AN INTRODUCTION TO SMALL SCREWS

Small screws are the backbone of modern day assembly operations. They are found in such diverse products as watches, computers, toasters, automobiles and surgical implants. Consider just how pervasive these products really are. For example, just about every light switch cover plate is held in place with two screws and the wires which run to that switch are carefully held in place by small screws. Your eyeglass stems are held in place with screws, and chances are the chair you are sitting on depends upon screws to hold it together.

In this section the basic products included are commonly referred to as tapping screws, machine screws, and SEMS. Let's take a look at tapping screws to see what would be most helpful for design/selection of these products.

TAPPING SCREWS

Tapping screws are threaded fasteners with the unique ability to "tap" their own mating internal thread when driven into preformed holes in metallic and nonmetallic materials. Tapping screws are installed from one side which facilitates assembly. Since they form or cut their own mating thread, there is an excellent thread fit which enhances resistance to their loosening in service. They can be disassembled and are generally reusable. There are a wide variety of combinations of sizes, thread types, head styles, drive mechanisms and performance capacities to choose from to satisfy the requirements of just about any engineering application in which the use of small size screws is a design option.

EVOLUTION

Tapping screws were commercially introduced in 1914. The first design — essentially copied from wood screws — was a hardened steel gimlet point Type A thread forming screw. Its principal application was joining thin gage sheet metal ducts in heating and ventilating systems, consequently its name "sheet metal screw."

By the late 1920's, broadening markets and new applications highlighted the need for new designs with greatly extended performance capabilities. A 40-year evolution followed. It can be traced through four distinct phases of tapping screw design — thread forming, thread cutting, thread rolling, and self-drilling.

Thread forming screws are a direct outgrowth of the first sheet metal screw. Thread forming tapping screws when driven into a preformed hole form their mating internal thread by displacing material adjacent to the hole and pushing it outward into the open spaces between the threads of the tapping screw.

Because thread forming is convenient only in fairly thin sections of malleable materials, thread cutting tapping screws were introduced to extend tapping screw usage to thicker sections and to harder, friable and other materials with limited deformation capabilities. Thread cutting tapping screws have cutting flutes or edges at their point so that when driven into a preformed hole, the screw acts as a tap and actually cuts its own mating thread.

In the early 1950's fastener engineers began to realize that rather than being just light load carrying attachment screws, tapping screws had "structural" potential. This led to the development of a whole new generation of screws known generically as thread rolling tapping screws. Based on the engineering principles pioneered in the design of swage-forming taps, thread rolling tapping screws have specially designed threads and points which permit the screw to form a mating internal thread by applying intermittent pressures at the crest of the screw's thread rather than over its full thread flank. By concentrating and localizing the thread

AN INTRODUCTION TO SMALL SCREWS

forming pressures, the compressed material adjacent to the hole flows easily and better fills into the tapping screw's thread flanks and roots. Because frictional resistance to driving is significantly lower than for thread forming screws, thread rolling screws can be driven into thicker sections, there is better control of driving and tightening torques, and joint strength and integrity are considerably improved. The engineering standards for thread rolling tapping screws define strict controls on material selection, heat treatments, mechanical and performance properties, all greatly extended beyond the requirements specified for thread forming and thread cutting tapping screws. Thread rolling tapping screws are truly "structural" fasteners.

One of the most expensive of the several items making up the total cost of assembly is hole preparation. Tapping screws need preformed holes if they are to function satisfactorily in their service application. Holes must be prepared within relatively narrow size limits. The introduction of self-drilling tapping screws in the early 1960's paved the way toward many interesting assembly cost saving opportunities by eliminating the need for the preformed hole. Simply stated, self-drilling tapping screws drill, tap, and fasten in one operation.

The thread forming, thread cutting, thread rolling, and self-drilling designs are the four major plateaus in tapping screw evolution. Other developments should also be mentioned. The first is the family of screws which has been developed for use in plastics, particle board, masonite and wood. High torques needed to drive conventional tapping screws into many structural types of plastic produced undesirable high stresses. In response, the fastener producers have developed a number of different designs which enhance plastic, particle board and masonite assembly. These designs focus on wide spaced threads, reduced included thread angles (from the standard 60° form) and other selected features based on single or multiple thread leads and concentration of forming pressures. These features, when combined in a given screw design, provide highly desirable characteristics for the assembly of these materials.

Another development in design is a tapping screw with a twin lead spaced thread, self-drilling point, and a "bugle" shaped head. On installation, the screw drives easily through the drywall, drills a hole in the steel stud, and forms its own mating thread. The "bugle" head with its concave underhead bearing surface compresses into the board without tearing the cover paper or damaging the gypsum core.

Many other offshoots and special adaptations of tapping screws are commercially available. For example, tapping screws are offered as SEMS (screw with preassembled washer), with preapplied sealing compounds, and with special "coarse-fine" threads to prevent screw removal after installation.

ENGINEERING STANDARDS

Three basic standards provide information relating to metric tapping screws. Each is presented in the following pages.

ASME B18.6.5M, page G–37, presents the dimensions of thread forming and thread cutting slotted and cross recessed head tapping screws. Also included are mechanical and performance requirements for carbon steel tapping screws.

Appendices give instructions for gaging various dimensional features and application guidance. SAE J1237, page G–80, provides the dimensional, mechanical and performance requirements for carbon steel thread rolling screws. Finally, IFI-504 provides the dimensional, mechanical and performance requirements of self-drilling tapping screws, page G–92. Information relating to tapping screw SEMS is included in ASME B18.13.1M beginning on page G–102.

TAPPING SCREW CHARACTERISTICS AND FEATURES

Threads and Thread Types

Standard tapping screws are identified by letter designations each denoting a specific combination of thread form and point design. All standard tapping screws have one of two thread forms, either machine screw or spaced threads. The point configuration (and/or modification of thread form) separates tapping screws into their basic groups of thread forming, thread cutting, thread rolling and self-drilling.

Tapping screws with machine screw threads have a 60 deg thread form not necessarily conforming to any standard thread profile (see page G–4). If a tapping screw with a machine thread is lost or needs service replacement; a standard threaded fastener of the same diameter-pitch combination can substitute and will assemble with the internal thread originally cut or formed by the tapping screw. Spaced threads have the conventional 60° included angle thread form, but with an expanded thread pitch. With fewer threads per inch, spaced threads have a steeper helix angle. This means their lead (axial advance per revolution of turn) is greater than screws with machine threads.

All tapping screws with the letter "B" in their designation have spaced threads. Those without a "B" have machine threads.

Thread forming screws are Types AB and B in metric. The principal difference between these two types is the point design. Type AB has a gimlet point while Type B has a blunt point with tapered lead threads having unfinished crests.

Gimlet points center into preformed holes and facilitate thread start, but they are longer and need more blind side clearance. Also, gimlet points tend to be sharp and may damage other components in the assembly if they contact.

Thread cutting screws are Types BF, BT, D, F, and T. Types BF and BT have spaced threads; the others machine threads. Other differences relate to the design of their cutting point. Each cutting point has some form of chip cavity to collect the workpiece material removed by the tapping operation. If the tapping screw is inserted into a blind hole, the chips accumulate and remain permanently sealed at the bottom of the hole. If, however, the screw taps completely through the engaged material, the chips drop into the assembly on the blind side. Consequently, before selecting a thread cutting screw, some thought should be given to the possible effect, if any, of the presence of small chips in the system. Entry of such foreign material may contaminate lubricants, fall into moving parts, or disrupt applications incorporating electrical or electronic circuitry.

Descriptions of the seven types mentioned above are given in ASME B18.6.5M.

All metric thread rolling tapping screws have a basic "machine" thread form with diameter-pitch combinations of the M profile series. Each type of thread rolling screw incorporates into its design a proprietary modification of the thread form and/or point to give the screw its ability to localize thread forming pressures and significantly reduce driving torques. Data on threads of thread rolling screws are given in SAE J1237, page G–80.

Self-drilling tapping screws are standard with thread cutting spaced threads, Type BSD, and with machine threads, Type CSD. However, several specially designed thread forms with various pitches and thread angles in

AN INTRODUCTION TO SMALL SCREWS

combination with various designs of drill points are commercially available. Because of differences in drill feed and thread lead, self-drilling screws are not suited for use in blind holes. When installing self-drilling screws, the drill point must completely drill through the engaged material before threading starts. There will always be drill chips and, if a thread cutting type is used, some thread tapping chips. Consequently, thought must be given to whether their presence will be objectionable. Data on Types BSD and CSD self-drilling tapping screws are given in IFI-504, page G–92.

The most important characteristic of tapping screw threads is major diameter. If oversize, driving torques increase; if undersize, thread shear area is sacrificed. Major diameters are easily inspected using a micrometer or plain GO and NOT GO ring gages. Other than this one attribute, tapping screw threads are not subject to any other thread gaging. And sensibly so as their function is to form or tap an internal thread, not mate with one already prepared.

Two other comparisons relating to tapping screw threads are worth comment.

Thread forming displaces joint material forcing it outward and into the tapping screw's threads. Because the internal thread minor diameters are smaller than the preformed hole size, there is more thread overlap, and thread shear areas are greater. Thread cutting removes material. The internal thread minor diameter is exactly the same as the original hole size. All other features of the joint being equal, it takes less driving torque to install a thread cutting screw, but at a sacrifice of the joint's capacity to resist thread stripping and screw pullout.

The more threads per unit length, the more joint material that must be displaced or cut away during screw installation. Consequently, tapping screws with machine threads usually require more driving torque than tapping screws with spaced threads. But, the more threads per unit length, the greater the resulting thread shear areas which, in turn, translates into resistance to thread stripping and screw pullout.

Materials, Treatments and Finishes

Tapping screws are made of carbon steel, stainless steel, brass and aluminum. Carbon steel tapping screws comprise such an overwhelming percentage of total tapping screw usage — probably 99 percent or higher — that the remainder of this discussion will be limited to just this one basic material. In fact, published data on the properties and performance capabilities of tapping screws of materials other than carbon steel are close to nonexistent.

Steel tapping screws are made of low carbon steel (several analyses are suitable) and case hardened to give them the extremely hard outer surface necessary to cut or form internal threads.

Case depth and case-to-core hardness relationships are important. If the case is too thin, the screw won't drive properly; if it's too thick, core torsional strength and screw ductility are adversely affected. Specific case depth limits are specified in ASME B18.6.5M. Also, included is the core hardness range after tempering and also specified is a minimum surface hardness.

A high percentage of tapping screws are plated or coated with zinc electroplating or zinc phosphate coatings. Today, cadmium is rarely specified because of its higher cost and possible toxicity in certain applications. Where good appearance is a prime concern, nickel or chromium platings might be considered.

Two problems are associated with platings. The high hardness, small size of tapping screws aggravates their susceptibility to hydrogen embrittlement. Consequently, considerable care must be exercised by screw manufacturers to obviate this possibility. Baking within a reasonable time following electroplating for specified time at temperature is generally practiced. For example, SAE J1237 establishes specific requirements in its Para. 3.3 (see IFI-142, page K–26).

Plating adds thickness and different plating materials affect drive and tightening torque relationships. Because of the sensitivity of hole sizes to proper driving and tightening, it is most important that when experimenting to determine the correct hole size for any application that the test screws have the same surface finish as the screws to be used in production. Recommended hole sizes for Types D, F, G and T are found in Section K, page K–16.

Head Styles

ASME B18.6.5M details the dimensions for only five different metric head styles (a 54% simplification from inch practice) including flat countersunk, oval countersunk, pan head, hex head and hex flange head. These head designs probably account for almost all metric tapping screw usage.

Thread rolling tapping screws are available in the same styles as thread forming and thread cutting tapping screws with an additional hex washer head style.

For self-drilling screws, flat countersunk, oval countersunk, pan and hex washer are standard heads. Hex heads are not favored because the drilling operation requires end pressure and an abutment to support the driving tool is useful, such as the cross recess in flat, oval and pan heads or the washer of hex washer heads.

While national standards recognize only six head styles as standard, many other special purpose heads are commercially available. Already mentioned was the bugle head for drywall screws. Others are round washer, wafer (low profile), acorn hex washer (high hex), and a number of tamper proof designs to prevent screw removal following installation. Screw manufacturers may be consulted for information and guidance.

Drive Systems

Drive systems relate to the means by which the head is torqued during screw installation and tightening. The two basic ways are by external wrenching and recesses. In general, external wrenching permits higher torques than can be applied through any of the recess designs.

Hex and hex washer heads are designed for external wrenching, although on special order both designs can be supplied slotted or with a cross recess.

Slots are a form of recess. Slotted head screws are standard for flat countersunk, oval countersunk and pan heads. Slot dimensions are detailed for each head style throughout B18.6.5M. Slotted heads are best suited for manual installation and not for semiautomatic or fully automated installation.

Slots are manufactured either by sawing them into a fully formed head or by forming them into the head during the primary upsetting operation. "Struck" slots are more economical because they eliminate the need for a secondary operation. However, there are a couple of by-product drawbacks. When striking slots into indented hex or hex washer heads, the rim of the indent tends to crush making it difficult to accurately measure slot depth and, much more importantly, reducing driver engagement area. Struck slots in circular heads retain their full driver engagement area, but the forming pressures tend to broaden the head diameter

AN INTRODUCTION TO SMALL SCREWS

perpendicular to the slot while decreasing it parallel to the slot. For some sizes and head styles it is a manufacturing difficulty to maintain head diameters within their specified max/min limits.

To accommodate high-volume automatic assembly a whole new family of recessed drive system designs evolved, all with a principal objective to deliver high torques while permitting easy entry and retention of driving bits and tools under high speed conditions. Currently, numerous designs of recesses enjoy some degree of popularity. B18.6.5M recognizes three of them as standard, all of the cruciform design, and designated Type I (Phillips®), Type IA (Pozidriv®), and Type II (Frearson®). The dimensions for these recesses are given with the various product standards throughout B18.6.5M.

Type II was the first cross recess ever introduced, followed by Type I, and then Type IA which actually is an improved Type I.

The square recess, Scrulox® (also sometimes referred to as Type III), is popular in Canada and has gained wide acceptance in the United States, particularly by the furniture making, mobile home, and marine industries. The square recess permits efficient high driving torques with minimal driver slop or cam-out. However, the design is not as well suited for high speed automatic assemblies as the cruciform recess.

Some of the other recesses now available are hex socket, the "hourglass" shaped Clutch®, the hexalobular Torx®, Torx Plus®, Supadriv® (an improved Type IA), Hi-Torque®, and Torq-Set®, these last two being popular for high-strength aerospace fasteners. As yet none of these recesses, other than Types I, IA, and II, have been accepted into ANSI/ASME standards. At this time ISO is preparing a number of product standards intended for incoming inspection featuring the hexalobular drive. Full dimensional and performance data, however, is available from the primary licensor or any licensee.

Screw Lengths

It is important when selecting screw length for any application that the screw be long enough to assure engagement of full form thread through the full thickness of the joined-to material. This means that the computed screw length must equal grip length (total thickness of all material in the joint) plus the length of the screw point. The length of point includes the incomplete threads and, additionally, for Type AB thread forming screws the length of the gimlet point and for self-drilling screws the length of the drill. The various product standards detail point length limits. When computing needed screw lengths, maximum values specified for points, gimlets and drills should be used.

Mechanical and Performance Requirements

Before giving application guidance, it might be useful to explain the mechanical and performance requirements specified in each of the four engineering standards.

ASME B18.6.5M

B18.6.5M includes thread forming and thread cutting tapping screws. It states that they are normally fabricated from carbon steel and processed to meet performance and test requirements specified in its Para. 3. In this paragraph chemical composition and heat treatment including total case depth and surface hardness are defined.

All sizes and thread types are then torsion tested. In the torsion test the screw is clamped in a holding device with the head free of the clamping surface and the head is torqued until failure occurs, which is usually by twist-off through the shank or at the junction of head-to-shank interface. The resulting failure torque must equal or exceed a specified value. Torsional strength values for thread forming and thread cutting screws are based on a tensile strength value of approximately 800 MPa.

SAE J1237

Requirements for thread rolling screws go far beyond those of B18.6.5M. A drive torque and torque-to-clamp load requirement are specified together with a proof torque and hydrogen embrittlement test. Also specified for hex head, hex washer head, and hex flange head is a minimum tensile strength and a wedge tensile strength for Types 9 and 10. The drive test provides that the screw shall form a mating thread without visible deformation of its thread while the maximum torque experienced during driving shall not exceed a specified value.

All thread rolling screws are ductility tested by bending their head through 7° with respect to their axis. Electroplated screws are tested for the presence of hydrogen embrittlement by demonstrating an ability to survive 24 hours when tightened in a threaded hole or nut, with a specified torque (about 75-80 percent of the minimum torsional strength).

Notably, J1237 recognizes that different surface finishes affect torque-tension relationships and separate values are specified for zinc electroplated screws vs. those with cadmium electroplating or phosphate coatings.

IFI-504

Self-drilling tapping screws with spaced or machine screw threads are required to meet specified material, heat treatment, torsional strength, ductility and hydrogen embrittlement risk management utilizing a hydrogen embrittlement torque test which is similar to SAE J1237.

Case and core hardnesses are established to meet the demands of a drilling operation. Screws are subject to a drill-drive test in which the screw must drill a hole and form an internal thread in a plate of a specified thickness and hardness within a specified time limit.

SCREW SELECTION AND APPLICATION

When a tapping screw is installed it takes effort — known as drive torque — to form or cut the mating internal thread. As torquing is continued, the screw seats, tightens, and at some level — known as ultimate torque — failure occurs by screw fracture, twist-off, or by thread stripping and screw pull-out from the engaged material.

In any tapping screw application perhaps the most important questions are, "What is the correct tightening torque? How much torque does it take to drive the screw, tighten the joint, and do it without damaging the screw or the joined material?" Obviously, the correct tightening torque lies somewhere between the drive and ultimate torques, and it's not unreasonable to suggest that midway might be optimum. However, several factors interrelate to influence the magnitude of drive and ultimate torques. Important are screw type, size, joint material composition and hardness, thickness, and the method to prepare the preformed holes. But, most critical is the size of the hole into which the tapping screw will be driven. Interestingly, all other factors affect hole size. It's the last design decision, and it's the most important. If the hole is too big, the screw may drive easily, but joint integrity is jeopardized and the screw will pull out at considerably lower ultimate torques. If the hole is too small, drive torques will be excessively high and screw head twist-off is risked. Even if the screw seats and tightens, the spread between drive and ultimate torques could be so narrow that production assembly failures are an almost certainty.

AN INTRODUCTION TO SMALL SCREWS

A brief look at the effect each of the various factors has on hole size may give some practical guidance on hole size determination and appropriate drive-to-ultimate torque relationships. All with a view to answering the question, "How much tightening torque?"

Screw Type

Generally, the broad circumstances of the application allow a relatively easy decision as to whether the right screw for the job should be a thread forming, thread cutting, thread rolling or self-drilling tapping screw. For example:

— will the screw merely attach or must it support sizeable externally applied loads?

— what is the material being joined to? Is it steel, cast iron, aluminum, plastic, wood, or other?

— what is its thickness?

— will the screw go through the material or into a blind hole?

— if through, are blind side clearances limited?

— will tap or drill chips be objectionable?

— will the preformed holes be drilled, cored, pierced, punched or extruded?

— how will the screws be installed; manually, semiautomatic, fully automated?

— is periodic disassembly expected?

— will the assembly be under vibration?

— is the environmental exposure corrosion-inducing?

— cost of fasteners, cost of assembly.

Major diameters of spaced and machine threads are different for tapping screws of the same nominal size. Consequently, hole sizes are different. However, for most applications only two sets of hole sizes are needed, one for thread rolling and thread cutting screws with machine threads, and the other for thread forming and thread cutting screws with spaced threads. Hole sizes proper for thread rolling and thread forming screws are usually satisfactory for thread cutting screws because, all else being equal, "cutting" torques are lower than "forming" torques. For plastic materials, the material type and screw type will impact hole size.

Screw Size

In the design of structural joints, good engineering suggests that, if a bolt/nut combination should fail due to overtightening during installation or overstressing in service, effort must be made to assure failure by bolt fracture and not by thread stripping. This same principal is valid when designing joints fastened with tapping screws, particularly if the joint will be service loaded. If a joint failure should occur, it is preferable that the screw breaks rather than its threads strip or the screw pulls out of the material it joins.

Resistance to thread stripping or screw pull-out is a function of material strength and thread shear areas, which, in turn, are dimensionally controlled by screw size, length of thread engagement, and depth of mating thread overlap. In tapping screw applications, length of thread engagement is the thickness of the joined-to material; depth of thread overlap depends exclusively on hole size. The other dimensional factor, screw size, also establishes the tapping screw's torsional and tensile strengths.

With any given thickness of material, using a larger size screw increases the ratio of tensile stress area to thread shear area and consequently trends the failure mode toward thread stripping or screw pull-out. Use of a smaller size screw reverses the ratio, but may increase driving torques unacceptably high and risk screw head twist-off. Balancing screw tensile strength capacities against resistance to thread stripping or screw pull-out suggests there may be a relationship between screw size and material thickness.

For threaded steel fasteners when used in compatible materials, it will generally be found that a length of full thread engagement equal to one times the fastener size (D) is adequate to prevent a thread stripping failure. It then seems reasonable that for thread cutting screws, where similar to a nut, the minor diameter of the internal thread is the original hole size, screw sizes equal to or smaller than the material's thickness should perform satisfactorily. Actually, because of their lower driving torques, thread cutting screws can be driven conveniently in materials with thicknesses of 1.5D or more. For thread rolling screws — with their low driving torques and helped by the better-filling and superior thread fit of the internal threads they form — a screw size of about 1.1 times material thickness is suggested. For thread forming screws — because of their spaced threads and high driving torques — it is difficult to develop adequate thread shear area to prevent the failure mode being thread stripping or screw pull-out. Fortunately, in most thread forming screw applications the joint is rarely subjected to high loading conditions. However, where it may be of importance to minimize thread stripping or screw pull-out to the degree possible, a screw size of about 1.3 times material thickness is a reasonable compromise.

These suggestions relate to steel tapping screws driven into mild steel joint material. For other joined-to materials, adjustments must be made to reflect their different shear strength capacities. Most importantly, these suggestions assume the preformed holes are of the proper size.

Material Hardness and Thickness

Obviously, the harder and/or thicker the engaged material, the greater the effort needed to drive a tapping screw. To compensate, the preformed hole size must be enlarged. But hole size adjustments are possible only within relatively narrow limits.

In general terms, the proper hole size approximates the diameter at mid-height of the tapping screw's thread. To retain any meaningful thread depth overlap the hole size can't be opened up much beyond a diameter at 75 percent of thread height. And, for small screws, these are small adjustment possibilities. For example, a M6.3 thread forming screw has a thread height of 1.37 mm. A hole at mid-height provides just 0.685 mm thread depth overlap. A hole at 75% of thread height permits only 0.171 mm of thread depth overlap or a possible hole size increase of only 0.342 mm.

For harder materials and thicker sections, thought should be given to selecting a larger screw size rather than opening hole sizes to allow driving of a smaller size screw.

Hole Preparation

Preformed holes can be drilled, cored, punched, pierced, or extruded. Drilled holes have straight side walls, cored holes are slightly tapered, punched holes usually have a breakout at the far side, pierced holes form an embossing drag on the far side, and extrusion elongates the hole and thickens the section to be tapped. When drilling, hole size selection and adjustments are dictated by available standard drill sizes. The other methods permit more flexibility as dies can be sized exactly. Cored holes with their tapered side walls may adversely affect either depth of thread engagement or driving torques, and may require unique design consideration.

Hole Sizes and Tightening Torques

There are no mathematical formulas, or even empirical relationships, which permit calculation of proper hole sizes for any tapping screw application. And, understandably so when considering the complexity of all the many interacting influences. ASME B18.6.5M includes in Appendix V a series of approximate hole sizes for metric tapping screws. Appendix VI includes approximate installation hole sizes for Type AB and some Type B thread forming screws and for Types BF and BT thread cutting screws. Approximations are based on given types of material, various thicknesses and method of hole preparation. No values have been included for Types D, F, and T thread cutting tapping screws. Recognizing the need for this information, the Engineering Committee of IFI's Division I has prepared recommendations which may be found on page K–16.

A review of the technical literature on tapping screws reveals the frequent recommendation that drive torques should be between one-third to one-half of ultimate torques. At first glance this recommendation appears reasonable, but without some additional qualifier it doesn't entirely make sense. For instance, it is possible to enlarge a pilot hole to a size where the drive torque becomes very low. But, in doing so, ultimate torque also drops and even though a 1:3 ratio may still remain, the joint is essentially worthless. So, a "qualifier" is needed.

In the three engineering standards for steel tapping screws, minimum torsional strengths are specified. These values are torques that "free standing" screws must accept without evidence of damage or failure. In an application, ultimate torque will be higher than torsional torque for the two reasons that the specified torsional strength is a minimum and ultimate torques include effort to overcome head and thread friction. Torsional torques can be used as an indicator to appropriate drive torques.

To maintain an adequate spread between tightening torque and ultimate torque, it is reasonable to establish a "first consideration" tightening torque equal to 70 percent of the screw's specified minimum torsional strength. If then, as mentioned earlier, a desirable tightening torque is midway between drive and ultimate torques, a "first consideration" drive torque would be 35 percent of the specified minimum torsional strength.

To establish final hole sizes and tightening torques the following steps are proposed —

1. Using the same material and thickness of the engaged material in the application, drill a hole with the mean diameter specified for the screw size and thread type.
2. Drive at a given speed a sample of the same screws to be used in production and record the maximum driving torque.
3. Continue driving at the same speed and record the torque at which failure occurs.
4. If the ratio of drive torque to ultimate torque is between 0.33 and 0.5, the chosen hole size is satisfactory. If the ratio is less than 0.33, repeat the test using a slightly smaller hole. If the ratio is greater than 0.5, retest using a slightly larger hole.
5. Establish the tightening torque at midway between drive torque and ultimate torque.
6. As a last check, measure the torsional strength of a sample screw by torquing a "free standing" screw to failure. The selected tightening torque should be

about 70 percent of the torsional failure torque.

While the previous discussion has been focused on metal installation, it should be noted that requirements into other materials such as plastics will change significantly.

Self-Drilling Tapping Screws

To this point self-drilling screws have not been mentioned for the simple reason they drill their own hole and it must be presumed the drill diameter is proportioned correctly for the following thread. However, once the hole is drilled and the screw begins to cut or form its mating thread, self-drilling screws act similarly to other tapping screws. The previous discussion is applicable and may help toward determination of appropriate tightening torques.

Machine Screws

Machine screws are included in ASME B18.6.7M beginning on page G–12. Metric machine screws include the following five standard head designs: flat countersunk, oval countersunk, pan, hex, and hex flange head. Used with these designs are four drives including slotted, recessed Types I, IA, or III. The threads are Metric – M Profile in accordance with ASME B1.13M and are gaged for dimensional acceptability in accordance with ASME B1.3M.

Steel machine screws are normally furnished to Property Class 4.8 in low carbon steel or 9.8 in heat treated steel in accordance with ASTM F568M. Other materials are customarily agreed to with reference to such material specifications as ASTM F468M or ASTM F738M.

RECOMMENDED TECHNIQUE FOR MEASURING CASE DEPTH

INTRODUCTION

The accurate measurement of case depth of fasteners which have been carburized or carbonitrided is often affected by conflicting results obtained by different laboratories. The conventional microscopic method relies on the ability of the technician to distinguish the line of demarcation between the case and the core, and with annealed or tempered structures this line is often not very sharply defined. Consequently, it is common for different people to come up with varying results on the same sample. The following recommended technique, however, greatly reduces the element of visual interpretation inherent in microscopic examination.

Samples are prepared by grinding to approximately one-half diameter on a longitudinal plane. They are heated for 7 minutes at 775°C and water quenched. Further grinding on 240 and 600 grit papers, followed by a 30 second etch in 2½ nital, rinse in methanol, and dry in an air blast, results in a structure as seen in the accompanying photomicrographs. The austenizing temperature of 775°C is sufficient to completely transform and harden the hyper-eutectoid case whereas the core will not harden. The polishing, while not up to full metallographic standards, is sufficient to clearly reveal the structure when etched. It is not necessary to mount the specimens in bakelite or lucite, which is a time-saving factor.

The following is a guide for Case Depth Measurement:

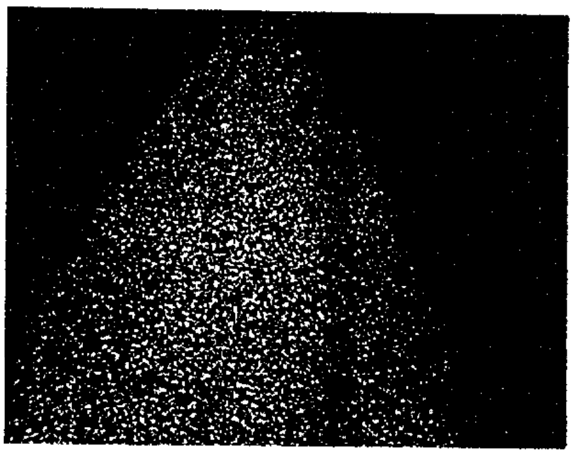
A. Standard Method

1. Prepare and quench samples as described in preceding paragraph.
2. Measure total case at thread flank, midpoint between crest and root. The depth of the case is taken as the line of demarcation between the hardened hypereutectoid zone and the unhardened core. Recommended magnification 100X.
3. Take readings on four separate threads and average results to obtain case depth of the screw. (The average figure rather than the minimum depth found at any one point should be used as the criterion for case depth, as a single low reading represents only a very small proportion of the total area involved.)

B. Referee Method

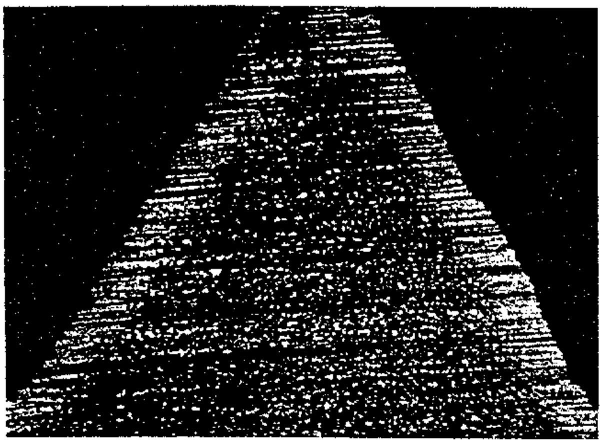
1. Take sample representing the conventional heat treatment of the part and mount and polish for microscopic examination.
2. Measure case with Tukon or equivalent microhardness instrument. Start at surface at midpoint of screw flank between root and crest, measure hardness at 25 μm increments. Total case depth will be perpendicular distance from surface to a point of Rc 45 minimum.

The accompanying photomicrographs illustrate comparisons between the structure of case and core produced by the method recommended herein and a regular quenched and tempered structure. Case depths were measured on each of three screws after carbonitriding and microhardness traverses were run. The same parts were then water-quenched from 775°C and case depths were again measured. Results of each method appear under the photographs.

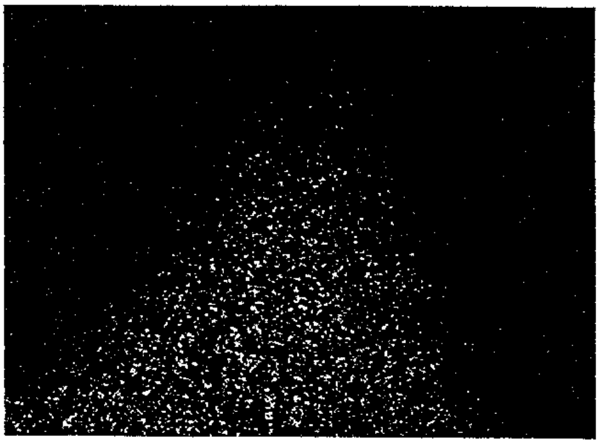


Structure of Case & Core After Anneal at 870°C for 7 minutes – Magnification of 100X, Nital Etch.

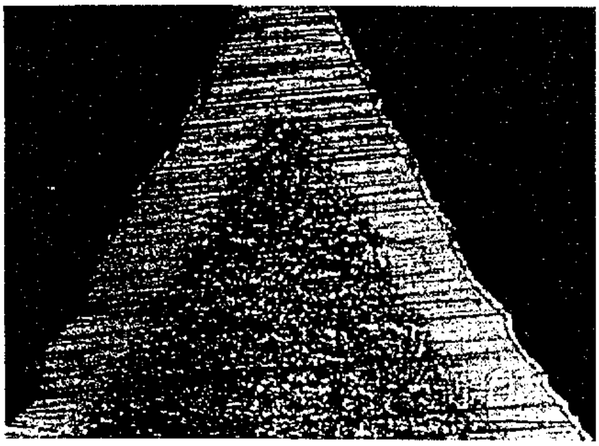
RECOMMENDED TECHNIQUE FOR MEASURING CASE DEPTH



50 µm Case Depth – Water Quench from 775°C
Magnification of 100X, Nital Etch.

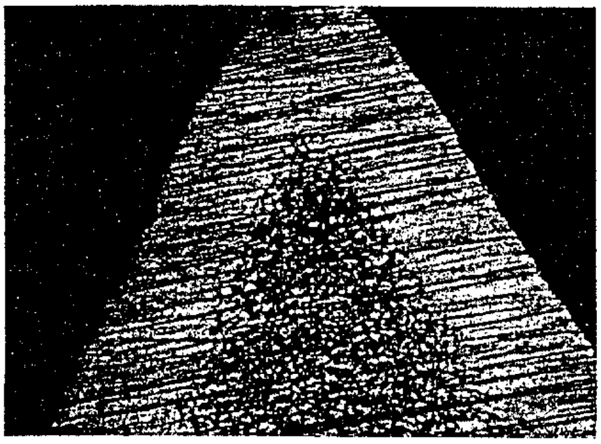


38/50 µm Case Depth, 50 µm to Rc 45 – Oil Quenched & Tempered – Magnification of 100X, Nital Etch.

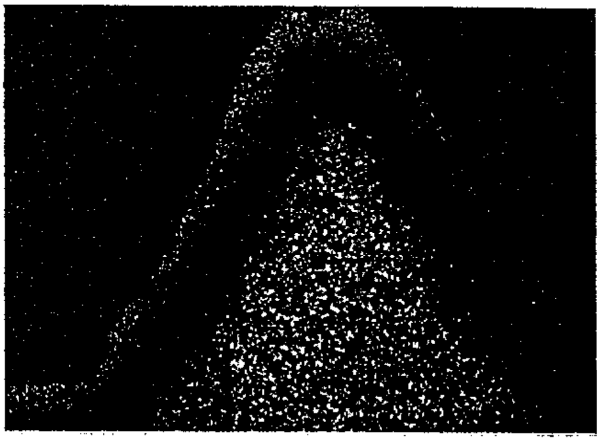


75 µm Case Depth – Water Quench from 775°C
Magnification of 100X, Nital Etch.

50/75 µm Case Depth, 63 µm to Rc 45 – Oil Quenched & Tempered – Magnification of 100X, Nital Etch.



125/140 µm Case Depth – Water Quench from 775°C
Magnification of 100X, Nital Etch.



100/125 µm Case Depth, 115 µm to Rc 45 – Oil Quenched & Tempered – Magnification of 100X, Nital Etch.