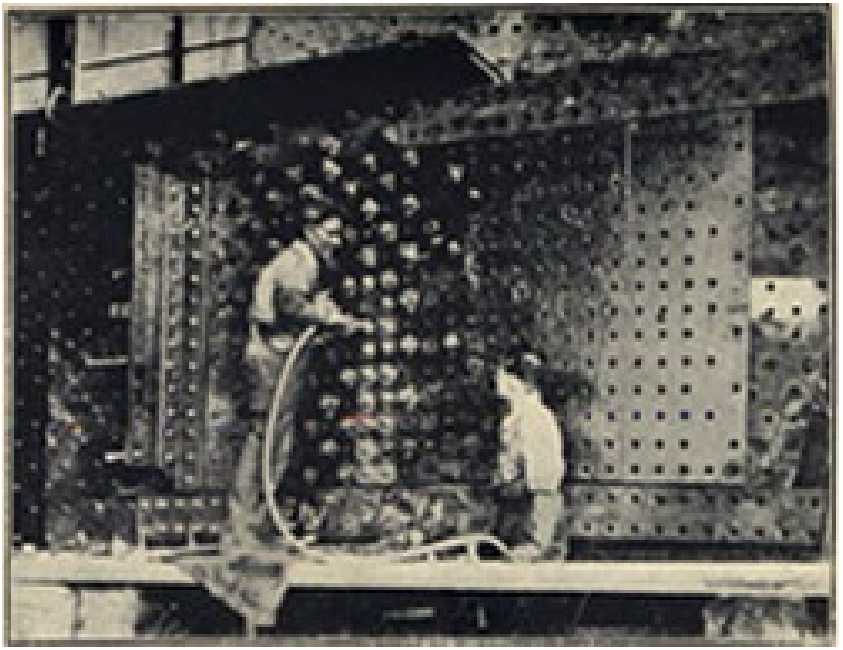
Rivets

Workers hammered heated rivets into shape using a pneumatic rivet gun while colleagues held and supported the rivets in position from the opposite side.



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Rivets

Some times they did this while enjoying a great view with no safety net…

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Rivets

Thanks to their efforts, 6 million rivets, 592 bolts and 53 tonnes of steel, we now have an excellent place to launch fireworks from!

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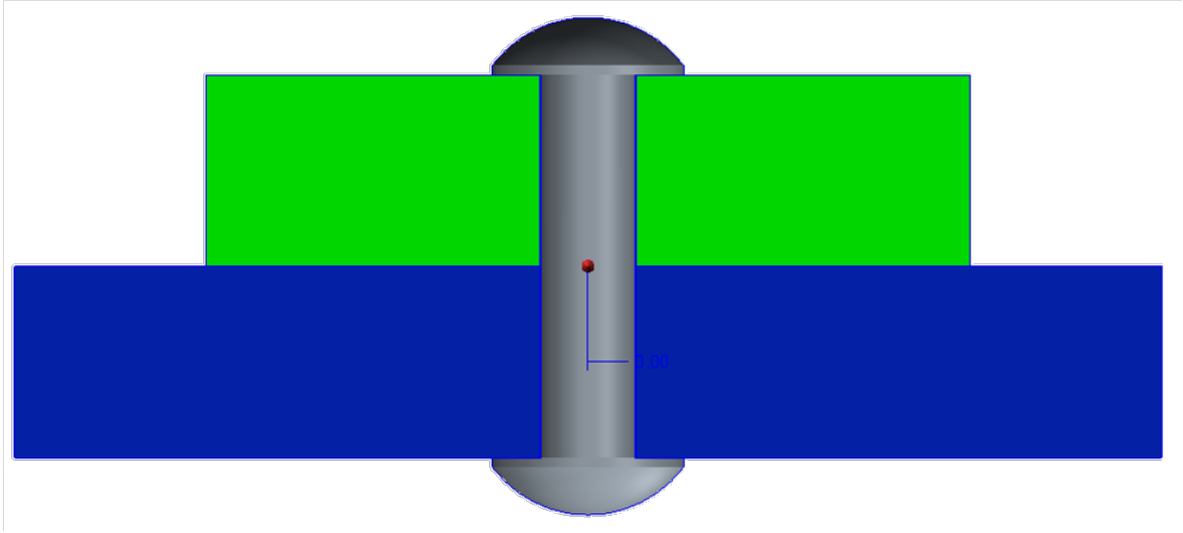
Rivets

Rivets provide a permanent joint that acts in a similar way to a bolt or screw. The tension in a rivet increases the friction between the components being assembled restricting movement in the shear direction.



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Rivets

They have historically been used over screws or bolts due to their simplicity and reduced cost of manufacture. Due to the increase cost of labour, they now are less popular.

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Rivets

A variety of rivets exist including; solid rivets, semi-tubular and blind rivets. They are also available with different head shapes depending on the desired application.

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Rivets

Solid Rivets have been used in the construction of the Harbour Bridge and many other large steel structures such as the Golden Gate Bridge.

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Rivets

They require to be compressed in order to form a secondary head and apply a compressive force to the two components being assembled. This role can now be conducted by pneumatic equipment but previously this may have been done by hammering.

When used in large steel structures, solid rivets were also heated prior to installation assisting with forming the second head and increasing the compression that it provided to the assembly once cooled.

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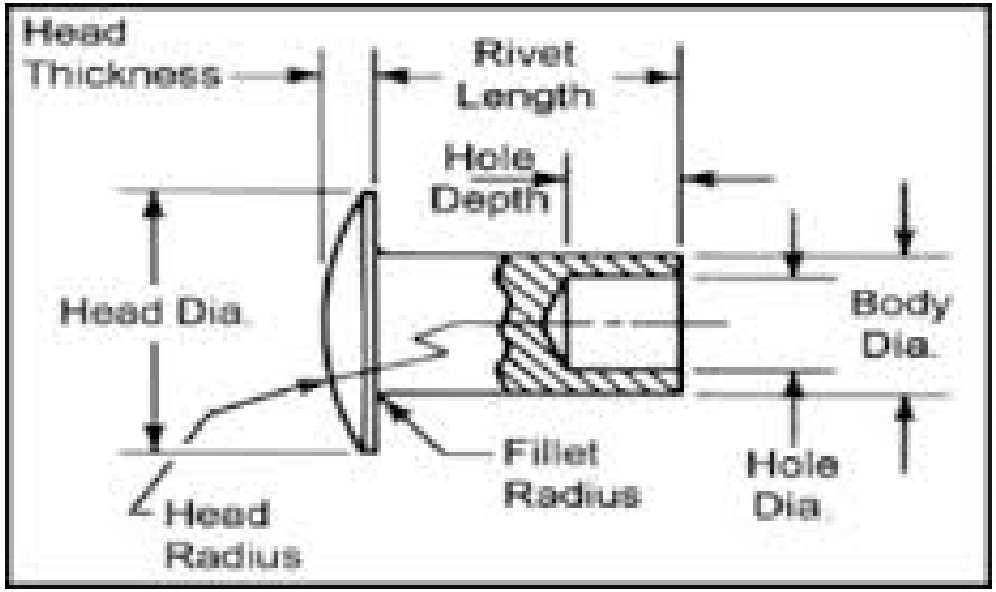
Rivets

Semi-tubular rivets have material removed from the end of the shank to reduce the pressure required to form the second head. This is typically a quarter of the force required for a similar solid rivet.



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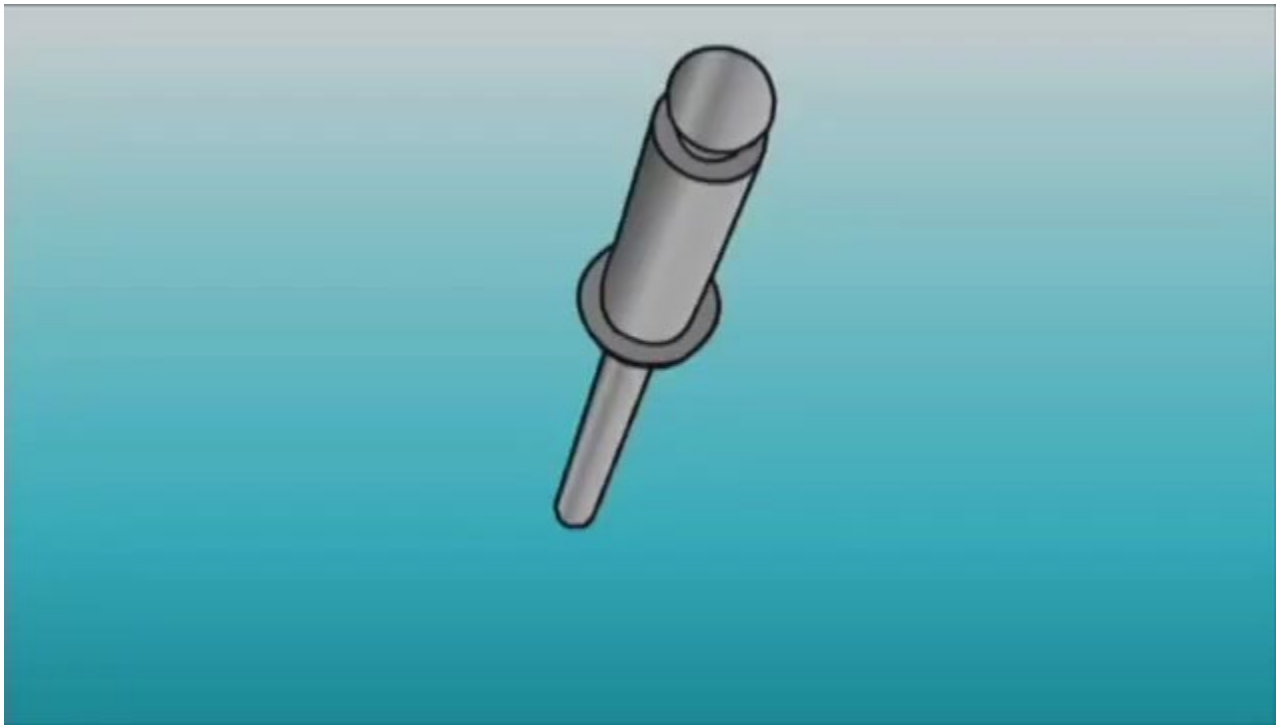
Rivets

The installation of Blind Rivets (also known as Pop-Rivets) naturally apply tension in the fastener without having to apply any heating.



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Rivets

Blind Rivets only require access to one side (hence blind) and also offer greater flexibility in the size of components that they can assemble.

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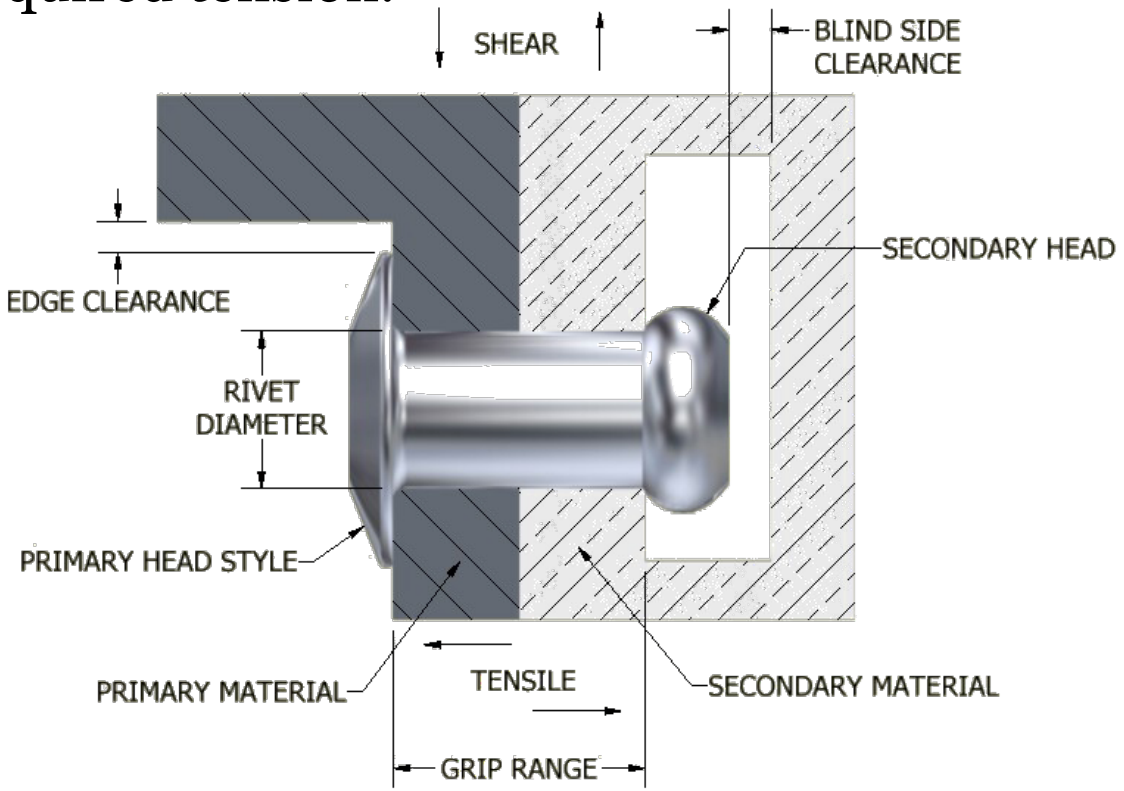
Rivets

When selecting any rivet, it is necessary to specify the diameter, the grip range (length), the head type and material required to apply the required tension.



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Welding

Rivets are not the only permanent joint that is currently available. Welding also offers a technique for two similar materials to be permanently joined together.

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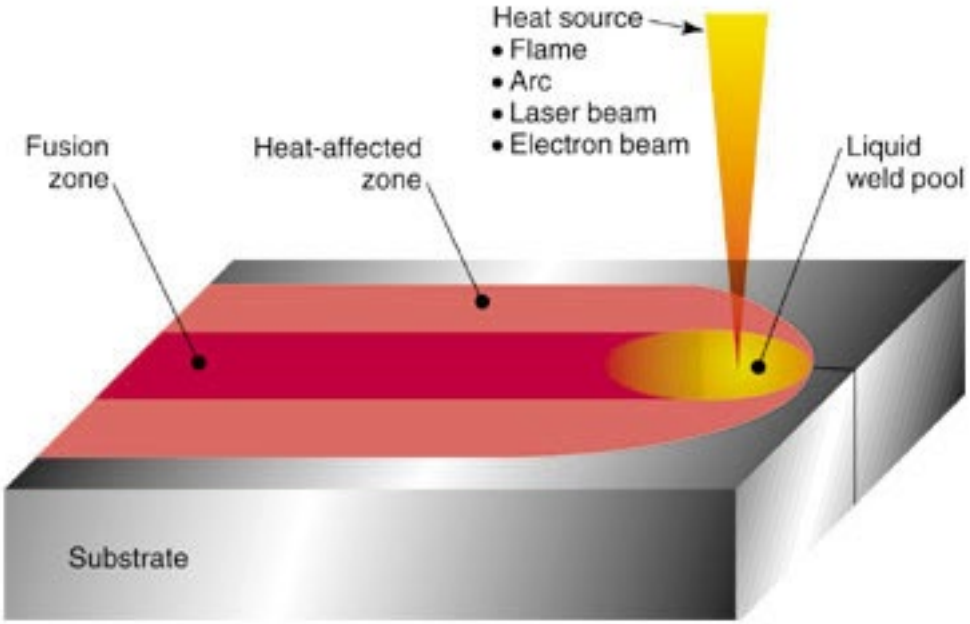
Welding

Welding is the process where two components are locally heated to the point that the material that they are made of melt and fuse together once cooled.



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Welding

Historically, this process has only been conducted with metals, but recent developments has seen welding being applied to plastics and composites.

Fig. 3: Welded Gulfstream G650 thermoplastic rudder

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Many different types of welding process exist including:

- Stick welding
- MIG welding
- TIG welding
- Spot welding
- Oxy-Acetylene welding

The first four options generate heat using large electric currents, while the last uses a high temperature flame.

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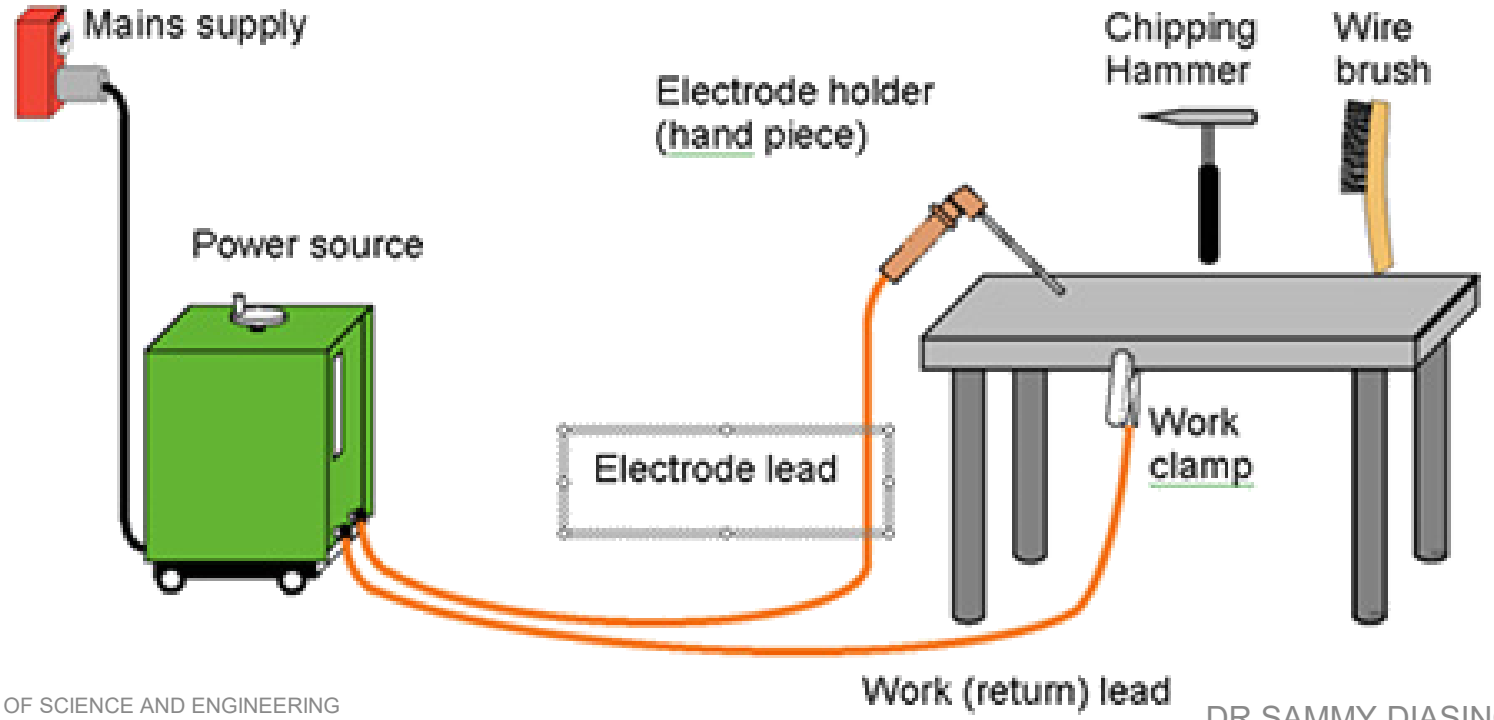
Welding

Stick welding utilises a sacrificial stick which has the same composition as the parent material being welded. Large currents are passed through the region being welded to melt the material.



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Welding

As welding is conducted, the stick is consumed, depositing itself into the final weld. As a result, the operator is required to move the electrode closer to the region of the weld as it progresses.

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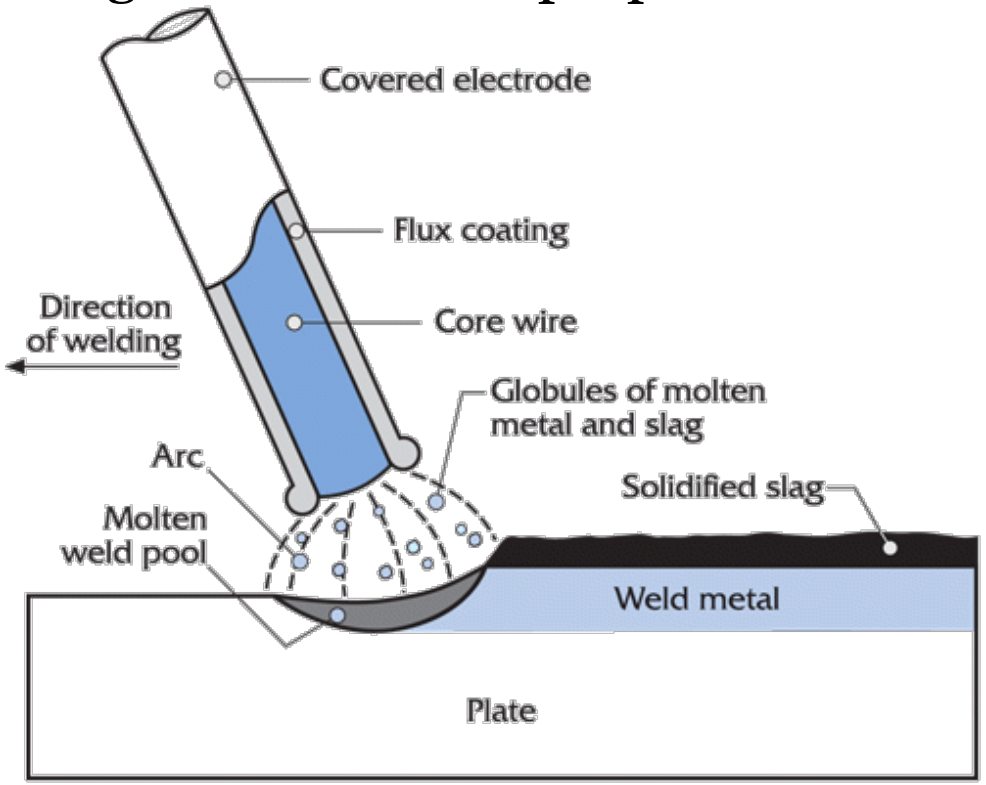
Welding

The external coating of the stick (or electrode) when melted generates a gas that prevents impurities entering the final weld and compromising its mechanical properties.



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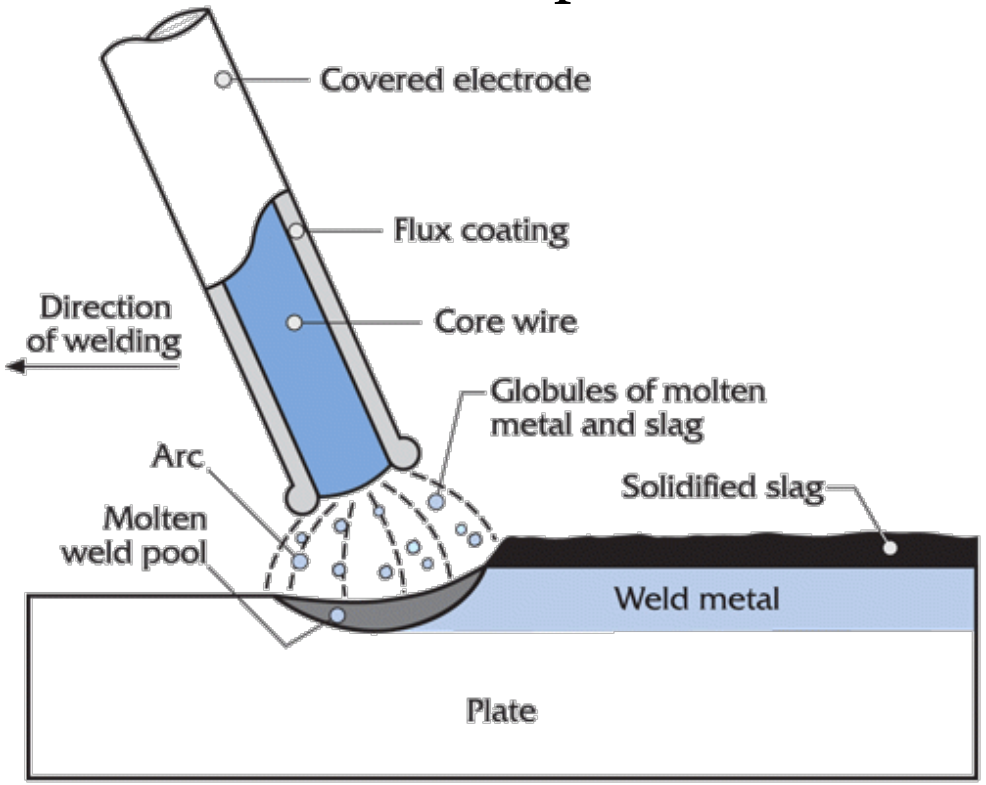
Welding

The process is heavily dependant on the distance maintained between the electrode and the parent material and as a result requires significant skill from the operator.



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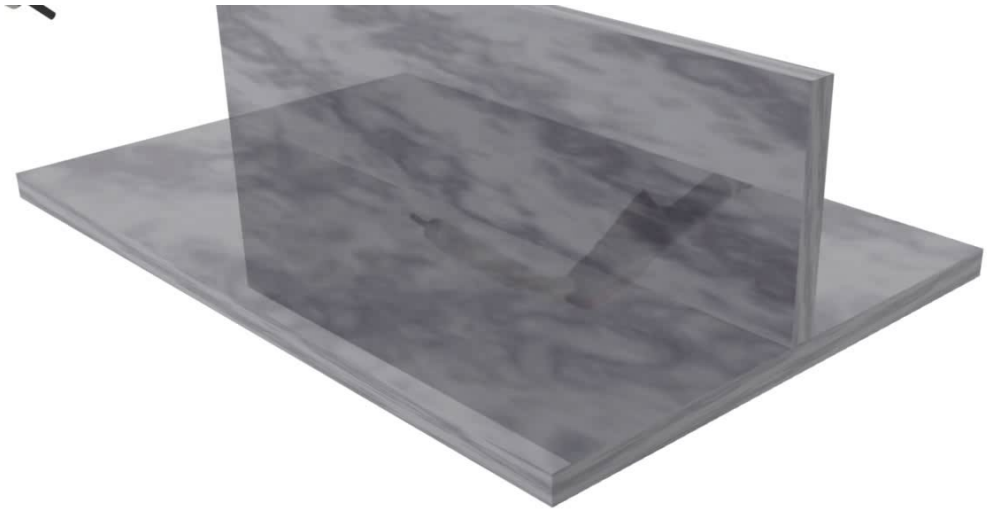
Welding

MIG (Metal Inert Gas) welding differs in that a wire, which acts as an electrode, is constantly fed to the region being welded making the process much easier for the operator.



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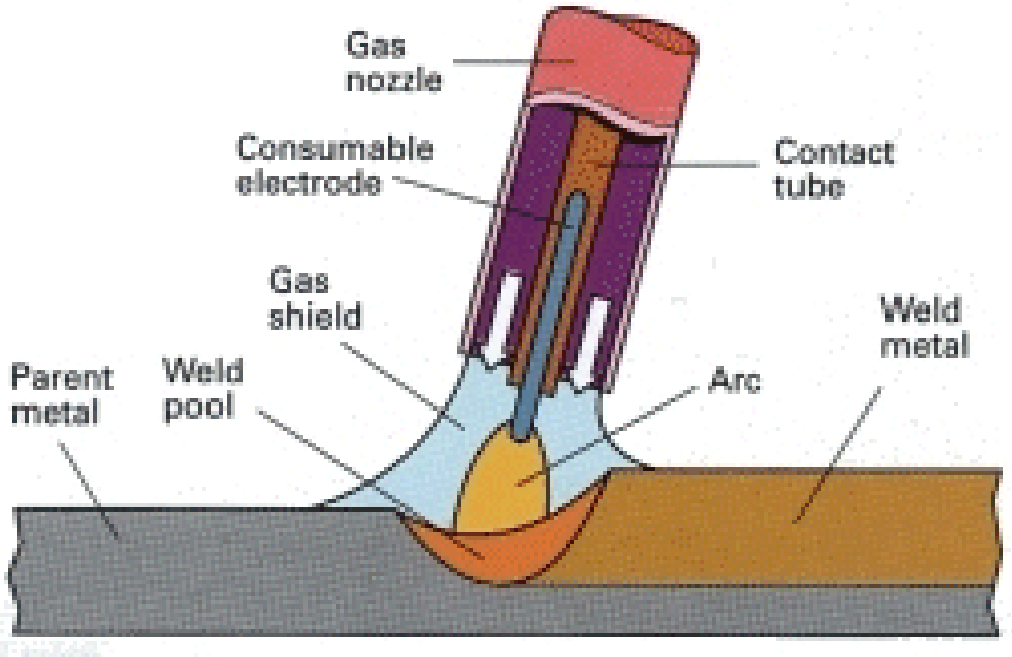
Welding

An inert gas is fed in the region surrounding the wire ensuring that the weld is not mechanically compromised by impurities.



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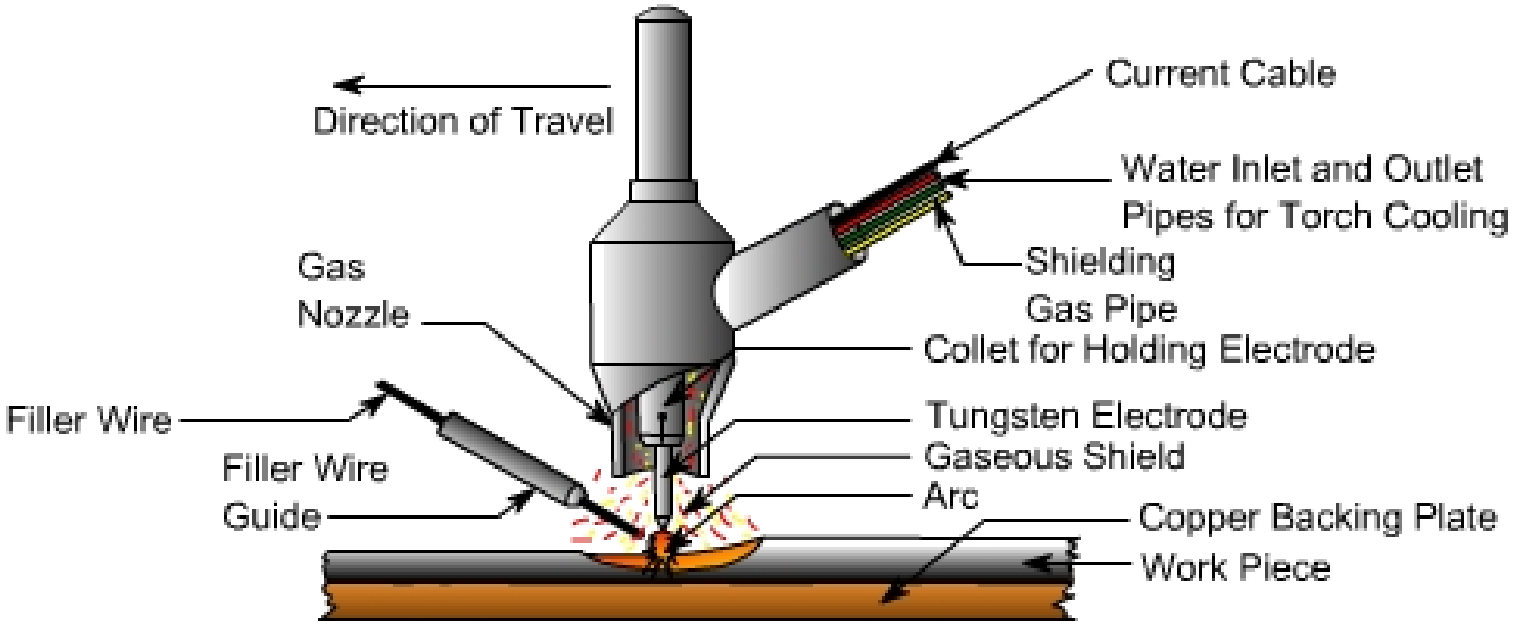
Welding

TIG (Tungstun Inert Gas) uses a tungstun electrode that is only used to create the arc which melts the material. An inert gas is also introduced from the electrode holder.



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Welding

The operator is required to feed by hand a wire into the welding region to contribute to the weld. The use of an electrode offers the most concentrated heating source making it the most suitable for detailed work.

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Welding

Spot welding utilises electrodes that clamp the two pieces of material and pass large amounts of currents between them melting them together where they have been clamped.

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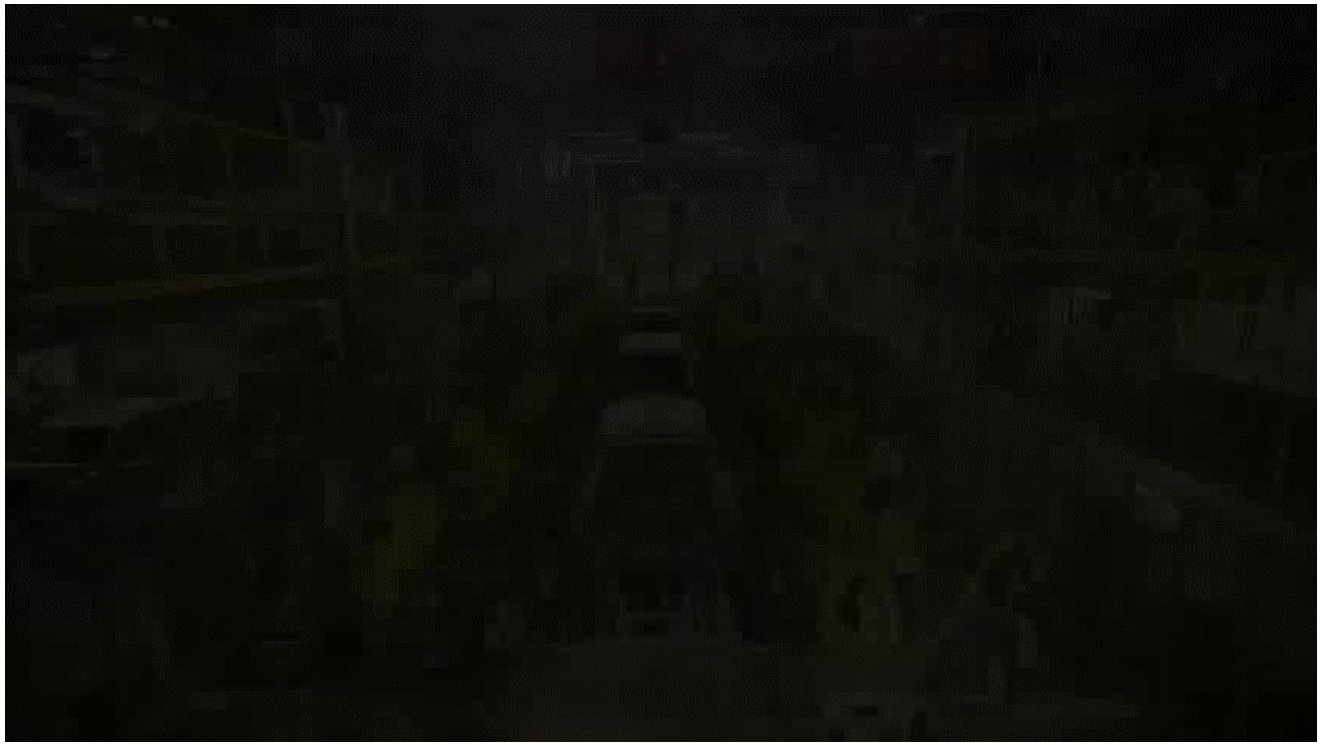
Welding

This is a common procedure used during automated mass production with components made from sheet metal such as car bodies.



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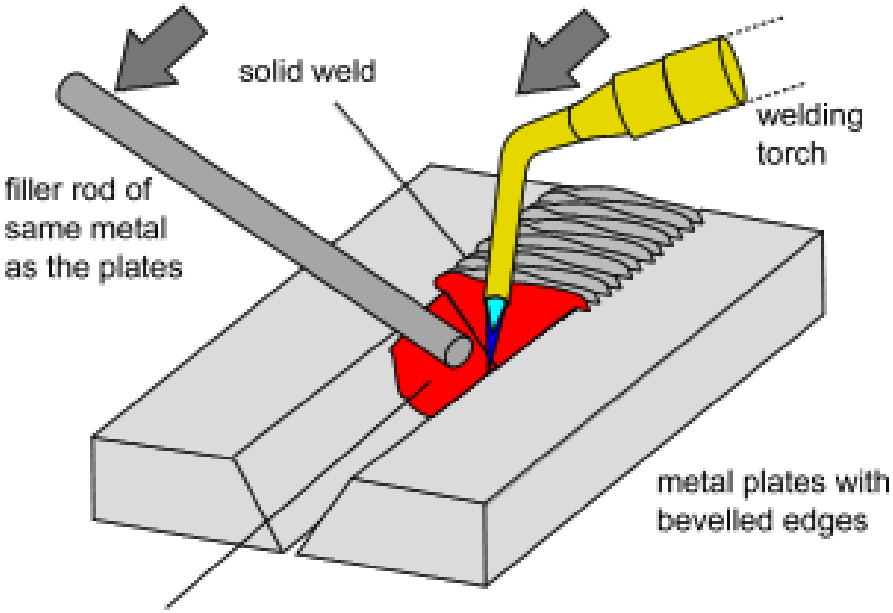
Welding

Oxy Acelatene welding utilises an ignited gas to heat the filler material and the adjacent parent material in order to achieve a weld.



Cross section of a completed weld. The edges of the metal plates and molten filler rod have fused together to form the join.

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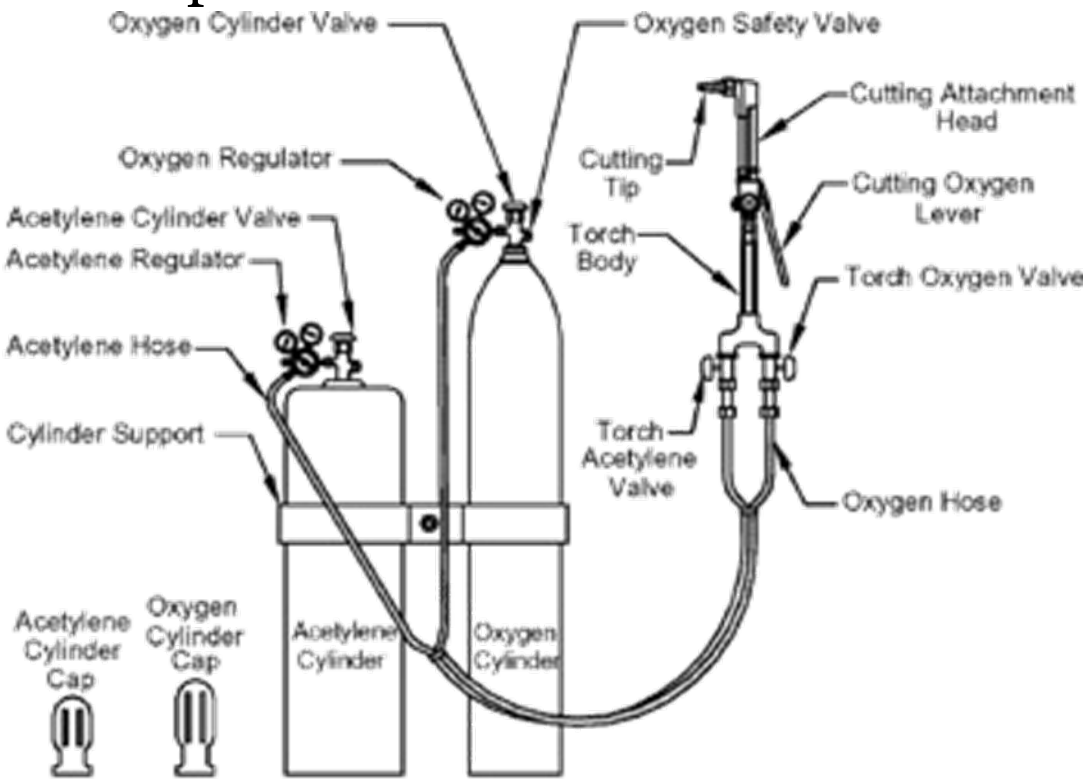
Welding

No electricity is required for this process as the torch is fed by a mixture of Acetylene and Oxygen cylinders that are pressurised and ignited with a spark.



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Welding

Since no electricity is required, this process is most suitable for remote locations and even allows for welding to be conducted under water!

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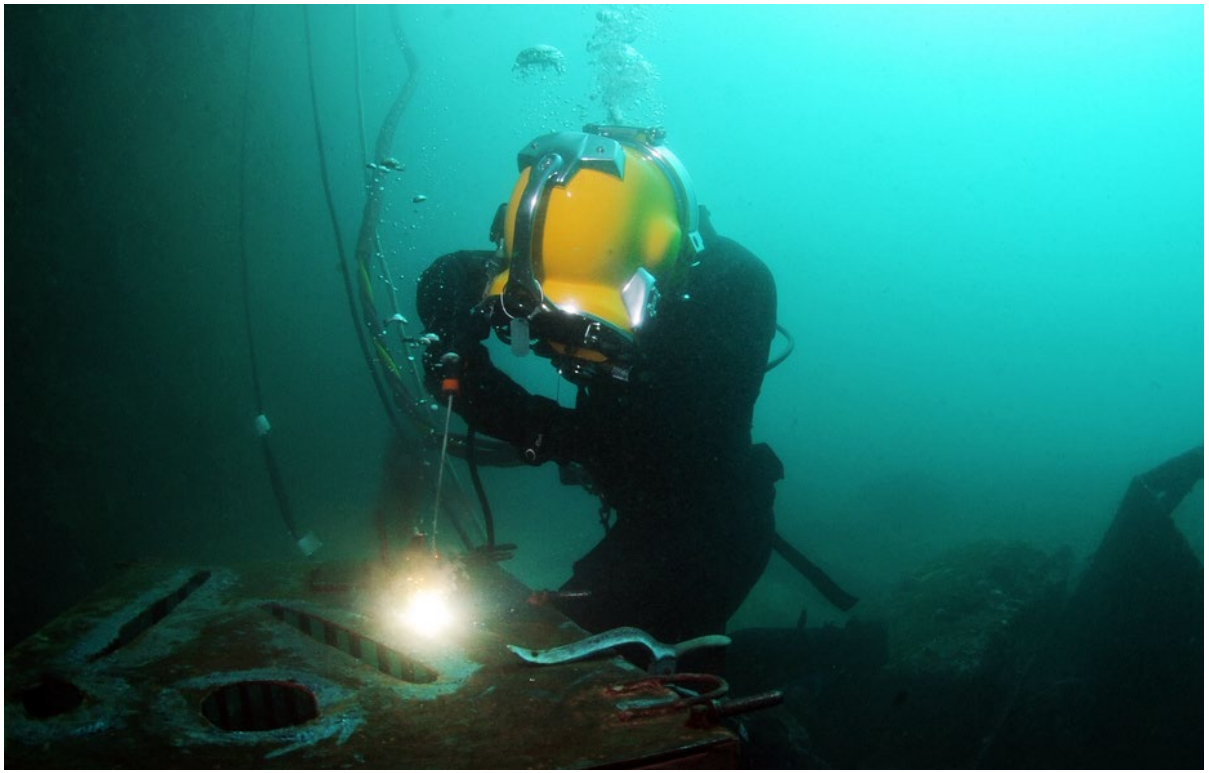
Welding

If you are comfortable using high currents while immersed in a conductive fluid, it seems that stick welding is also a possibility under water…



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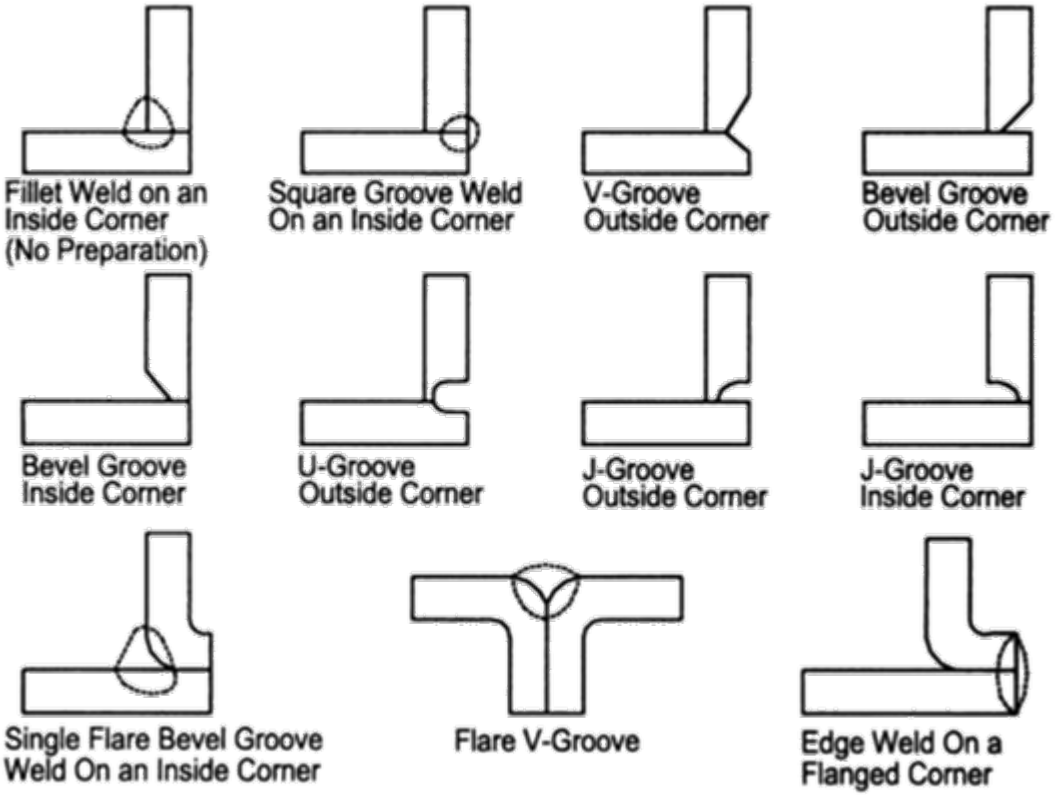
Welding

Bead, Fillet, Plug or **Groove** welds are all names given to welds that describe their location on a component.



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Welding

A consequence of the heat that is imparted on a component that has undergone welding is the geometry may be distorted as a result and it will therefore be difficult to achieve the necessary tolerances.

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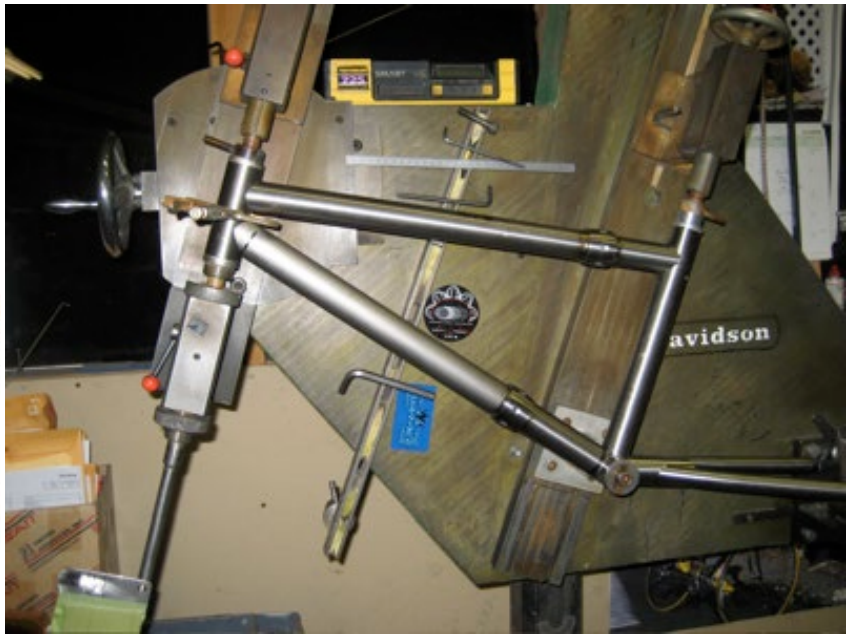
Welding

In order to ensure that the final welded component has the required accuracy, jigs and clamps are often used to hold and position the components regardless of the welding technique used.



What methods are used when we wish to permanently join components made of different materials when fasteners are not desirable?

MACQUARIE University

What methods are used when we wish to permanently join components made of different materials when fasteners are not desirable?

*We use **Bonded Joints** that may include either brazing, soldering or cementing.*

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Bonded Joints – Brazing

Brazing is when two different materials are joined by using a third material that has been heated to fill the gap between the two components utilising capillary action. This provides a very smooth/neat finish.

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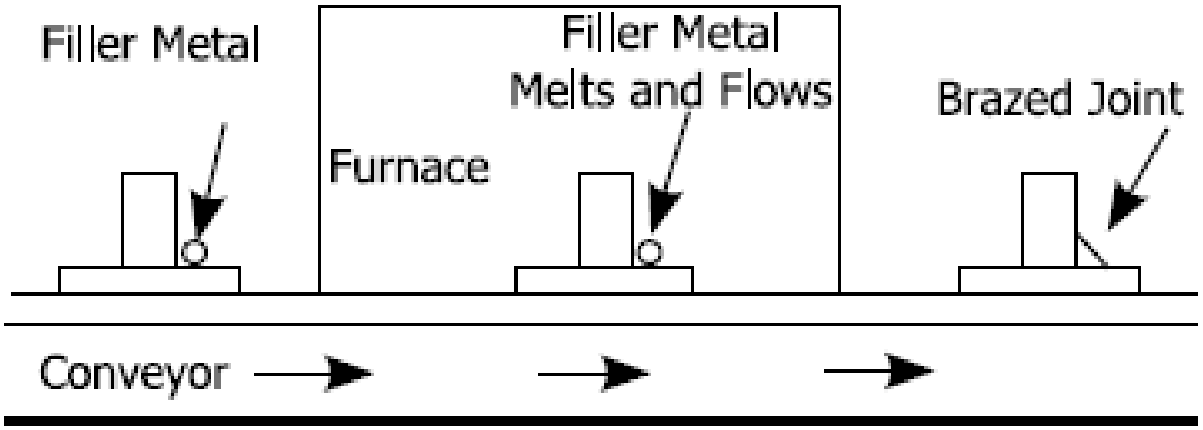
Bonded Joints – Brazing

The components are heated to temperatures greater than 427^{O}C (800^{O}F) using either a furnace or a high temperature flame to melt the third material allowing the capillary action to occur.



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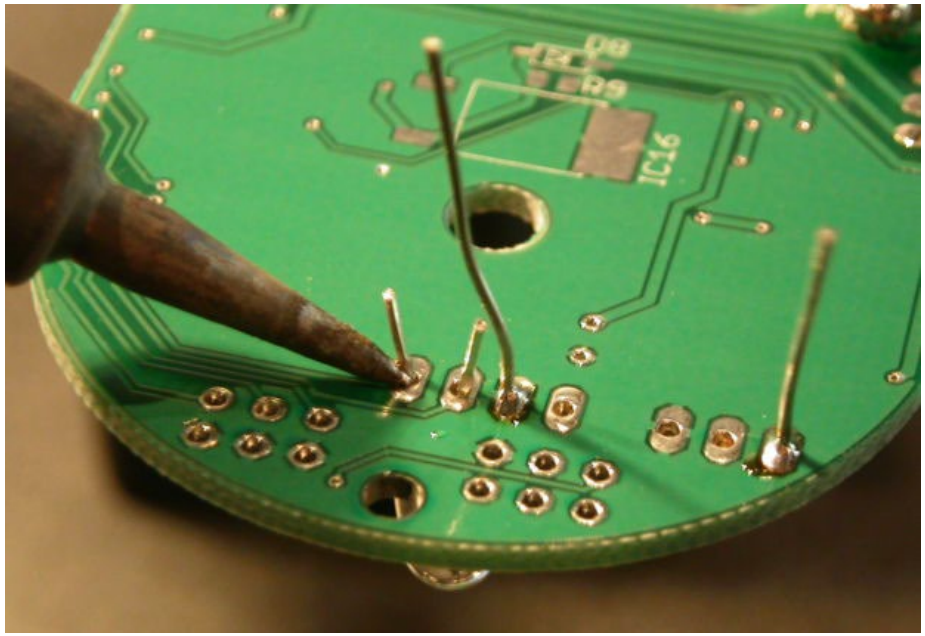
Bonded Joints – Soldering

Soldering is similar in process to Brazing, but conducted at temperatures less than 426^{O}C. Joints using this technique should ensure that the parent materials take all the loads. Typically utilised for electrical applications.



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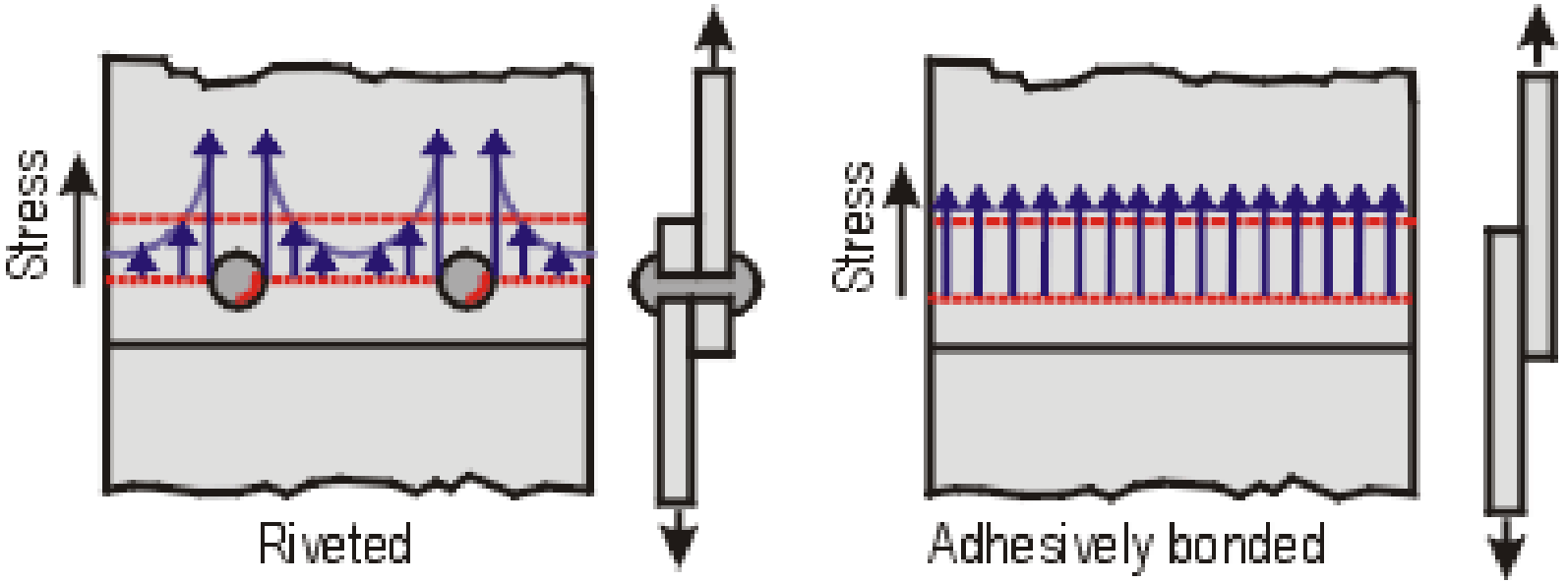
Bonded Joints – Cementing

When an adhesive is utilised to join two components, this is called Cementing. Adhesives offer advantages over fasteners in that they provide much more distributed loads.



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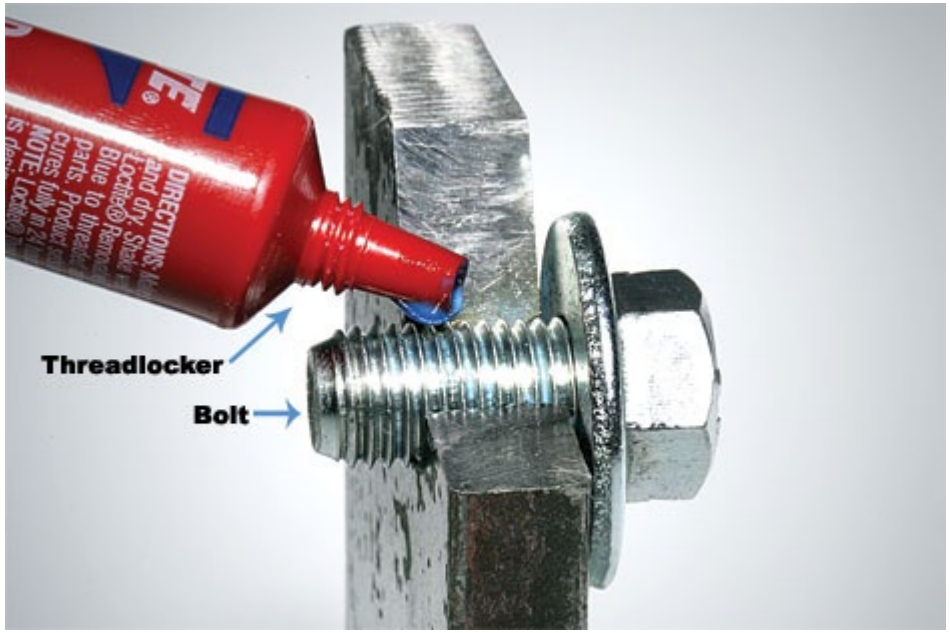
Bonded Joints – Cementing

Most adhesives remain inert until some curing process activates the adhesive. This process may include:

Anaerobic curing



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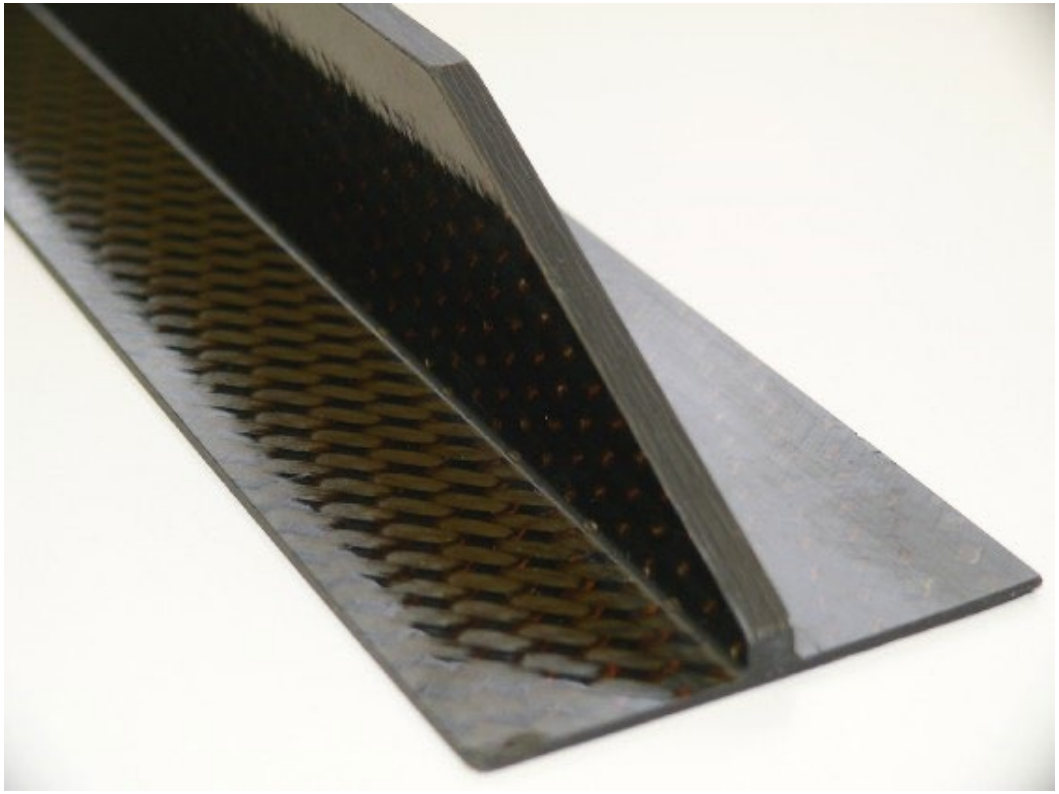
Bonded Joints – Cementing

Most adhesives remain inert until some curing process activates the adhesive. This process may include: *Heating*



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Bonded Joints – Cementing

Most adhesives remain inert until some curing process activates the adhesive. This process may include: *Interaction*

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Bonded Joints – Cementing

Most adhesives remain inert until some curing process activates the adhesive. This process may include: *Solvent evaporation*

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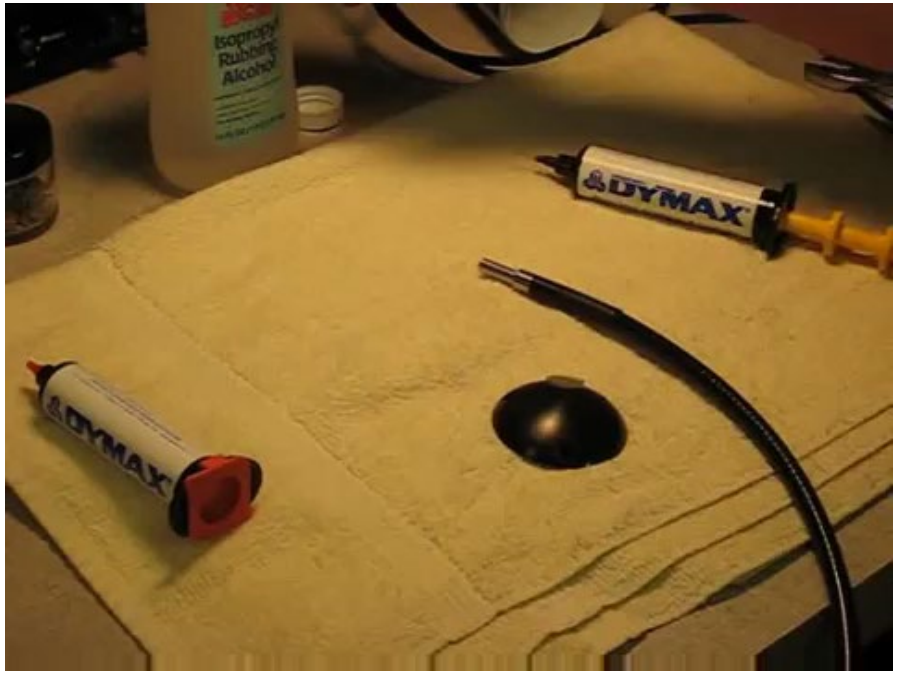
Bonded Joints – Cementing

Most adhesives remain inert until some curing process activates the adhesive. This process may include: *Ultraviolet light*



Due to the scale, complexity and need to maintain equipment, it is necessary to use a selection of permanent and non-permanent joints.

Fasteners include bolts and screws as well as rivets all of which are available in a large variety.

Welding and bonding offer more permanent joints, but care must be taken to ensure that the process selected meets the geometric tolerances required.