

DUPONT PERFORMANCE POLYMERS

SELF TAPPING SCREWS: HOW TO CHOOSE THE RIGHT ONE

Self-tapping screws provide an economical means of assembling components, especially where dissimilar materials must be joined together. They offer a particular advantage where occasional disassembly may be necessary for rework, maintenance or repairs.

Self-tapping screws are divided into two major types: thread-forming or thread-cutting screws. *Thread-forming* screws deform the plastic into which they are driven, producing a permanent thread; *thread-cutting* screws physically remove material, in the same fashion as a machine tap, to form the thread path. In addition, special wide spaced and usually thinned thread-form modifications are available for both types of self-tapping screw designs in order to optimize their use for plastic assemblies.

In specifying the self-tapping screw that will work best, designers will find that a knowledge of the material's flexural modulus—a measure of a plastic's stiffness—is the primary guide to its ability to manage the stress exerted by varying screw designs. Recommendations that follow are based on the suitability of a particular screw type or design for engineering plastics within four stiffness categories. The stiffness categories are defined by 23 °C (73 °F) and 50 percent relative humidity flexural modulus: less than 1.4GPa (200 kpsi); 1.4 to 2.8GPa (200 to 400 kpsi) ; 2.8 to 6.9 GPa (400 to 1000 kpsi); and greater than 6.9 GPa (1000 kpsi). A general overview of the fastener types recommended for the various families of DuPont engineering resins can be found in **Table 1**.

Table 1. Fastener Type

FASTENER TYPE			
Threadforming	Threadforming / Coarse (Type BT) Threadcutting	Coarse (Type BT) Threadcutting	Fine (Type T) Threadcutting
Unreinforced Delrin®	Reinforced Delrin®		
Unreinforced Zytel®	Reinforced Zytel®		
		Zytel® HTN	
	Minlon®		
Hytrell®		Rynite®	
Unreinforced Crastin®		Reinforced Crastin®	
Unreinforced Sorona®		Reinforced Sorona®	
FLEXURAL MODULUS RANGE			
< 1.4 GPa (<200 kpsi)	1.4 to 2.8GPa (200 to 400 kpsi)	2.8 to 6.9GPa (400 to 1000 kpsi)	>6.9GPa (>1000 kpsi)

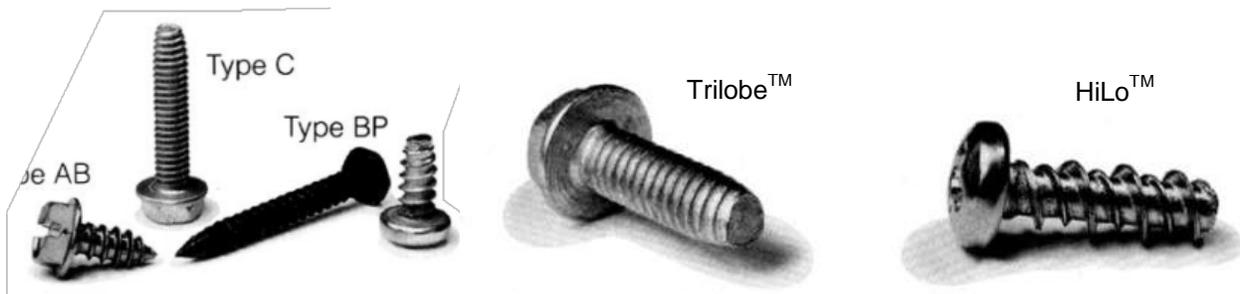
Approximate guide of fastener type for resin family

Thread-Forming Screws

Thread-forming screws are usually less expensive than thread-cutting screws and the threads they produce offer the highest resistance to back-out (loosening torque). Their advantages are offset to a degree, however, by the fact that they can cause a high and concentrated hoop stress within the plastic boss. While stiffer plastics usually cannot manage this stress, resins with flex moduli of 1.4 GPa (200 kpsi) or less may. Included in this category are most unreinforced DuPont™ Zytel® nylon resins and DuPont™ Hytrel® resins. Conventional thread-forming screws used with these resins produce strong joints.

Resins in the second category, plastics with flex moduli ranging between 1.4 and 2.8 GPa (200 to 400 kpsi) may transition between the use of thread-forming and thread-cutting screws, but generally, thread-cutting screws should be employed. Unreinforced DuPont™ Delrin® acetal resins and unreinforced grades of Zytel® nylon resin based on PA612 are an exception. The low coefficients of friction offered by these two materials literally smooth the way, permitting threads to be formed with a minimum of stress.

When using a thread-forming screw with material in this stiffness group, however, consideration should be given to modified thread-forms designed to reduce radial pressure, like the Trilobe™ or Hi-Lo™ REMFORM® or EJOT PT® thread-forms for plastics. The Hi-Lo™ is available in both thread-forming and thread-cutting types, with the latter recommended for use on materials with an even higher flex modulus. The Hi-Lo™ thread forming fastener has a double lead thread where one thread is high and the other low. A sharp 30 degree thread angle allows for a deeper cut into the material and reduces the radial stress that would be generated by a conventional 60 degree thread angle form. It has a smaller than conventional minor diameter which increases the material in contact with the thread. The result is a stronger fastener with greater resistance to pull out.



Examples of various thread-forming screws

Thread-Cutting Screws

A third group of resins, with flex moduli in the 2.8 to 6.9 GPa (400 to 1,000 kpsi) range, typically gain strength and stiffness from glass fiber and/or mineral reinforcement. Resins in this category include glass-filled Delrin® acetal resins; those compositions of Zytel® nylon reinforced with up to 13 percent (by weight) glass fibers; and DuPont™ Minlon® mineral reinforced nylon. Toughened glass reinforced DuPont™ Rynite® PET polyester resins also fits in this grouping because of its ability to accept conventional thread-cutting screws, although 30% glass reinforcement produces a slightly higher flex modulus of about 8 GPa (1,200kpsi). Thread cutting forms which present a large robust cutting surface to expel the cut debris are preferred over those which have a narrow channel which may be more easily clogged.

In these stiff materials, thread-cutting screws will have high thread engagement and high clamp loads. They will not induce high residual stress that could cause product failure after driving.

The last group of plastics that have flexural moduli over 6,9Pa (1,000kpsi), are relatively brittle. Their tendencies to granulate between screw threads can cause fastener pull-out at lower than predicted force

values. Resins in this very stiff category are the 33 percent and higher glass-reinforced Zytel® nylons, Zytel® HTN grades and all other grades of Rynite® polyester. For these very stiff resins, the finer threads of a T-type thread-cutting screw are recommended. Even when fine pitch screws are used in these very stiff plastics, threads will usually shear when the screw is backed out. If fastener removal and reinstallation are required, the boss should be large enough to accommodate a replacement screw in the next larger diameter. However, care must be taken that the boss is not any larger than necessary as an overly-thick boss can lead to molding issues (sink marks and voids), which can reduce the mechanical properties of the boss. Larger screws used for repairs will provide greater clamp loads than the original installation.

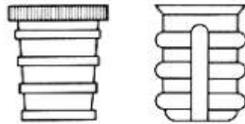


Examples of common thread-cutting screws

Metal Inserts

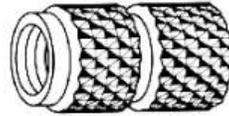
An alternate and longer lasting solution for the mechanical fastening of plastic parts is the use of a threaded metal insert. This is especially true for the stiffest plastics which are best served with the self-tapping screws with the finer type T thread cutting forms. Five types of inserts are commonly used: ultrasonic, thermal, molded-in, expansion, or solid bushings. With ultrasonic and molded-in inserts, plastic material may flow within undercuts and grooves allowing for more holding power. Generally, with expansion and solid bushings, friction and pressure alone against the outer knurls and grooves hold the insert in place. In any of these solutions, the tapped inner hole normally accepts a standard machine screw. This is beneficial for parts requiring frequent disassembly and reassembly or that require an electrical grounding connection.

1. **Ultrasonic inserts** are pressed into place as the plastic is melted by high-frequency ultrasonic vibrations. It becomes secured as the melt solidifies. This is the preferred installation for DuPont thermoplastic resins as it creates a relatively low-stress installation.

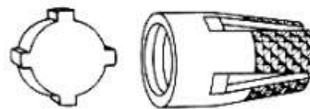


2. Thermal inserts are similar to ultrasonic inserts except that the insert is preheated and then pressed into the plastic. A localized area of material in contact with the insert melts and flows around the insert's undercuts and knurls. The insert is held secure upon solidification of the material. This is also a preferred low-stress installation option.

3. **Molded-in inserts**, shaped to minimize stress, are prepositioned directly in the mold and become an integral part of the component after the molten resin flows around the insert and freezes.



4. **Expansion inserts** are slipped into pre-molded or drilled holes, locking in place as the screw expands the insert.



5. **Solid bushings** are generally two-piece inserts. The body is screwed into a prepared hole and a ring locks it in place.



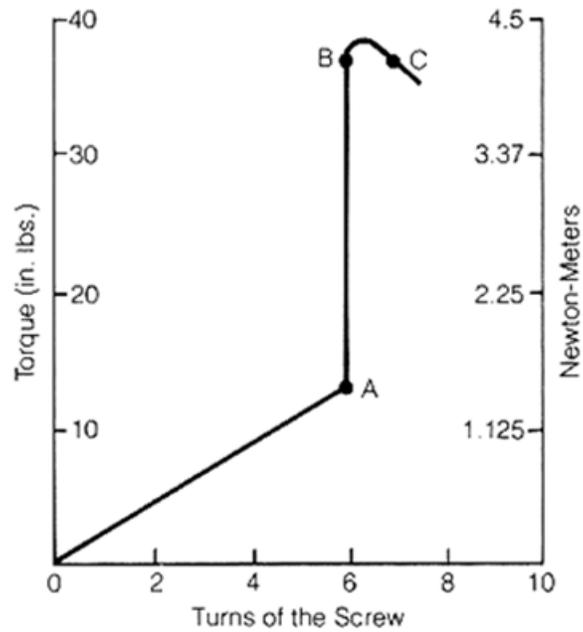
Other Important Factors

When designing for self-tapping screws, a number of factors are important:

- **Boss Hole Dimension**—For the highest ratio of stripping to driving torque, use a hole diameter equal to the pitch diameter of the screw.
- **Boss Outside Dimension**—The most practical boss diameter is 2.5 times the screw diameter. If the boss wall is too thin, it may crack. Higher stripping torques are generally not achieved with thicker bosses.
- **Effect of Screw Length**—Stripping torque increases rapidly with increasing length of engagement and levels off when the engaged length is about 2.5 times the pitch diameter of the screw. Seating torque, however, continues to increase with increasing length of engagement.

Strip-To-Drive Ratio

The torque-turn curve in the graph below shows how a self-tapping screw responds to applied torque. Up to point "A", driving torque is applied to cut or form a thread and to overcome sliding friction on the threads. Successive turns require more torque as the area of thread engagement increases. At point "A", the head of the screw seats upon the part being assembled. Any further application of torque results in compressive loading of the threads and approaches point "B", the stripping torque. At point "B", stress in the threads reaches the yield point of the plastic, and the threads begin to shear off. Threads continue to strip off to point "C" when the fastening fails completely.



Torque-Turn Plot

Strip-to-drive ratio, the ratio of stripping torque to head seating torque can be used to evaluate the performance of a fastened joint. For high volume production with power tools, this ratio should be about 4-to-1. With well-trained operators working with consistent parts and hand tools, a 2-to-1 ratio may be acceptable. In any case, lubricants must be avoided because they drastically reduce this ratio.

The ultimate test of a self-tapping screw is the pull-out force. In a well-designed boss, it can be calculated from;

$$F = S_s A = S_s \pi D_p L$$

Where:

F = Pull-out force

S_s = Shear stress = $S_t \sqrt{3}$

S_t = Tensile yield stress

A = Shear area = $\pi D_p L$

D_p = Pitch diameter

L = Axial length of full thread engagement

Pull-out strength does not generally decrease with time. A first approximation of the stripping torque for a particular design may be estimated by the following:

$$T = Fr \frac{p + 2\pi fr}{2\pi r - fp}$$

where:

T = Torque to develop pull-out force

F = Pull-out force

r = Pitch radius of screw

p = Reciprocal of threads per unit length

f = Coefficient of friction

Performance verification may be obtained by running prototype tests on boss plaques or flat plaques molded in the plastic selected. Prototyping with molded bosses in the material of interest is highly recommended. It should be noted that in-use conditions such as temperature, humidity, UV and chemical exposure will affect the long-term performance of a screw joint to a degree based on the material(s) being assembled and type of screw selected. Material factors such as creep (which is dependent on time and temperature) can decrease the loosening torque of the screw over time.

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