



Holes To Fasten Things With

by Peter Standring

Holes cost money! OK, so the statement doesn't have the impact of, $E = MC^2$ but non-the-less it is a fundamental truth. Try to buy one, make one or create one and it can become both expensive and confusing.

Two stories on this problem come to mind, one read about, the other shown. Many people travelling the iconic Route 66 through Winslow, Arizona will have passed by Meteor Crater. Formed around 50 000 years ago by an asteroid, it found media fame when NASA used it to train its Moon bound astronauts. Before that, a Philadelphia Lawyer spent much of his summers and most of his money digging holes in the bottom seeking the meteorite which did the damage. When he died, virtually bankrupt with nothing to show for his efforts, his wife wrote to the Governor of Arizona asking if he would like to buy the hole. He politely refused her invitation by saying he already had a bigger one, the Grand Canyon.

On a much smaller scale, a friend of mine who had a business refurbishing large forging presses etc., invested half a million British Pounds in constructing a deep pit within his factory. On completion, he was very concerned to find his local taxman refused to allow his investment as Capital Expenditure. Inviting the official to view his pit, my friend was intensely frustrated to find that to the taxman, his hole



was not considered an investment and therefore not deductible as Capital Expenditure.

"Very well," my friend told the taxman, "I will give you the hole in lieu of my tax payment."

These two stories, whilst amusing to those not involved, do carry a message. In Arizona, the crater, which could not be grazed, farmed or sold, was retained by the family and is now a Visitor Attraction. Unfortunately, my friend had no success with the taxman and eventually had to write his hole off as a loss.

This tells us that it's the location and what you put in the hole that matters. In the wrong place and empty, a hole is just a hole and has little value.

Old Holes

The ability to take two disparate items and use a third to fasten them together is mankind's first and most fundamentally important invention. Woven grass and vines could be used to tie a stone to a stick but sharpening a stick to produce a hole must have ranked with the discovery of fire when it was used to produce clothing and shelter.

Over time and no doubt through much experimentation, early humans learnt how to produce holes in harder materials such as wood, bone/shells and stone. The purpose of the holes being to aid fastening.

Boats, made from animal skins and later wooden strips tied together provided waterway transport and trade. The wheel, first in solid form then as a spoked system was only made possible by the ability to create more consistent holes. With metal casting, the use of cores to form holes and later techniques of lost wax processes, made holes the 'centre' of advanced technology.

However, the ability to create metal plates and sheets from gold, copper alloys and later iron, introduced a major difficulty of how and where to make the holes which could be used to fasten them. Since the population groupings where technological developments could take place were regionally based and required protection from other similar groups, it followed that the survival strategy would be defensive and the leaders, militaristic. This meant that those creating holes in hard to work, generally metal products, would be making things to fight with.

Holes made in woven fabrics required binding to prevent tearing and unravelling. In the same way, punching holes in sheet metal would produce splitting and tearing along with thinning, sharp edges and burrs. These defects could not be allowed on holes used to fasten armour with woven thong or of jewellery with thread. So, metal workers, very quickly discovered the need for edge protection.

The ancient methods of producing holes in hard materials is interesting. In Neolithic (Stone Age) times, monument builders, like those at Stonehenge in the UK made the blind holes (mortise) which the (tenons) on the top of the upright stones fitted into to make the famous Trilithons (lintels). Earlier examples in oak timber have been found in Germany. The world famous full size Egyptian 'Solar' boats buried to carry ancient Pharaohs across the night sky were also found to have been constructed using mortice and tenon joints along with through holes to tie items together. Egyptologists and others are still debating how holes, tens of centimetres long and 50mm diameter were produced in

granite sarcophagi. Examination of the internal hole surfaces has revealed close concentric rings. Cores have been found to show that the holes were made using copper tubes. Archaeologists questioned, was this done wet or dry using a hard loose grinding medium or one which was impregnated into the copper like a modern diamond cutting tool? The purpose of these often blind holes was to hold wooden pegs used to lift objects weighing tonnes

Simply viewed as a manufacturing operation, it seems to this author that such concentric rings would be formed by the rapid replacement of copper tooling once an effective cutting surface had been lost. The first thing any competent worker does is to learn how to make the job easier. And, if the Pharaoh of the day was paying a bonus to get his eternal resting place completed before he died, then the worker wouldn't require a statistical process control (SPC) chart to determine when to replace worn tooling! Surely, a smart Pharaoh would then introduce a 'Time and Efficiency Scheme' employing 'Time and Motion' personnel who in turn would morph into Ergonomists?

If our post Industrial society lasts for over three thousand years as did that of the Ancient Egyptians, perhaps we could demonstrate, 'there is little new under the sun!'

Holes for fasteners

As the Bronze Age gave way to Iron, the need to create better, more accurate holes increased. As with all holes, the key aspect is not how to make it but what it is used for. In short, 'functionality' is the reason to do anything and without that, no hole would be produced.

So holes could be for passing something through; fluid, individual or continuous elements, ropes, chains etc.. Or, putting two or more holes in line will allow them to be joined by a fastening device. Alternatively, a non through hole can be modified to accommodate a single side entry element which can also offer a fastening option. In every case, the material will determine the nature of the hole and what can be fastened to it.

Anisotropy is the term used to define the strength a material has in different directions of loading. For example, as shown in Figure One, a piece of timber will have better properties along the grain than across it. The twist in the fibres of a rope will increase its properties by reducing the prospect of the fibres being split laterally. This twisting,

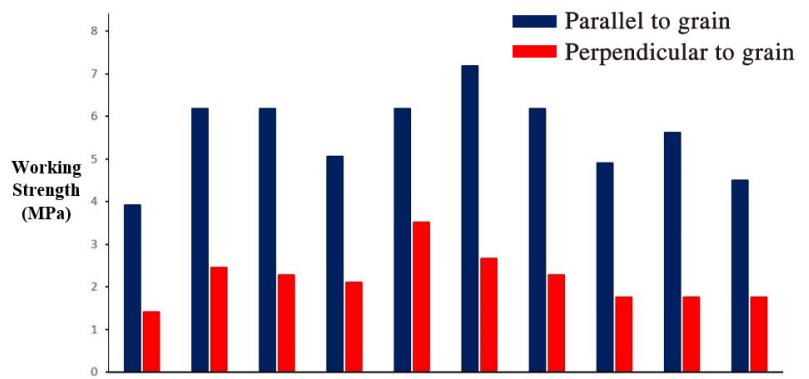


Figure 1. Compression of Common Structural Grade Timber (Dry)



folding, welding and retwisting is the secret of long ago sword manufacturers being able to produce strong blades having hard cutting edges. Making holes to use for fastening in any material having anisotropic properties requires careful consideration. In the deep drawing of sheet metal, the presence of 'earring' in the drawn product demonstrates the anisotropic properties of the material.

In the same way, some modern synthetic materials which have isotropic (uniform) properties, for example, board produced from bonded wood chips, building blocks and printed circuit boards etc. such materials will require consideration when selecting the type of fasteners which could be used.

It is perhaps no surprise that the designs used by workers of wood were reproduced by early metalworkers. The first guns/cannons were made using barrel technology. Side trunnions were used to provide elevation. The geometry of woodworking joints were changed from rectangular to circular to provide spindles and pins required for a wheel to turn. Terms like chassis, running board, trunk/boot, hood/bonnet have been transferred directly from the wooden horse drawn carriage to motor vehicles. However, the benefits that iron, then steel products provided quickly caused the development of fastening devices which utilised the strengths and durability of ferrous metals over wood. Mass produced screws added an extra dimension to the centuries old joining of wood by dowels and nails. Threaded metal bolts, screws, nuts, washers and rivets in huge numbers were produced globally, regionally and locally by individual companies which used them.

Notwithstanding this explosion of demand and inventive spirit, unless two or more parts were clamped together, every fastener required a hole for it to be placed in. Moreover, the majority of the holes were not provided by the fastener manufacturer. So, for a fastener to function in a designed manner, it was necessary for the hole it was being used with to also be, 'satisfactory for purpose'.

Not Just Any Hole

The drive for mass production was a product of the need for interchangeable parts. To make standard parts created a demand for standard machines on which they could be produced. This in turn created the ability to produce quality products in high quantities virtually anywhere. Once rolling, this particular ball began its journey downhill and through considerable product standardisation and company rationalisation has brought us to where we are today.

In the boom time of machine building, most iron based structural elements were produced by sand casting. This was a cost effective process which offered a thermally stable product with excellent vibration damping and wear properties. A significant disadvantage however, lay in its often hard (chilled) and uneven surface. Holes drilled into cast iron also required 'spot facing' if the surface adjacent to the hole was to be at right angles. Assuming this wasn't a practical possibility, then a special purpose washer arrangement would be required as an interface between the potentially unsatisfactory component surface and the axial alignment with the hole.

Punching a hole in thin metal sheet (strip) or in plate metal material requires suitable tooling and a press capable of applying the force necessary to do it. Both of these are expensive and therefore would require sufficient demand to justify the cost. The quality of the resulting hole(s) is dependent on the suitability of the press, the design/manufacture/condition and set-up of the tooling, along with the condition of the material being worked. Soft materials tend to smear, advanced high strength



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steels can create very large breakthrough releases of energy which negatively affects the tooling. This is why on hot formed, cooled in the die auto parts made from boron steel, laser trimming of the ~1900 MPa items represent the only sensible option.

The equivalent of a blind hole in a product could be a groove in a shaft or inside a hole. This could be used to accommodate a spring circlip or washer designed to prevent the axial movement of a rotating element along a shaft as in the case of fixing a gudgeon pin in a piston where thermal expansion during service might cause a problem. It could also provide a bayonet type fitting.

There are many engineering applications where the quality of a hole is of critical importance in fulfilling the design function of the fastening device used. The aerospace industry is one where the drilling of holes in a fuselage or wing requires a new tungsten carbide drill to be used once a specified number of holes have been produced. Despite being one fifth of the way into the 21st century, it is quite

astonishing that making holes by rotational means (drilling) is still, after millennia, the basic technique employed. This, despite it being a highly inefficient and wasteful process. Perhaps, this is yet another of the benefits obtained by the use of self piercing rivets?

Blind holes can be used without modification by applying anchor expansive systems to secure them, or through modification of the original hole by introducing a locking feature, usually a thread or insert. In this case the aspect ratio of the hole geometry relative to what it is used for is fundamentally important. Naturally the material the hole is made from and the application will also be fundamental to the design process.

On a steel frame building or indeed any assembly where damaged, misaligned or non aligned holes are encountered, the quick fix of using the designated bolt to force it through will invariably damage the bolt thread and compromise the design intent. As a great many insurance warranty claims have proved, incorrect assembly of fasteners can cause both financial and reputational damage through unnecessary early failure.

Conclusions

“Measure twice and cut once”, is a wise adage. In a domestic setting, drilling holes in walls requires careful checks to see what is there before starting. Drilling into hidden pipes and/or electric cabling is a common occurrence. Also, in many modern homes, the material being drilled into must be known in order to use the correct tools, settings and cutting techniques/parameters. This must also be done in consideration with the function. If it is to be used for fastening, then the correct type of fastener must be used.

This simple ‘flow chart’ of thoughts for the ‘handyman’ is no different to those required in any commercial operation where fasteners used in industry are required. **As always, safety comes first, followed by functionality then practice.** Get it right and no one will notice, get it wrong and a disaster could be lurking just round the corner.

The taxman told my friend, “A hole is nothing so how can you claim tax relief on nothing?”

This may be a philosophical argument but if true, then how can so many fasteners be successfully fastened to nothing? ■



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