Miniature Thread Forming Screws for Plastics and Light Metals for Electronics Applications

by Laurence Claus

As handheld electronic devices have gotten smaller and lighter, the fasteners that hold them together have had to follow suit. Although miniature metric and imperial machine screws have been used in eyewear, watches, and cameras for many years, it is only relatively recently that very small variants of thread forming screws have become commonplace. It is impossible to explain why this is the case, but probably stems from the fact that thread forming in plastics and light metals is a practice that has itself only recently gained universal acceptance.

There are a variety of reasons why thread forming fasteners are attractive to all industries. Of course, the primary one is the significant cost advantages that are realized. Not only do thread forming screws eliminate separate tapping operations and costly pre- or post-molded-in inserts, but they generally eliminate the need for locking features and adhesives. With very small screws this advantage alone can be very compelling, as the adhesive generally must be applied manually during assembly, which is both time consuming and messy. Thread forming screws can also eliminate other assembly issues such as cross threading, a particularly vexing problem with small screws, and, provide cost savings by enabling the use of smaller bosses and lighter weight plastic or light metal materials.

Figure 1. Selection of Miniature Fasteners

Fundamentals of Thread Forming

Thread forming is just as the word suggests. The screw acts not only as a screw but as a tool or tap to form its own thread. Thread forming is one of two ways that a screw can create its own thread. The other variant is thread cutting screws. These, however, tend to be older technology, more variable in performance, and create debris, so that they are generally poor options for electronics.

Figure 2 illustrates the typical torque versus time (or angle) plot of a thread forming screw. Although values and shape will be different from one screw to another, the general pattern of this plot is universally true of all thread forming screws whether they be for steel, plastic or light metals. Understanding and interpreting these plots, therefore, is key to understanding and predicting how the screw will behave in serial production.

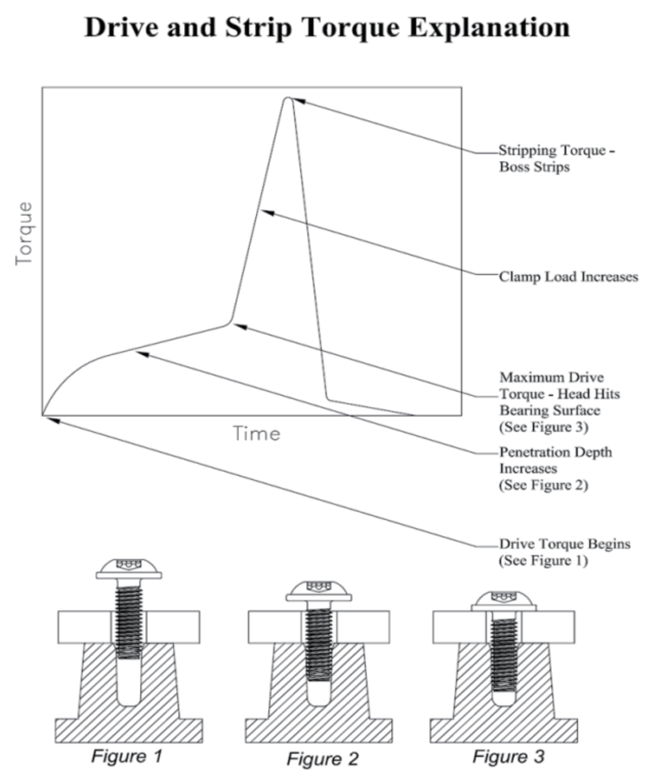


Figure 2. Explanation if Torque versus Time Plot

The first key point on this plot happens very quickly and is the sharp and nearly immediate rise in torque at the beginning of the cycle. This represents the torque required to form the first thread. In theory, this contribution to the total torque remains unchanged for each subsequent thread formed. In reality, it may vary a little as the thread progresses deeper into the hole due to variation in local material properties or tapering of the pilot hole. However, the main point is that the thread forming contribution to the torque occurs mostly at the beginning of the cycle. This torque contribution is primarily a function of the thread geometry and material strength. It is almost exclusively dependent on how much force the functional part of the thread forming tip of the screw must exert on the material to form the first thread.

After this initial sharp rise, the plot tends to flatten out and rise much more gradually with increasing time (or angles of rotation). This portion of the curve is the contribution of thread friction with each additional engaged thread. The slope of this part of the curve is again influenced by thread design and now the influence of lubrication. Although lubrication is generally unnecessary and ill-advised for thread forming into plastics, it can be very important for thread forming into steel and aluminum. (It is especially important with aluminum which has a tendency to gall when in contact with certain other metals.)

Once the head seats against the material to be clamped, the first inflection point of the plot is obtained. This value is considered to be the Driving Torque (Td). After this the driver will continue to put energy into the system, and the torque rises very sharply, very quickly, until a second inflection point occurs. This second inflection point is normally when the joint strips, but in some cases may be when the screw breaks or the joint collapses, etc... This is usually referred to as the Stripping Torque (Ts) in plastic thread forming, Failure Torque (Tf), or Ultimate Torque (Tu). Regardless of the industry naming convention, it represents the same thing, the maximum torque that the joint can effectively withstand. It is between the Driving Torque and the Ultimate Torque that clamping load is generated in the joint.

Like all joints it is the responsibility of the fastener engineer or end user to understand the parameters of the joint so that a "safe" tightening torque can be recommended. In other words, the challenge is to design a joint with a sufficient margin between the maximum Driving Torque and the minimum Ultimate Torque to accommodate the repeat accuracy of the driver and guarantee that every screw is completely driven without failing the joint.

Fundamentals of Thread Forming Screw Design

For Plastics

There is a wide selection of thread design choices on the market today. The important thing to realize, however, is that not every one of these choices embodies state-of-the-art technology. Screws like many things tend to evolve over time and the technological advances often lag the market need. This is definitely true for thread forming screws for plastics, where many of the traditional and most commonly employed designs are spillovers of designs developed for other purposes but used for plastics because they were the only thing available at the time. Unfortunately, these designs are not state-of-the-art or optimized for the purpose they are being used for. As a result, failure rates and quality spills are often greater in number or magnitude than is desirable by any world-class manufacturer employing state-of-the-art quality and manufacturing systems.

Fortunately, there are thread forming screws expressly designed for plastics that utilize state-of–the-art technology, engineering, and know-how, that take many of the special nuances of these plastic materials into consideration. When considering these screws, a couple of important factors to look for are:

Thread profile

The smaller the angle of the thread profile the lower the resulting radial force component and greater the axial force component. This is particularly beneficial in plastics where extreme radial forces result in excessive hoop stresses and cracking, bursting, and crazing of bosses. The increased axial force component is advantageous in assisting the deformation of the material as the threads are formed. Figure 3 illustrates the difference in force components as the thread profile angle is reduced. In this example, a standard 60° thread flank is compared with a state-of-the-art EJOT® Delta PT thread profile, a compound thread profile ranging between 20°-30°. It is easy to see that the radial component of the state-of-the-art fastener is roughly half of the standard screw. Figure 4 illustrates this same concept in actual bosses. In this example the basic diameter of the screws and the bosses are identical. It is obvious that the standard 60° thread form would require a much larger boss to prevent cracking. In addition to the obvious quality issues that arise here, those tasked with identifying potential cost savings should take note that state-of-the-art thread forms allow the use of smaller bosses. This means lighter weight designs and less material usage.

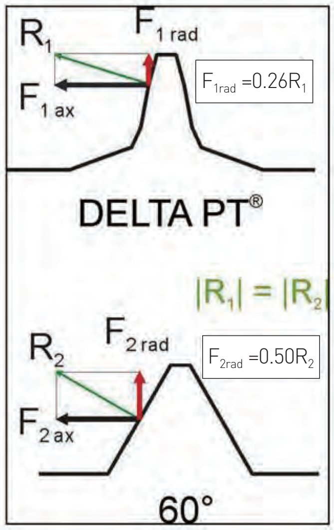
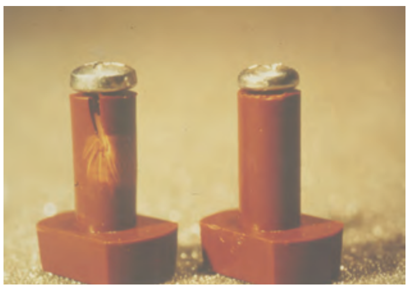


Figure 3. Comparison of Force Components on Standard 60° Thread and State-of-the-Art Thread profiles



Sheet metal screw   DELTA PT® screw

60° flank angle   small flank angle

Figure 4. Comparison of 60° Thread and State-of-the-Art Thread in Identical ABS Bosses

Stress Risers

Plastics can fall into several structural categories, the two primary ones being amorphous and semi-crystalline. The amorphous plastics, which include ABS and PC, are particularly sensitive to stress concentrations. One of the more common thread geometries still used today for thread forming into plastic is one where the thread is not round. These non-round thread geometries contact only at tips or lobes and, thus, place stress concentrations at these points. Although this is potentially advantageous when thread forming into steel, it can be quite detrimental when thread forming into plastics. In addition to risking boss cracking, these stress concentrations relax and the joint losses much, if not all, of its clamp load. From a long-term perspective this is definitely unwanted behavior.

Relief for Displaced Material

One of the things that early designers learned about thread forming in plastic was that the ease and extent that the plastic material "flows" was greater than expected. Unfortunately, they learned the hard way that when the material would hit an obstruction, usually the core or wall defined by the minor diameter, the material would become "damaged" and quickly relax causing clamp load loss and poor long-term performance. As a result, state-of-the-art thread forming fasteners have made provisions for this and provided design features that do not obstruct this flow in any way and provide extra space at the core to accept it. Figure 5 again illustrates an EJOT® Delta PT and how the core is recessed to accept plastic material. Interestingly, this fastener design also has a compound thread profile that was experimentally developed to assist in the flow of material and prevent any points that the material might "stall" or contact with the screw threads or root and create a localized area of damaged material. These features are intended to reduce stress risers and damaged material which will relax and result in clamp load loss over time.

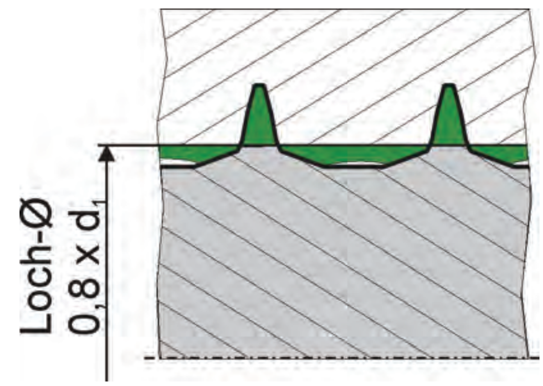


Figure 5. Relief in the Thread's Root for Displaced Material (Green Shading Represents Displaced Material)

For Light Metals: Aluminum, Magnesium, and Zinc

It really is not appropriate to lump all three of these materials together, as they each behave quite differently and have their own unique performance characteristics. Just like the screws for thread forming into plastics though, there are state-of-the-art screws available today that have taken many of these unique characteristics into consideration and employed features to address and optimize them. A number of good solutions exist for aluminum but there are only one or two that provide state-of-the-art performance for magnesium. Figure 6 illustrates one of these designs, the EJOT® ALtracs Plus®. Immediately one sees that the thread profile is far from standard. Like other state-of-the-art screws, this profile in combination with other features is meant to address some of the unique qualities of magnesium. The point here is less about the specific screw and more that in today's manufacturing environment solutions exist that bring state-of-the-art technology and know-how to challenging and demanding problems.

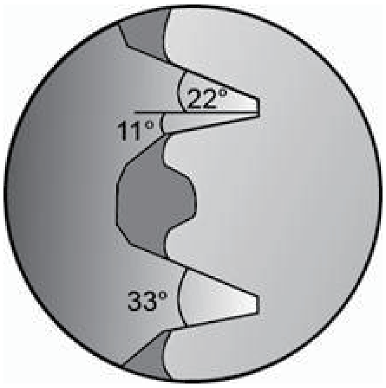


Figure 6. State-of-the-Art Thread Forming Screw Profile for Magnesium (EJOT® ALtracs Plus®)

Challenges of Employing These in Miniature Screws

Miniature screws provide some unique challenges for both the manufacturer and assembler. The primary one being that the industry is simply far less prepared to handle very small screws than larger ones. Although there is no one universal figure for which screws get classified as miniatures, generally the line of demarcation is in the vicinity of 3mm. Screws smaller than this, all the way down to 0.6mm in diameter, are commonly produced, but special handling and considerations must be employed. In addition to special practices to collect the parts and prevent loss, the challenges of inspection are significantly greater. The biggest challenges come, however, in subsequent processing, such as heat treating and plating. The parts are so small that they must be contained in special containers that prevent their loss during these processes yet don't interfere with the process itself. A great deal of special handling must go into the manufacture of these parts, which explains why these parts, although small in raw material content, are quite expensive.

The challenges do not end with the screw manufacturer, however. The end user must get the screws assembled into an electronic device. In the same way that handling is a challenge for the manufacturer, so it is with the end user. The smaller the screw, the more difficulty that it can present. Because of their size, loss is a real factor. A small spill, rip in the packaging, or even sneeze from an operator can send a large quantity onto the floor -lost to production.

Another problem is feeding and getting the recess aligned with the bit. In many instances, the parts are automatically fed to the driver or to a convenient location where the operator is able to pick the part. For the smallest screws they are really too small to realistically expect an operator to manually pick and place the screw. In these cases, one must depend on the driving equipment having adequate feeding or picking capability.

The recess can make a significant difference to the ease or difficulty of assembling small screws. Depending on how the part is fed into or onto the end of the driver bit, "bit stick" can be very important. This is where the recess and bit are designed so that the part will stick to the end of the bit without drooping or falling off. This allows the operator to transfer the part to the assembly point without fumbling with it or worrying about whether it is going to fall into the electronic device being assembled. One such recess for miniature screws with this functionality is Totsupura®, a cruciform style recess screw with 0° recess taper (near vertical walls) that allow the parts to stick fit on the bit.

The other issue with driving such small screws is regarding the ability to transfer torque. The more vertical the wall, the better the torque transfer will be. Again, this is critically important because parts this small are much more difficult to rework than parts just slightly larger. When considering miniature thread forming fasteners, torque transfer can be very critical.

Summary

In summary, miniature thread forming screws, especially for plastics and light metals, are an excellent choice for the electronics industry. This is especially the case for assemblies where weight and cost savings are particularly important. However, not just every screw or design is going to work. Therefore, one must carefully understand the process and the goals to be accomplished and wisely pair the right screw with the joint. ■

Acknowledgment:

The author would like to give special thanks to EJOT® Verbindungstechnik of Germany and EJOT® Fastening Systems (Taicang) Co.,Ltd of Taicang China, who provided most of the pictures and illustrations for this article. Although this article cites several specific features of state-of-the-art fasteners from EJOT®, there are certainly other fasteners that employ similar state-of-the-art technology and know-how.

It was the intent of this article not to specifically promote a particular product, but rather to present an understanding of thread forming into plastics and light metals and how this technology can be combined with miniature screws for use in electronics and other applications that utilize small screws.