Getting A Head

by Peter Standring

There are a number of single item products which require more than one integral feature in order to provide the function for which they were designed.

For example, a needle requires an 'eye', a fishing hook, an 'eye', a barb and a bend and a screw requires a 'driver.' This is not the separate tool which is used to operate the screw but the corresponding element which is an integral design feature and without which no screw can function. In this article, a screw is defined as any single item threaded fastener which can produce a mechanical joint.

Except when threaded rod is used as a stud, virtually all screw fasteners have heads. These serve two fundamental purposes. One is the external surface geometry basically designed to carry out the jointing function. In the case of a hexagonal head, this also provides a driver. The second element of most fastener heads relate to their internal surface shape within the outer geometry and this is used exclusively for 'driving' the screw.

Interestingly, with the possible exception of a slotted screw head designed to be used with a flat screwdriver, all other 'driver' geometries carry a name, either of its designer or the company which first brought it to the market. This is not, as far as this Author is aware, the case for the external head geometries.

For completion, it is worth mentioning that although 'grub' screws don't have what could be described as a 'head' they do since that is where the internal socket, slot, or driving feature is found to operate them.

Screw Head Geometries

All screw fasteners for use on wood or metal are designed to secure things. The vast majority hold things together but they could, with other items, spacers, nuts etc., hold them apart. Some screws also function independently as hooks for the reasons given in the opening sentence. In this article, consideration will only be given to screws which are used as fasteners and it will focus on the head geometries of these.

Whilst everyone is familiar with the standard terminology for screw heads: round, flat, hex and the dimensions associated with them, it is difficult to find much information which deals collectively with them in any generic manner. So, whilst these musings on the topic can represent no more than a toe in the water, by exploring the possibilities (and difficulties) of addressing screw head 'classification' it does provide a start.

Where heads are used on threaded fasteners to abut against and hold a surface, it follows that the abutting element of the screw must extend beyond the radius of the outside diameter of the shank/thread (r). The longer the radius (R), the greater the volume of material displaced from the initial rod/wire, to facilitate this.

Working from first principles, **Figure 1** shows a half section of a screw shank. If the lateral flow (R) during head formation was uniform, this would result in a circle of material extending beyond the shank. The underside of the shaped material would then be at right angles to the longitudinal axis. However, if the upsetting operation were to be carried out inside a die, it would be possible to form a radial surface which was not perpendicular to the screw axis but at some angle say $\alpha+$ or $\alpha-$ to it. In the real world, a right angle to the shank axis would represent the Flat underside of a bolt head with or without an integral washer. An $\alpha+$ value of between 30 to 60 degrees would produce a countersunk screw head or between π and $\pi/2$, a conic head. Of course, since this is a mental exercise with no practical bounds, the value of α could be whatever we speculate it might be. The full range of possible under head profiles produced by changes in α are illustrated in Figure 1 and listed in **Table 1**.

Fig. 1 Changes in head profile produced by variations in α

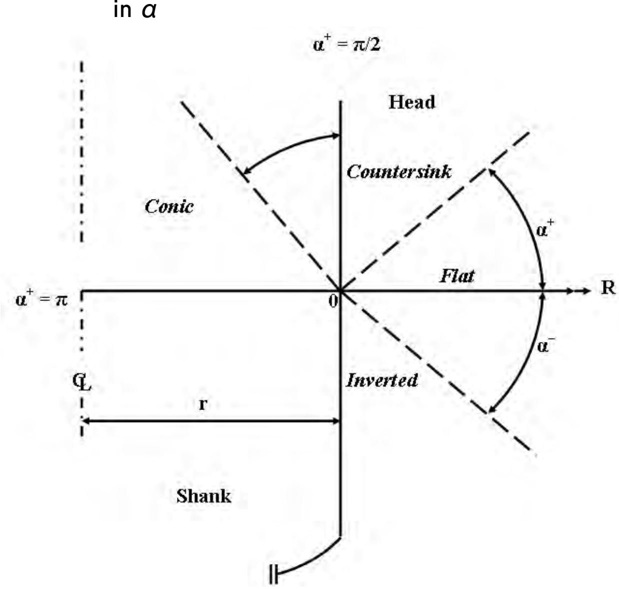

Table 1 Changes in head profile produced by variations in α

A	Underside of Head Relationship with α	Head Profile
1	$\alpha+ = \pi$	No head (grub screw)
2	$\pi \leftarrow \alpha+ \rightarrow \pi/2$	Conic (r = R at transition)
3	$\pi/6 \rightarrow \alpha+ \leftarrow \pi/3$	Countersink
4	$\alpha+ = 0$	Flat
5	$\alpha-$	Inverted (nib/square neck)

Of course, the lateral flow of material does not have to produce a symmetrical circular head. As shown in **Figure 2** and **Table 2**, by selecting different values of β_1 and β_2 with respect to R, this geometry can result in multi faceted surfaces. Hexagon or square sections are perhaps the most common but could include a thin rectangle where the length (L) is significantly greater than the width (W) to produce a 'T' shaped head.

Fig. 2 Plan view of head produced by variations of β_1 and β_2 with respect to R

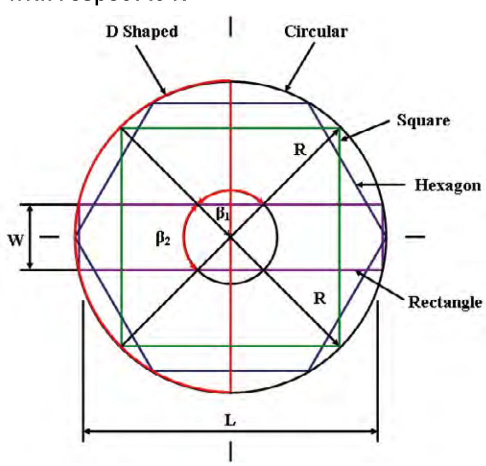

Table 2 Changes in plan view of head produced by variations of β_1 and β_2 w.r.t. R

B	Relationship of β_1 and β_2 for a Constant Value of R	Plan View of Head
1	$\beta_1 = 2\pi$ and $\beta_2 = 0$	Circular
2	$\beta_1 = \pi$ and $\beta_2 = 0$	D Shape
3	$(\beta_1 = \beta_2 = \pi/2) \times 2$	Square
4	$(\beta_1 = \beta_2 = \pi/3) \times 3$	Hexagon
5	$(\beta_1 \rightarrow \beta_2) \times 2$	Rectangle

The next geometric consideration could be the thickness of the head (t) determined from the underside transition from the screw OD or bolt shank travelling upwards.

As shown in **Figure 3** completion of the outer head geometry would be obtained from identifying the upper surface profile. This could be flat, domed, and/or contoured as indicated in **Table 3**.

Fig. 3 Changes in head profile produced by variations in Φ

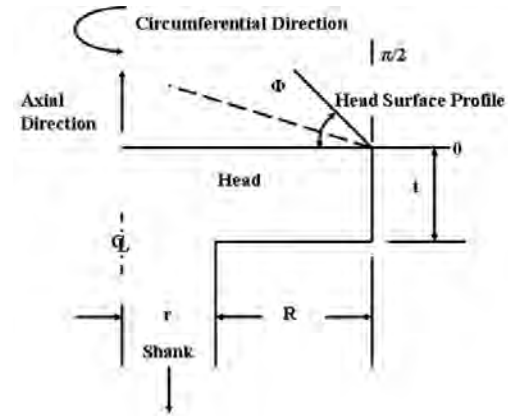

Table 3 Changes in head profile produced by variations in Φ

C	Upper Surface of Head Relationship with Φ	Head Profile
1	$\Phi = 0$	Flat
2	$0 \leftarrow \Phi \leftarrow \pi/2$ (in an axial direction)	Conic
3	When $0 \leftarrow \Phi \leftarrow \pi/2$ varies w.r.t. R + r	Domed/Round
4	$0 \leftarrow \Phi \leftarrow \pi/2$ (in a circumferential direction)	Profiled

Ignoring for the moment the internal head geometry, Figures 1-3 and Tables 1-3 can be used to classify any screw fastener head. Of course, as will be noted, the above only relate to head shapes which are centred on a common longitudinal axis. Heads which are off set to the shank axis can also be considered using the above classification simply by inputting a translation between the shank and head axes.

How to use it

Given this generic description, a hexagonally headed bolt would be classified as: A4, B4 and C1.

A square head as: A4, B3 and C1.

A countersink head as: A3, B1 and either C1 or C2/3 if it was flat, domed or round.

In the digital age the use and often misuse of words to describe items can be inaccurate and/or misleading. Any classification which reduces descriptors to a digital form must be beneficial in simplifying matters and minimising potential errors.

With some threaded fasteners, generally more noticeable on wood screws, there is a distinct mismatch between the input torque applied through the driver to that of the neck of the thread to transfer it.

Too small a pilot hole, too much interfacial friction between the wood and screw can lead to head failure. This is often apparent when attempting to remove an over tightened screw when it shears at the neck. A simple head design modification identified through analysis based on the proposed classification could solve the problem?

From a user point of view, it is perhaps surprising how much focus has been placed on fastener drivers when it is clearly the application of the fastener which matters? As with any design, it is the function which needs to be achieved. Over design will work at a cost, under designed fasteners represent accidents waiting to happen. Optimal design is one which ticks the functional box along with additional issues associated with the: how, why, when and where it is applied.

From the ubiquitous driver slot in screw fastener heads, through many variations on a similar theme, driver geometries have proliferated. This has caused much consternation and expense amongst those who need to service equipment often held together by fasteners which sometimes use subtly different driver geometries. The many disadvantages of a slotted fastener generated the technical need to explore new ideas which the early development of cold forming made possible in producing the Robertson and Phillips types. Some later driver geometries, of which there have been many, were basically commercial, resulting from the need to obtain new patents or to break existing ones and not necessarily for improved applications. Interestingly, the same classification of outer head geometries described above can also be employed to specify the features used on the drivers. For example, a slot would be b5 in Table 2, a square b3, a hex b4 etc., and so on, the lower case letters signifying the driver geometry.

Conclusions

The human mind is infinitely inventive and as can be seen in the rich diversity of fasteners, has accomplished many things in the last hundred plus years.

Size, shape, output, cost, nothing it seems is impossible.

Progress is always made through solving problems, the big ones: fire, farming, speech and language led directly to transport, industry, finance and all of our aspirational desires.

It is difficult to imagine how different our lives would be without the humble fastener and perhaps even more difficult to consider how it will progress and be improved in the future. But one thing we can be certain of is, that it will be.