The Art of Thread Forming Fasteners

Part Two — Thread Forming into Plastics, Light Metals & Steels

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In *Part One* of this two-part series, we looked at the general principles of thread forming that apply uniformly regardless of screw or material type. In an ideal world, "one size would fit all" and any screw could be universally used in any material. However, anyone that has ever tried to thread a standard sheet metal screw into polycarbonate or into a thick steel plate might attest to catastrophic results. Why? Quite simply, the fastener being used was never designed to perform in these materials.

Therefore, the first ground rule that any Fastener Engineer or Designer must employ is to choose a fastener that was designed to work in the material and the situation intended. There is some excellent fastener technology that works well in the applications it was designed for, but not so well with other materials. So it is incumbent on the Designer to know as much as possible about all aspects of the joint and not to simply assume that because the fastener works well in thread forming such-and-such a material, that it will work well in a different one.

Thread Forming into Thermoplastics

Because plastics play such a prominent role in the things we interact with and are all around us, it is hard to believe that the full-scale use of thermoplastics and particularly, "engineered thermoplastics" is actually a relatively recent occurrence. Like most technologies that trace their implementation to recent memory, it is still easy to find individuals that can clearly remember the developmental history. Unfortunately, new technology is often delayed due to early missteps. Take for example, early ABS brake systems that vibrated so much that they "scared" users and were not applied correctly. At one point there was talk about banning this life-saving technology from automobiles. In a similar vein, thread forming in plastics has often been challenged by concerns derived by early Designers' usage of screws designed for wood or sheet metal. Fortunately, screw designs exist today that have been specifically engineered for thermoplastics and work well, even with the more demanding resins.

But to begin the conversation of thread forming into plastics, one must have a basic understanding of plastics and their physical properties. Unlike most steels, which exhibit relatively consistent physical properties across all varieties, the physical properties of one type of plastic can be significantly different than another, so that what might work well for the one doesn't for another. Plastics are comprised, in general, of long chains of repeating molecules. The basic repeating structure is called a monomer and when many of these repeating units are combined together, the result is a polymer. All thermoplastics are polymers and hence, are comprised of many of these long molecular chains.

These polymers can be configured into two basic types of plastics, amorphous plastics and crystalline plastics. The amorphous plastics arrange their polymer chains in an undefined and random manner. It is analogous to a bowl of spaghetti where each noodle in the bowl is randomly mixed and intertwined with those surrounding it. Common amorphous plastics are polycarbonate and ABS. One of the primary and unique characteristics of amorphous plastics is that they are very stress sensitive.

For the Fastener Engineer, this is very important because these joints will be prone to relax or crack if too much stress is exerted on them, potentially relieving the joint of the desired clamping load.

On the other hand, crystalline polymers arrange some (although not all) of their polymer chains in a defined order. Although not a perfect analogy, keeping to the theme of pasta, crystalline polymers would exhibit areas of structure arranged like a lasagna. Common crystalline polymers would be the entire family of nylons and polypropylene. Although they are still prone to stress, they are much less so than the amorphous plastics, and the Fastener Engineer has to worry more about concerns with column strength of the boss (that is the ability to support the clamp load) and the drive and strip torque performance.

Perhaps more than other thread forming situations, understanding a little about the plastic material being used will go a long way in developing the proper design strategies for the joint. However, understanding the features of the thread forming screw is equally important. Following are several important considerations when pairing a fastener for a plastic thread forming joint.

Thread Profile

Because the strength difference between the plastic material and the screw is generally several magnitudes of difference, the angle of the thread profile can be significantly reduced from typical thread forming screws for metals without compromising required strength or performance. Although there is a critical point where the profile of the screw thread can practically get too low, the advantages of a lower angle, more knife-like thread profile is easily understood. The "sharper" the profile, the easier it is to start deforming the material. One might compare it to attempting to cut something with a steak knife versus a butter knife. Likewise, **Figure 1** illustrates the force vectors acting on a traditional 60° angled profile and one half of that. It is immediately apparent that the radial component of this force is reduced by almost one half. The ability to reduce this force component is particularly advantageous in amorphous plastics because it is this radial force component that pushes out against the boss, and which may crack it. **Figure 2** shows the case where identically sized fasteners with 60° and 30° angled profiles were installed into identical ABS bosses. The resulting outcome is dramatic in showing the effect that just the thread profile can exert. Therefore, the thread profile plays an important role in both reducing the initial thread forming torque, and also protecting the boss from cracking and perhaps allowing overall more compact joint designs.

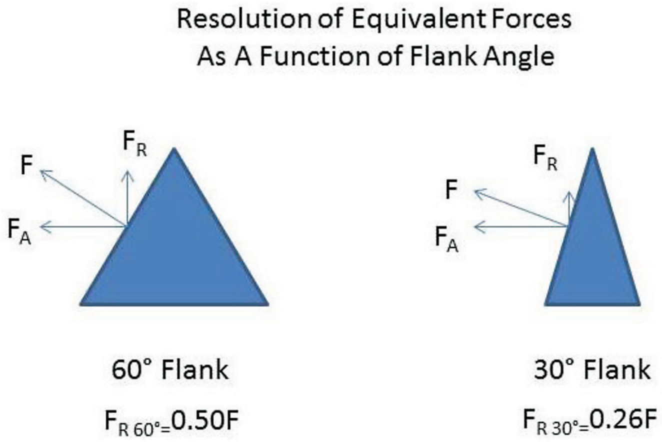

Fig. 1 — Force vectors acting on a traditional 60° angled profile and one half of that.

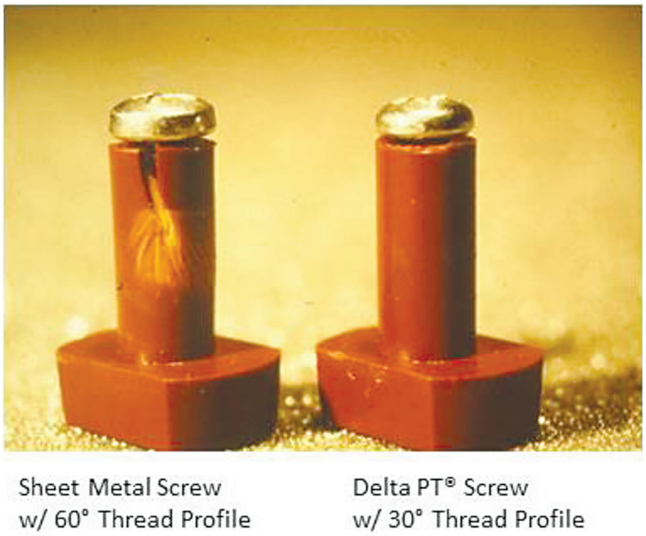

Fig. 2 — Identically sized fasteners with 60° and 30° angled profiles installed into identical ABS bosses.

Stress & Relaxation

The primary goal of most threaded joints is to create and maintain a clamping load. However, one of the challenges of accomplishing this in plastic materials is the tendency of these materials to relax or creep away from stress. The good Designer will keep this in mind and take all the steps possible to limit the introduction of any unnecessary or excess stress.

It has been previously described how the thread profile can play a role in this, but there are other factors that introduce stress as well. In addition to the actual thread profile is the geometry of the threaded cross-section. Some designs are fully round while others are nonround. A fully round cross-section will disperse the forces more evenly in the plastic than a non-round cross-section. In the case of plastics, these nonround geometries consolidate the stresses at their contact points resulting in stress concentrations. As previously discussed, this can be detrimental, especially in the more stress-sensitive amorphous plastics.

A second special consideration regarding stress and relaxation in plastic screw joints pertains to the clamping load and installation torque. Traditional understanding of the Fastener Engineer is that the higher the clamp load that can be achieved, the better. However, plastics are counterintuitive and experience shows that the higher the load placed on the plastic, the more it will relax over time. Therefore, it may be better to actually utilize a lower installation torque than the joint is able to handle because the resulting relaxation will be less and the joint will actually stabilize to a higher retained clamp load than if it started at a higher initial clamp load. Therefore, choice of installation torque is quite important and should in most instances be kept as low as practical.

The relaxation of the joint is also directly proportional to the degree to which the deformed material retains its strength. Some plastic thread forming screws have provisions to accommodate the movement of the plastic material during the thread forming process. When plastic material "moves" during thread forming, which in some plastic materials can be a considerable amount, and repositions itself against the screw, those screws that have made provision for this movement will provide a far more stable joint than those that do not. Take for example the act of lifting the inner bag of cereal from its box and then replacing it. When the bag gets taken out of the cereal box, the cereal in the bag is no longer constrained by the sides and repositions itself differently in the bag so that the space at the bottom is now a little more "full". When this repositioned bag is placed back into the box it now pushes out on the sides of the box because there is more cereal in the lower part of the box than before. If the box were a threaded plastic joint, over time that stress would relax causing loss of clamp load. Therefore, thread forming screws that have been specifically designed for plastic often have relief or other means to provide a way for the deformed material to move and reposition itself without being stressed and resulting in unnecessary load losses.

Drive & Stripping Torque

Like any thread forming application, drive and failure torque are critically important. Thread forming screws are usually designed in an attempt to minimize the driving torque and maximize the failure torque. In the case of plastic joints, failure is usually, although not always, a result of the thread stripping out so that stripping torque often replaces the term for failure torque. Normally, general design recommendations can be followed that allow pretty good drive-to-strip-torque results. However, with the right lab equipment it is not difficult to conduct empirical trials to completely optimize performance. Regardless of whether general design guidelines are used or the optimal design parameters are established by experimentation, this is a critical step in engineering the joint because the relationship between the driving, stripping and installation torques is necessary to obtain a reliable joint.

Joint Design

Proper joint design is very important to overall success, so that it is critical to work with a fastener where design recommendations exist and are reliable. With so many different variants today in the same plastic family, it may be difficult to find an exact recommendation, but even a "general" recommendation for a specific plastic family will be better than guessing or applying a "one-size-fits-all" philosophy. In most cases, the important design-recommended features should include the minimum boss outer diameter, the pilot hole diameter and the minimum engaged thread depth. Other important factors that might be available include the maximum allowable or recommended draft angle of the pilot hole, a counter bore design and strategies for adding strengthening features or avoiding sink marks.

There are many other factors that can play a role in thread forming into plastics that a more comprehensive resource would cover, but these represent a couple of the more important considerations. Because of the potentially unique nature of plastic joints, it is always a good idea to employ good fastener engineering and design practices on these types of joints and seek design counsel from both the resin supplier and the fastener manufacturer.

Thread Forming into Steel

Because significant savings can be achieved by eliminating stand-alone tapping operations, thread forming into steel has long been an accepted manufacturing practice and there are multiple choices of fasteners marketed for this purpose. Like the previous discussion regarding plastic thread forming fasteners, not all thread forming fasteners for steel are alike or perform equally well. In the same way that it is good practice to choose thread forming screws for plastics carefully, it is also true for thread forming screws for steel. Following are several important considerations when choosing thread forming screws for steel.

Screw Strength

One of the characteristics that sets apart thread forming screws for steel is their need for strength and hardness. Because they are forming threads in materials much like themselves, they must be strong enough to prevent the threads from collapsing during thread forming or the screws from breaking. This is normally accomplished with traditional 60° thread profiles and machine screw pitches. For typical applications, the vast majority of such parts are case hardened. The hard outer case provides the threads with a significant hardness differential from the steel they are forming. However, case hardened screws lack ductility and there are many applications today, which require the screw to possess some ductility. It is not uncommon, therefore, to have a thread forming screw for steel with an induction hardened point providing the strength and hardness to form a thread and a through-hardened body to provide the functional ductility required by the application.

Drive & Failure Torque

With thread forming screws for steels, one of the primary distinguishing factors between different varieties is drive and failure torque performance. This is critical because small improvements in driving torque can have a dramatic impact on the ergonomics or ease of assembly for the end user. Operator fatigue is a hot issue in manufacturing today, so that any improvement, albeit even a small amount, can be very favorably received by the user.

A number of features are employed to provide the maximum separation possible between the driving and failure torques. Normally, greater consideration is given to lowering the driving torque because it has greater benefits on the functionality of the screw. Since failure torque may rely to a much greater extent on the consistency of steel's physical properties and strength than on actual screw design, the Screw Designer is less motivated to apply his or her attention here. Instead, additional motivation to improving driving torque can be attributed to the end user perception that the more "ergonomically friendly" a screw design is, the "better" it is.

To lower driving torque, the point design, screw geometry and lubrication serve major roles. In most cases, the point area is tapered so that not all forming occurs at one time and is nonround either by geometry or by relief features placed in the screw during manufacture. These serve to lower the thread forming torque. These screws are almost always lubricated, which plays a significant role in reducing the thread friction torque. Over the years, there have been significant advancements in lubricants and there are many good options available today specifically designed for thread forming screws into steel.

Joint Design

Like thread forming screws for plastics, recommendations of the proper joint design or pilot hole size for thread forming screws for steel should be utilized. It is not good practice to simply apply the recommendations from a different thread forming screw because they were readily available. Fortunately, there is a good body of knowledge available and most predominant thread forming screws on the market have experimental and practical experience backing them up.

Thread Forming Screws for Light Metals

In an effort to not belabor a point, light metals (aluminum, magnesium and zinc), behave differently than either plastics or steels. Therefore, it remains true that special consideration should be given to each unique application and it should not be assumed that because a screw performs well in steel or plastics that it will with light metals. However, there are only a few screws on the market specifically designed or field tested for these materials, especially magnesium and zinc. This may be testimony to the fact that these materials are not yet utilized to the extent that both steel and plastics are, or that options from the steel or plastic applications often perform acceptably in these materials. Whatever the reason, it does not diminish the fact that these materials have unique needs of their own and best practice would be to understand the available options and choose the one that will provide the best performance for that specific material.

This two-part series has only scratched the surface of thread forming technology and innovation. Although the technology has been around for many years, as people continue to grow comfortable with it and understand its many benefits, it will continue to grow in favor and be adopted by more OEMs. Understanding how and why it works, the many advantages it provides and being able to clearly communicate these to a customer or end user will increasingly become an expectation of the fastener manufacturer. Therefore, it is important to be knowledgeable on these basic principles and as many of the unique requirements of specific materials as possible. To learn more, visit the website listed below.

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