Thread Rolling Screws - Screws Forming Threads in Mild Steel

by Laurence Claus

A number of years ago I was approached by a potential customer to provide a quote on a large volume of a simple pan head machine screw with a pre-applied adhesive. One thing led to another and we were soon having a conversation about some of their fastening challenges from which I learned several valuable pieces of information. I learned that they had a high incidence of scrap in a variety of mild steel components that utilized these machine screws because of thread tapping issues. I also learned that they had experienced field problems with the machine screws falling out, which had led them to add an expensive adhesive to the machine screw threads.

I inquired if they had ever considered using thread rolling screws and was, honestly, shocked to learn that they did not even know what a thread rolling screw was or why it might be a compelling option for their situation. I took the opportunity, therefore, to educate them about Thread Rolling Screws and explain how such fasteners might prove very beneficial to them.

Thread rolling screws have been around for many years. They are a form of self-tapping screw or one that creates its own internal thread. Self-tapping screws act like thread taps and depending on their configuration either cut or form the threads. Thread Rolling Screws are of the forming variety. This innovation has saved manufacturers and assemblers millions of dollars each year because they eliminate often troublesome and expensive thread tapping operations. Additionally, many Thread Rolling Screw designs provide a small, but noticeable, amount of Prevailing Torque (or the torque remaining in a joint that provides some resistance to self-loosening.)

Self-tapping screws are used in many different applications including wood, concrete, plastics, aluminum, magnesium, mild steel, and even human bone. Each material exhibits different and unique behavior, and, thus, utilizes only a subset of all the self-tapping screws on the market. In other words, there is no single universal self-tapping screw design that works well in all materials. For mild steels (those in the HRB 70-100 category), the proven self-tapping screw falls into the Thread Rolling Screw family. The remainder of this article will explore the engineering, design, and advantages of using this type of screw in mild steel applications.

What is Thread Forming?

Self-tapping screws come in two varieties, those that cut the internal thread and those that form the internal thread. Although some applications exist where thread cutting screws outperform the other options and are the design of choice, they are generally rare today, and thread forming screws make up a larger portion of the market. Unlike cutting threads which remove material, thread forming screw threads move the material around. Thread Rolling Screws only behave as thread forming screws.

F***igure 1*** illustrates the typical installation of a thread forming screw relative to torque generated as the screw progresses into the application. This graph illustrates the increasing amount of torque (Y-axis) as the screw progresses further into the application as measured by either time or angle of rotation (X-axis). If we were to compare this plot with one of a machine screw, we would see that they are very similar except for the very beginning of the plot. In Figure 1 we see that at the very beginning there is a near immediate and sharp increase in torque that lasts for a short time (in fact, only one screw rotation). This initial spike in torque represents the torque required to form the leading thread. Since Thread Rolling Screws are of the forming variety, the thread forming portion of the screw must push, displace, and reconfigure the material in the cylindrical pilot hole to form a complete internal thread. A machine screw does not exhibit this initial spike in torque because the internal thread has already been formed by tapping.

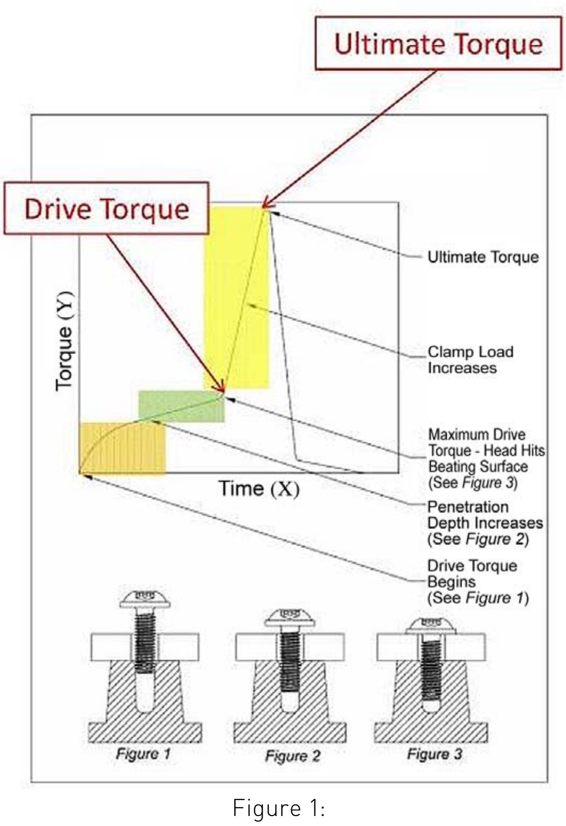

Figure 1:
Torque Behavior- Thread Forming Screws

Returning to Figure 1, after this initial spike the torque can be seen to level out into a gently sloping upward line. This portion of the plot represents the friction generated when each subsequent thread of the screw enters the just previously formed thread. Thus this portion of the graph represents the thread friction torque. This increase continues until the head just seats against the clamped material and all the joint components are "snugged up". This point on the graph represents the Driving Torque.

At this point the joint is snug and the only additional movement is going to come from the joint compressing or the screw stretching. This explains why the torque rises up at a very steep slope until one of the joint components is overloaded and the joint fails. This point is known as the Ultimate Torque, although many call it the Stripping Torque because that is the most likely failure mode of most self-tapping screws.

The reason I consider Ultimate Torque to be the better term, at least with Thread Rolling Screws, is that other failures such as torsional screw breakage and overload of the clamped material may occur.

Generally, the relationship between the Driving Torque and Ultimate Torque is the most studied relationship when designing a thread forming application. This is partly because this relationship is easily quantifiable with the right experimental tools, but probably more so because this relationship determines the quality of the joint and, in some cases, whether the joint design parameters will allow successful assembly. When validating a joint this is usually the most commonly tested parameter although other tests to optimize pilot hole diameter, installation speed, pull-out resistance, prevailing torque, or to understand the joint relaxation behavior may all be conducted.

Thread Forming Considerations:

Drive and Ultimate Torque:

As the section above just introduced the number one consideration contemplated by users and designers of thread rolling screw joints is the behavior and influence the Driving and Ultimate Torques. The previous section made it clear that it is important for these two values to be as far apart as possible. This is important because the further apart these values are the more margin of safety the user has to guarantee that the screw is always seated and never stripped. If the values are too close, the installation equipment may not be sufficiently precise enough to assure that the installer doesn't end up with one of these two undesirable conditions.

Although the difference between these two values is important, the magnitude of the Driving Torque is also critical. End users desire for this value to be as low as possible since this determines how easy or difficult it is to install the screw. It will also influence where the Tightening Torque must be specified. If the Tightening Torque gets too high, it will become necessary to install protective devices on the installation equipment to protect the installer from the high torque reaction forces.

Tightening Torque:

One must understand all that is going on in the joint to be able to recommend a Tightening Torque. The Tightening Torque will be determined based on the statistically lowest Ultimate Torque and statistically highest Driving Torque. Once this "window" is understood, a Manufacturing Engineer can review the accuracy of the installation equipment and make a determination where the proper Tightening Torque may be established. It should be understood that unlike a standard bolted joint, which depends highly on stretching the bolt to generate and maintain clamp load, most Thread Rolling Screws are limited because too much joint tension results in shearing the internal threads (stripping).

Pull-out:

Some applications may have service loads or uses that effectively are trying to pull components apart. In these cases, the joint designer has to consider Pull-out loads. As we will see in the next section, there are different designs and configurations of Thread Rolling Screws. By their special geometry some of these may be more prone to lower pull-out loads than others. If this is a consideration then pull-out testing will need to be conducted to determine the average pull-out loads that the screw will tolerate.

Self-loosening:

Some of the Thread Rolling Screw designs are not circular but rather have multiple lobe designs. These screws create localized stress concentrations at the lobe tips.

The material at these stress concentrations reacts by relaxing and minutely flowing back around the lobe. The effect of this is that the screw receives some natural locking or Prevailing Torque that is not seen in fully circular screws or machine screws. Therefore, it is usually unnecessary to add any type of locking feature to a Thread Rolling Screw.

Thread Strength:

As with any self-tapping screw, Thread Rolling Screw threads must be stronger than the material they are forming. Since most Thread Rolling Screws are being used in mild steel, they must be strengthened by heat treating to achieve a sufficient strength differential from the mild steel material they are forming. For this purpose, most Thread Rolling Screws are carbonitrided (case hardened). Case hardening develops a very strong and hard outer shell. Unfortunately, because they are very hard they are also inherently brittle and vulnerable to breakage under certain stress or environmental conditions. For this reason, applications where the Thread Rolling Screw must retain Metallurgical Toughness, such as seat belt anchor bolts, instead of case hardening they are neutral hardened and then the thread rolling portion of the screw is induction hardened to a significantly higher strength. In such a case, the thread rolling portion of the screw has the requisite hardness and strength while the body of the screw, which serves as the application's functional component, remains tough and resistant to brittle failure.

Ergonomics:

In recent years one of the most critical considerations regarding the use of Thread Rolling Screws is ergonomics. Ergonomics is an area of study that seeks to improve the efficiency and safety of human interaction with manufacturing processes. Companies that are concerned with ergonomics have learned that the more difficult it is to drive a screw the more fatiguing it is to workers that have to repeat the action all day long. Therefore, many companies have placed high priority and laser focused attention on getting the Driving Torque ever lower. In other words, the lower the Driving Torque, the longer and more comfortably an operator can perform this fastening task.

Another ergonomic concern is the reaction of the installation equipment when reaching the desired Tightening Torque. The reaction is the jolt or twisting that occurs in the installation tool when the Tightening Torque value is reached. Many of you may have experienced this unpleasant action before when using a power drill. Let's say you are drilling a hole in a steel plate. Just as the bit is about to punch through the back side of the plate it gets bogged down, stopping the bit, and twisting the drill in your hand. If you are unprepared for this or it is quite strong it may injure your wrist or twist the drill handle from your grasp. In the case of larger fasteners installers may have to contend with such a reaction force every time they install a fastener. Left unchecked or having to cope with this many times a day, it is both unsafe and fatiguing. To avoid such problems installation equipment is routinely fitted with reaction bars that counter this reaction force and make the installation more ergonomically friendly.

Thread Rolling Screw Designs:

One of the first and perhaps most prominent Thread Rolling Screw designs today is the Taptite® and its many improved cousins. (Taptite® is the registered trademark of REMINC of Rhode Island USA.) The Taptite® and its many related cousins are either partially or fully trilobularTM in design. This innovative thread form has gained worldwide recognition and is, perhaps globally, the most widely used Thread Rolling Screw in mild steel. Instead of being fully round the cross section is triangular in shape with three distinct lobes at each apex. This design provides advantages such as lower Driving Torque and a natural Prevailing Torque which assists in the prevention of self-loosening. Today there are many different variations on this design ranging from screws that are trilobularTM in shape along their entire length to ones that only maintain this shape at the point.

Of course there are other designs and brands of Thread Rolling Screws. Most of these are also not fully round and have cross sections that are five or seven lobes in shape.

Regardless of the brand or type of Thread Rolling Screw the important thing is whether it is well designed for the specific application. Like any applications engineering activity it is important to assess the specific requirements of the application and choose the best fastener for the job. For example, one might choose a different type or style of Thread Rolling Screw if pull-out is the number one consideration relative to, say, ergonomics.

Conclusion:

Thread rolling screws are an innovative and excellent choice for many mild steel applications. The savings alone from not having to pre-tap the pilot hole is reason enough to consider this style of screw. However, one size does not necessarily fit all and it behooves the end user and the designer to know a little bit about self-tapping fastener engineering to assure that they are choosing the right screw for the job and using it to its highest potential. ■