When the first tapping screws started appearing in the market, the inventors probably had no idea how radically their inventions would change the face of fastening history. Tapping screws refer, of course, to a broad family of screw types that do not rely on mating with a preexisting female thread because the screw is designed to form it. This innovation opened up new application pathways, particularly in construction applications where these screws were able to not only form threads but to pierce and fasten thin sheet metal together or connect wood products, often without the need of pilot holes.

Basics of Tapping Screws

by Laurence Claus

As time progressed many additional designs were developed and new applications fields introduced. In fact, there has probably been no time in history that surpasses the present day for the many and varied uses of tapping screws. These screws have evolved from several helpful construction applications to an important category of fasteners in industrial applications.

Cutting or Forming?

Self-tapping screws come in two varieties. There are versions that are intended to form or displace the material they are threading into and there are cutting versions that cut away material to form the internal threads. Both varieties work along similar principles as their respective threading taps would work in a tapping process. Thread forming varieties are continuous thread forms and rely on geometry to flow the material into the internal thread form. Cutting screws have grooves or slots that provide knife-like sharp edges that cut the thread path into the component.

The earliest tapping screws were derived from designs intended for wood or sheet metal. Unfortunately, these screws lacked tight tolerances and often had large thread profile angles, all of which conspired to make early self-tapping screws inconsistent and often unreliable in certain materials. They found thread forming varieties more difficult to work with and often favored the cutting versions. Although the thread cutters appeared to work alright in some applications, they, generally, remained unreliable and inconsistent and added a new complexity of how to handle the chips they formed.

In some application instances, neither thread forming or thread cutting screws worked well. Thermoplastics are one material type for which this was true, resulting in a great deal of user skepticism whether it was proper to use self-tapping screws in thermoplastics at all. As a result most early plastic threaded fastener connections were comprised of molded or pushed-in internally threaded metal inserts. These added significant cost and were not always that much more reliable than direct fastening methods.

With advancements and innovations in design the pendulum has turned and many of these early problems have been resolved and thread forming versions have replaced thread cutting versions in all but a few types of material. Regretfully, these early deficiencies resulted in a lot of skepticism and slow acceptance of thread forming varieties of tapping screws, but over the last thirty years, successful application has erased user hesitation to employ thread forming designs.

Fundamental Fastener Engineering

Although there are unique requirements for designing forming versus cutting applications much of the fastener engineering is the same. Regardless of screw type or application the primary concern is developing a joint where the screw is completely assembled, the threaded member is not stripped (or otherwise exhibiting a failure), and the joint has a modicum of clamp load to hold it together. Although this sounds straight forward, maybe even simple, it is not. There are many challenges that are faced, some of the more significant ones are:

- **The material that will be threaded into is weak leaving it vulnerable to stripping.**
- **The material that will be threaded into is strong and brittle leaving the screw threads vulnerable to collapse or failure, the threaded material vulnerable to premature stripping, or cracking from excessive radial stress.**

- **The material that will be threaded into is very thin providing only a very small amount of thread engagement and making it highly vulnerable to stripping.**
- **Inconsistent pilot hole sizes result in less than optimum radial engagement.**
- **Inability to start with a pilot hole necessitates piercing or drilling and opens the door for initiating high radial stresses.**
- **Minimal clamp load retention.**
- **Stress relaxation results in clamp load loss.**
- **High driving torques and low stripping torques contribute to difficulty in achieving successful assembly or a meaningful clamp load.**
- **Installation equipment that is not capable to precisely install parts at the desired torque level (or other settings) required for successful assembly.**

This list is only a partial one but represents a compilation of some of the more common challenges. Each particular category of tapping screw application, however, will experience its own unique and expanded list of challenges. Take for example the challenges of fastening very thin mild steel sheets. In addition to the self-tapping challenges, thin sheet joining poses a multitude of additional hurdles, and, although there may be some overlapping challenges with other tapping screw application fields, they fundamentally will be very different.

Since each category of application may be very different let me address in general terms two commonalities between them all.

Low Driving Torque

In theory, a machine screw installed into a mating tapped hole has little or no driving torque because the internal mating thread has already been formed so that the only torque is generated by the minimal frictional interaction between mating threads. With tapping screws the conditions are very different and we need to exert torque to cut, form, and pierce. Since clearance is tighter there is also more friction between mating threads. In the case of both cutting and forming tapping screws we can influence this by the size of the pilot hole prior to thread creation. The larger the pilot hole the less the threads are radially engaged in the material and the lower the driving torque. Unfortunately, it is not so simple, as the reduced radial engagement initiates rapid stripping or necessitates long axial engagement which requires long screws, deep installation sites, and raises the driving torque defeating the goal to keep it low in the first place. The problem is further exacerbated when the fastener must pierce or generate its own pilot hole. Although some materials, such as soft wood species, can be pierced and a screw installed without a pilot hole, these tend to be more the exception than the rule. Most materials require pilot holes for successful installation. In these cases, a pilot hole can be formed or drilled, or the fastener can possess a feature, such as an integrated drill point, to bore a pilot hole. These features, however, require both torque and axial load to make the screw successfully work.

This outcome is important to many users of these types of fasteners because higher driving torque and axial load input equates to increased installation effort. This is likely not a significant issue to the homeowner that has two screws to install but is a serious issue to the assembler that has to install hundreds or even thousands of such screws each day.

Low Failure Torque

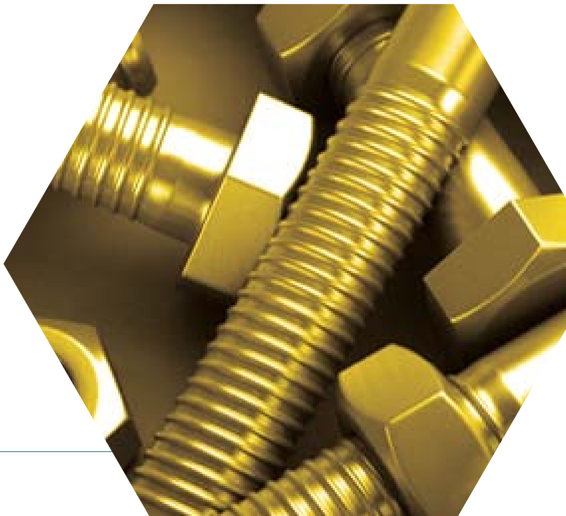
Although most of these fasteners fail by the threads stripping due to the "weak" material they are being fastened into or because of limited engagement (thin sheet joining), I do not want to suggest that this is the only failure mode. In fact, other failure modes include screws breaking from torsional overload or joint components failing from warping, buckling, or collapsing. Whatever the actual failure mode, having it occur at a low torque value, i.e. one close to the driving torque value, is extremely undesirable.

One may ask why this is important, especially since there is bound to be some margin between where the driving stops this failure occurs. Although that is true and in a perfect world we would always be able to hit that sweet spot during installation, the reality is that conditions are always less than perfect. In other words, if we recorded driving and failure values over multiple trials we would discover that they don't repeat the same values every time. If we conducted an experiment and determined the statistical variation present we could establish a "safe", statistical maximum driving torque where the screws are always installed and a "safe", statistical minimum value where the screws will never fail. Unfortunately, these points often overlap communicating that under those conditions no truly "safe" installation conditions exist. Even if there is margin between these two points, if it is minimal we may not be able to produce an installation strategy with a driver or tool that is capable of meeting the required very narrow variation window.

Thread Forming Screws

In addition to the long list of general challenges for tapping screws, applications where thread forming screws are being considered may have some additional, unique considerations. The primary consideration is the material itself. Does the material possess the ability and tolerance to be deformed? Take for example, Polymethyl Methacrylate (PMMA), also known as Plexiglas. Anyone that has ever tried to drive a screw through this material has probably encountered difficulty, i.e. material cracking or crazing around the fastening site. This is because PMMA is a highly amorphous thermoplastic and extremely sensitive to stress. With a little heat or very high driving speed (to generate heat), however, thread forming tapping screws can be installed in PMMA without cracking it. PMMA, therefore, is technically capable of receiving thread forming tapping screws but, as we know, under normal conditions simply does not have the ability to tolerate them.

Thread forming screws require materials that will readily deform and are "weaker" than the forming tapping screws are strong. General categories of materials that fit these requirements well include mild steels, aluminums, wood, and thermoplastics.



Thread Cutting Screws

Over the years many different varieties of cutting edges have been tried on cutting screws. The most popular, and probably most effective, continue to be those that possess a shank slot. A shank slot is little more than a slice out of the shank near the tip exposing a sharp edge along the affected threads. These sharp edged thread tips act like a knife to cut into the material and the geometry of the slot directs the waste material away from the cut. Other cutting features include axial slots, such as those found on a Type F tapping screws, or interrupted thread flanks turning the thread into a little saw blade.

In the early days, because forming tapping screws were pretty unreliable, often thread cutting screws got designed in. Unfortunately they were not much better and generally don't do well in materials where forming varieties work. Therefore, thread cutting screws are best utilized in very hard and brittle materials such as thermosets, wood, and masonry.

An additional consideration that must be taken into account when using a cutting tapping screw is provision for the chips and debris that are generated. Remarkably, a sizeable amount of debris can be generated and it needs a place to go. Therefore, when using a blind hole, additional space must be left at the bottom to catch the chips.

Tapping Screws in the Future

Although the original tapping screw variations are still around and some designs, like the Type AB, enjoy widespread usage, the future of tapping screws is in innovative designs that target unique applications. What I mean here is that instead of having one general all-purpose tapping screw that works in everything, users have learned and responded to using tapping screws designed for more narrow purposes, such as those specifically designed for mild steel, thermoplastic, thermoset, aluminum, thin sheet metal, magnesium, masonry, wood, and plastic/wood composite applications.

As more experience is gained and new materials come on the market, innovative designs emerge that allow tapping screws to be used where formerly they were not possible. As an example, in the last couple of years, one innovative company alone, EJOT Verbingstechnik of Germany, has developed new tapping screws for thread forming into carbon fiber reinforced thermoplastics (CFRP), Expanded Polypropylene Foam (EPP), and an improved and new version of their thread forming line of fasteners for plastics.

Summary

The application challenges facing tapping screws are wide and varied. They illustrate the challenges that engineers are up against and tell us that we cannot take the application of these fasteners for granted. When choosing a tapping screw, therefore, one cannot be willy-nilly and should investigate and understand the conditions of the application to make the best choice possible. The good news is that many innovative products exist today to help users solve these challenges and where solutions don't exist today, they likely will in the future.