螺絲頭部凹槽設計剖析

Recess Drive Systems for Screws

by Laurence Claus

Precariously balancing atop a ladder, you find yourself holding the new light fixture you're installing in one hand and in the other a screw driver with a screw delicately balanced from the tip. To your chagrin the ladder jiggles a little and the screw drops to the floor leaving you perched on a ladder holding a light fixture you can't now connect. Whether you are into "do-it-yourself" projects or would never find yourself in this situation, this scenario repeats itself many times a day in many different ways throughout the world. Perhaps ending more successfully than the above example, the screw is driven into place providing the holding power it was designed to give. This is only possible because screws are designed with a drive feature, often an internal recess that accepts a screw driver bit that enables assembly.

Threaded fasteners, since their inception, have had to have some sort of design or feature that allowed them to be driven. Although most internal recesses are relatively new (less than 100 years old), slots have been used for a very long time. Slots are simple, easy to use, and pretty effective. However, newer designs introduce an array of technologies that address many of the challenges that fastener engineers and designers commonly face.

This article will explore the challenges faced by fastener engineers related to driving screws and how different recesses address them. Additionally, it will explore the four main categories of internal recess drive systems: slotted recesses, cruciform recesses, vertical wall recesses, and tamper resistant recesses. This article will supply some fundamental advantages and disadvantages of each of these families of recesses and compare and contrast them to one another.

Engineering Challenges

There are multiple ways to drive a screw, but probably today's most common method is with an internal recess. Using an internal recess usually allows for a more compact head design, easier access during assembly, and fewer necessary driving tools. Not all recesses, however, provide the same functionality and the designer and user commonly must consider limitations when specifying or choosing the right recess to use. The most common limitations include: tendency to cam-out (strip), ability and efficiency to transfer torque, "bit stick", bit life, ability to engage the driver at off-angle approaches, and availability of driving tools.

Most everyone has been frustrated at some point when the torque required to drive a screw exceeds the strength of the recess and the recess strips rendering it impossible to either drive or loosen the screw beyond that point. This is known as "camming out" and represents the number one complaint of users everywhere. In addition to potentially rendering the screw useless, it often can leave the recess scarred and unsightly. This problem is often "assisted" by designs that "encourage" the bit to back out at critical torque levels or poor manufacturing practice which creates a "sloppy" fit of the bit.

The primary function of the recess is to transmit torque during installation. Some recesses, particularly the vertical walled ones, are better designed to provide this than others. In fact, some of these vertical walled recesses are able to transmit very high torque loads and are favored by designers and users in applications that are best serviced by an internal recess and require high pre-loads.

There is nothing more frustrating than aligning a screw with its mating nut member only to have it fall off the end of the bit prior to installation. Users and industries across all spectrums struggle with this, so that many inventive individuals have either designed new recesses or improved on old ones to provide what is known as "bit stick", or the ability of the bit to engage and retain the recess, even if fully unsupported in a horizontal or inverted vertical position.

One of the more often overlooked considerations for choosing a recess is the bit life. As costs for bits rise and bit life goes down, the associated operating cost can actually be quite substantial. Therefore, the specifying party should take the anticipated life of the bit into account. Several of the more recent entries into the market have been empirically tested and shown to have significantly better life than their predecessors and competitors. Therefore, when considering the total cost of the joint and addressing this issue, one can save thousands of dollars a year.

One of the biggest limiting factors of internal recesses is their relative ability to drive when approached by the driver in an off-angle orientation. In some instances because a hole is being approached blindly (can't clearly see it) or because there are obstructions that prevent the part from being driven squarely into the joint, the alignment of the recess and the driving bit is not square. If this misalignment is too great, the engagement is reduced and increases the chances of cam-out. Vertical wall recesses are particularly subject to reduced capability at off-angle driving.

One of the greatest challenges for recesses newly launched in the market is availability of tools. Even if the recess addresses many of these other limitations better than the older alternatives, this stumbling block will often prevent wide scale adoption of the recess. In essence, OEMs don't want to create a situation where field service is hindered because of tool availability.

Slotted Recesses

Slotted recesses can be traced back to the very earliest commercial screws. Remarkably, the design hasn't changed much over all this time. Today's slots are either cut into place using machines that move the parts in a dial past a fixed arbor with a turning slitting saw or they are formed during the heading operation. Slotted head screws accept the flat blade of a regular screw driver. Although this technology has been utilized for many years, the slots tend to be relatively shallow so that the screw driver blade is subject to slipping out of the slot causing collateral damage to the area around the screw head. Additionally, the torque transfer is not very good. **Figure 1** illustrates an example of a slotted head drive.

Figure 1

Subsequent improvements to the slotted recess include the Hi-Torque® (or Dovetail) Drive. **Figure 2** shows such a recess. The ends flair into a dovetail shape so that driver engagement is better, lessening the chances of driver slippage. This design also allows better torque transfer. It was designed for and is used almost exclusively in aerospace.

Figure 2

Cruciform Recesses

In 1932 John Thompson of Portland Oregon invented a driver and recess that would soon thereafter be purchased and improved upon by Henry Phillips. This cross-shaped (cruciform) recess would become the first of many similar designs and be universally recognized as the Phillips® recess. **Figure 3** shows a Phillips® recess, also known generically as an ASME Type 1 or ISO Type H recess. It has four identical "legs" configured in a cross shape. The walls of each leg taper downward towards the convergence point of all four legs. This tapered configuration accounts for the primary limitation of this recess design; when a critical amount of torque is applied the bit begins to thrust itself upward and out of the recess. As less and less bit is engaged the recess eventually cams out. This has left many an installer cursing the failed screw. Besides this natural tendency to push the bit or driver out, the Phillips® recess has better torque transmission than a slotted head and was thus considered, at the time, a big improvement. This recess compensates well for off-angle approach of the driver.

Figure 3

Figure 4

There have been a number of refinements over the years. These include combining the features of a Phillips® and square drive to come up with a Phillips® Square-Driv® and adding ribs to both the recess and driver to provide bit stick capability, known as the Phillips®ACR®. **Figure 4** shows a Pozidriv® recess. This was a refinement of the Phillips® and made the walls of each leg nearly vertical and added four small ribs between the legs. The nearly vertical walls eliminated the tendency of the bit to push out and the added ribs, though small, increased the ability to transfer torque. The Pozidriv® is generically known as an ASME Type 1A or ISO Type Z. Like other cruciform recesses the Pozidriv® exhibits good off angle capability.

Figure 5

Figure 5 shows a Torq-set® Drive or what is generically referred to as an offset cruciform. This drive system is used primarily in aerospace applications and is easily identified by the legs being offset from one another. Once again, torque transmission and off-angle capability are good.

Other cruciform recesses exist. Among them are Frearson®, Quadrex®, Totsupura®, and the Camera Cross. These are more limited in market acceptance and generally favored by individual industries or within certain geographic regions.

Vertical Wall Recesses

As a family of recesses, the vertical wall recesses have the best torque transmission. However, because they rely on having the bit firmly engaged in the recess, they usually do not perform well when approached by a driver in an off-angle orientation.

Figure 6 shows a hex recess, sometimes known as an Allen recess. This was the first of the vertical wall designs and is common in cap and socket head screws. With a well formed recess and the right engagement it has excellent torque transmission but does not work well in thinner head designs, is not easily engaged in automated production, and very poor off-angle performance. Additionally, it is subject to fine cracking at the hex tips.

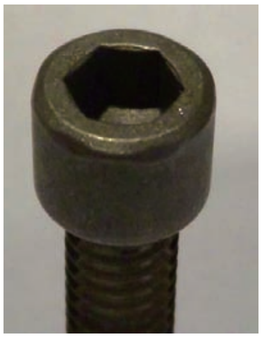

Figure 6

Figure 7 shows a Torx® recess generically known as a six lobe or ASME Type VI. Torx® was developed in 1972 and its characteristic lobe shape is defined by circular geometry. Torx's® excellent torque transmission and ease of assembly revolutionized automotive screws and today has gained nearly universal acceptance. Recent enhancements such as Torx® TTAP® provide bit stick capability and ClearDrive™ addresses the penchant for recess fill.

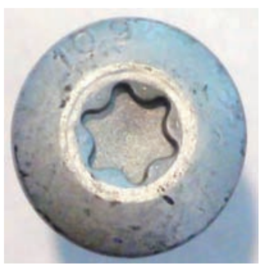

Figure 7

Figure 8

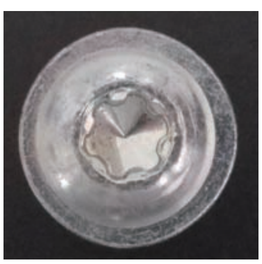

Figure 8 shows a Torx Plus® recess. Torx Plus® is an improvement over the original Torx® and is defined by elliptical geometry. The TorxPlus® has better torque transmission than Torx®. Although not developed for this, it was determined through experimentation that this design provided significantly enhanced bit life. When combined with angled entry ramps at the top of the recess, this design is excellent for guiding the spinning bit into the recess during automated assembly. This is known as Autosert®. A Torx Plus® TTAP® version provides bit stick capability.

Figure 9 shows a square recess known as a Robertson Drive. This recess provides good torque transmission and is commonly used on deck screws and in furniture applications.

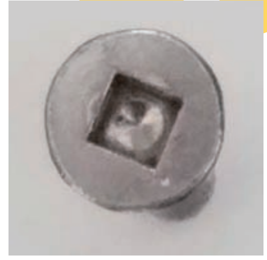

Figure 9

Figure 10

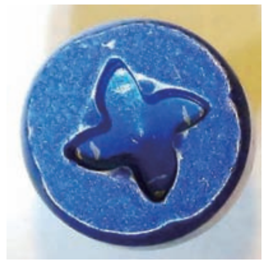

Figure 10 shows the Mortorq® recess. This and its counterpart, Mortorq Super®, are recent entrants into the marketplace. This uniquely shaped vertical wall recess has excellent torque transmission with less bit engagement than some of the other vertical walled recesses. This is an advantage because heads can be designed with lower recess depths and thus lower head heights. For low profile applications this can be a significant advantage.

Other vertical wall designs include Spline Drive and Twelve Point recesses.

Tamper Resistant

No drive is perfectly "tamper proof" but many are tamper resistant. These drive systems are used when the producer does not intend for easy disassembly. These commonly find usage in applications such as prisons, public restrooms, and playgrounds.

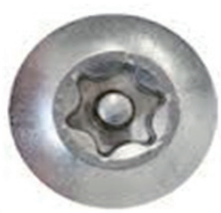

Figure 11

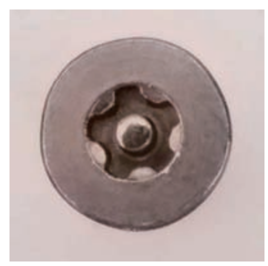

Figure 12

Figure 11 shows a Torx® tamperproof. The design incorporates a post in the center of the drive blocking engagement of a standard driver bit. Unfortunately creative individuals were able to get around the post by modifying a standard driver bit by placing a hole in the end. Therefore, when Torx Plus® was released the tamper resistant version was changed from six to five lobes and had a center post. In this way, it was impossible to use a modified bit and only controlled tamper resistant bits will work (See **Figure 12**).

Other tamper resistant drive designs include one-way heads, Tri-Wing® (also used in aerospace), and a wide variety of unusual (or one-time design) recesses.

Conclusion

Table 1 provides a summary of the different recesses with respect to performance characteristics:

Table 1

Recess	Torque Transmission	Off-Angle Capability	Bit Stick Capability
Slot	Poor	Poor	Limited
Hi-Torque®	Moderate	Poor	Moderate
Phillips®, Type 1	Moderate	Good	Limited
Phillips® ACR®	Moderate	Good	Good
Phillips® Square-Driv®	Good	Moderate	Moderate
Pozidriv®, Type 1A	Moderate	Good	Limited
Torq-Set®	Good	Moderate	Limited
Frearson®	Moderate	Moderate	Limited
Quadrex®	Moderate	Moderate	Limited
Totsupura®	Moderate	Moderate	Good
Torx®	Good	Poor	Limited
Torx Plus®	Excellent	Poor	Limited
Torx® TTAP®	Good	Poor	Good
Torx Plus® TTAP®	Excellent	Poor	Good
Mortorq®/Mortorq Super®	Excellent	Moderate	Limited
Hex (Allen)	Good	Poor	Moderate
Spline Drive	Excellent	Poor	Moderate
Twelve Point	Good	Poor	Limited

Today there are a multitude of good choices for internal recess drives. The designer needs only to match their functional requirements with the advantages of the different recesses.