Part two in a two-part series

Comparison of Machine Screw Drive Styles

by David D. Archer

5.0 Test 3

Prevailing Torque, Hand Started

Not all fasteners are free-running, generally due to locking features or thread generation with thread-forming or thread-cutting screws. Along with insertion speed studied in the previous tests, the drive feature of most interest to most users is the ability to drive the screw under adverse conditions. This and Test 4 will provide this comparison.

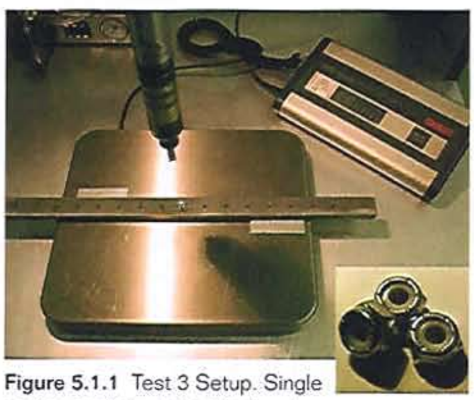

Figure 5.1.1 Test 3 Setup. Single center pocket contains lock nut (shown in inset). Axial load is measured on scale.

5.1 Test Procedure

The purpose of Test 3 is to drive screws under the same conditions as Test 1 into a prevailing torque locknut. The nut utilized was a nylon insert locknut. This type of nut was used because they provide a more consistent level of prevailing torque than a deformed thread metal locknut and at least as consistent as nuts with a Nylon patch, while being more readily available. While there are advantages of other types of locknuts in actual production, for the purpose of this test the Nylon insert was judged most desirable. The maximum initial prevailing torque for a non-metallic #10 locknut, as specified by the Industrial Fastener Institute (IFI), is 18 in-lb.

Introduction

Part one of this article, published in the September/October issue of **American Fastener Journal,** compared the time it took to drive #10-32 screws with various drive styles under a variety of conditions. This conclusion of the article expands the comparison of drive styles to considerations other than relative drive time.

Rather than modifying the nut member used in Test 1 to retain a row of locknuts, the single station setup shown in Figure 5.1.1 was created, as it was expected that all the screws tested would drive without difficulty when driven in-line with the nut axis. The nut member was placed on a digital scale so that the axial load applied during driving could be measured.

5.2 Test Results

As was expected, the test showed that all drive styles could be driven successfully into the locknut. Therefore if Test 1 had been conducted with an internal thread of the same level of prevailing torque as these locknuts, the relative results would be expected to be effectively identical, with the absolute run times about 0.25–0.50 second greater due to slowing of the driver to overcome the added load of prevailing torque.

The "natural" end load applied to the free-running screws in Test 1 was approximately 2 pounds. Additional end load was not required to drive the screws in Test 3 as long as the driver axis was maintained in line with the screw axis. There was a natural tendency for the operator to apply a greater end load (4–5 lb.) with the locknuts, but this was not required.

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Table 7.1.1
Head Dimensions of #10 Screws (inches)

		DIAMETER	HEIGHT
1	Pan – ex slotted	0.373	0.133
2	Pan – slotted	0.373	0.110
3	Flat	0.362	0.116
4	Button	0.361	0.101
5	Oval	0.362	0.176
6	Round	0.359	0.137
7	Binding	0.399	0.123
8	Fillister	0.313	0.180
9	Truss	0.448	0.118
10	Hex	0.312	0.120
11	Socket Cap	0.312	0.190
12	Hex Washer	0.414	0.151

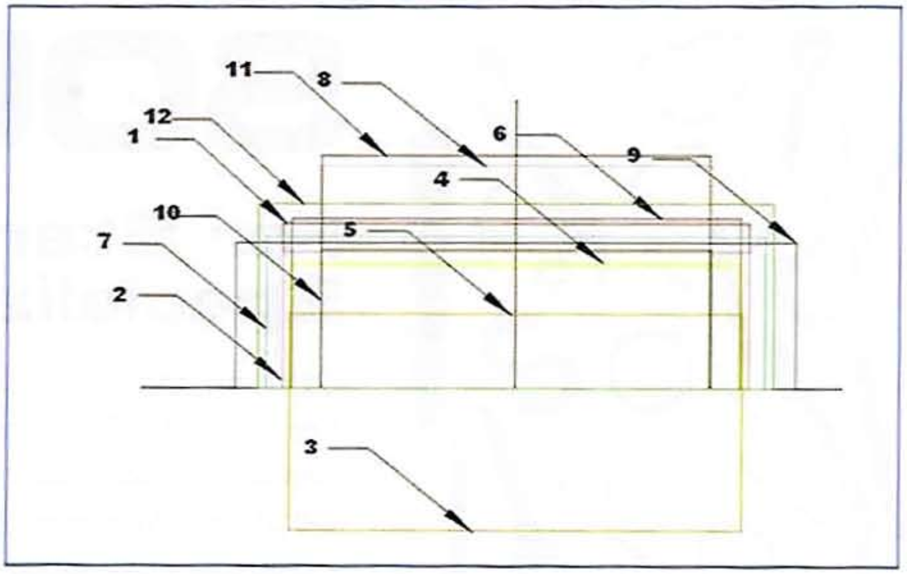

Figure 7.1.1 Relative size of various head styles

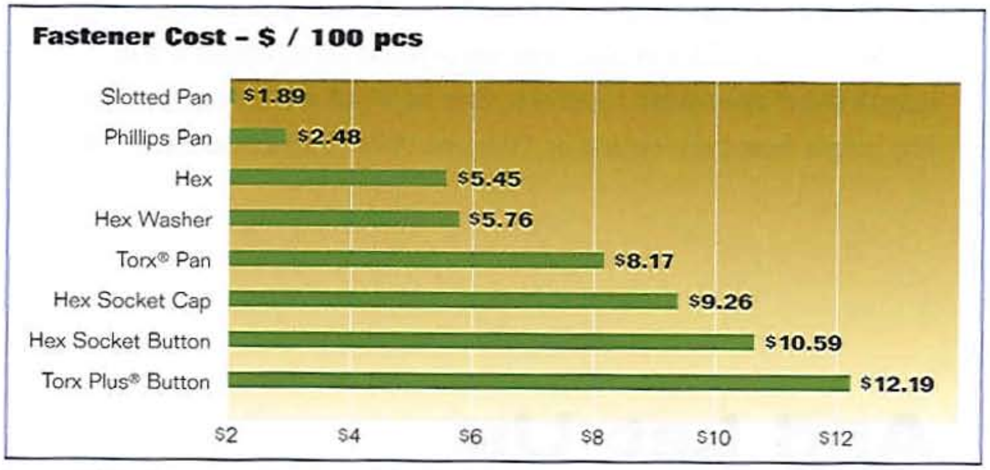

Figure 7.2.1 Summary of the price paid for the fasteners tested

the Phillips drive, where the pointed bit highly concentrates stresses during cam out.

7.0 Other Data

Although not directly related to drive style performance, other information that can influence the choice of drive style is the cost of the screw and the size of the head. That data is presented in this section.

7.1 Head Dimensions

As stated earlier, there are a number of reasons for selecting a particular head style. These include:

- Appearance
- Space restrictions
- Need for a flush head
- Bearing area/diameter considerations
- Presence of locking features

Appearance needs are difficult to consider in a quantitative manner, while locking features are an important area that will be investigated in detail in future test reports. The remaining three considerations can be associated with drive style. The desire for a compact head to overcome space limitations will tend to drive the user to internal drive styles and away from external hex drives that require bit clearance around the screw head.

If packaging is not a consideration, it is generally an advantage to use a larger diameter head as it will provide a greater bearing area, which in turn will reduce the tendency to embed the screw into the material of the mating component under the screw head. This is of particular concern when clamping plastics, metals with low compressive strength, or when using high-strength fasteners. When the fastener's bearing surface and the surface of the mating component are not parallel and don't result in full contact, the advantage of increased bearing area is diminished or lost.

Table 7.1.1 provides a summary of the diameter and height of most #10 screw heads. The accompanying Figure 7.1.1 could represent any screw size, as the relative size stays constant.

7.2 Fastener Cost

While consideration of the cost of the screws tested did not enter into the test results, cost is obviously an important consideration in fastener selection. Figure 7.2.1 compares the price paid for the fasteners tested. A couple of important considerations should be kept in mind when reviewing Figure 7.2.1. First, it should be remembered that the three highest cost screws are high-strength alloy steel fasteners with more than twice the tension capacity of the standard machine screw. However, depending on the application, this added strength cannot always be utilized. Second, because these screws were purchased at retail in 100 count boxes, the costs are heavily influenced by availability and demand considerations. In other words, the cost differentials shown are greater than can be explained by pure manufacturing considerations, and for large users like the automotive, appliance, or computer industry these costs would not show as great a span and there would likely be some changes in the relative position. It should also be noted that in addition to normal manufacturing costs, licensing also enters into fastener pricing. It is common for a patent-holder to

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6.0 Test 4

Off-Axis Driving

A more aggressive test of a drive style's ability to react input torque is, in addition to introducing a locknut, to position the driver at an angle to the screw axis. While off-axis driving is never preferred, it is often a reality due to access issues and is a capability that licensees of new drive styles promote as a reason to use their design.

6.1 Test Procedure

The same nuts and pocketed nut member used in Test 3 were also used in Test 4. The nut member was clamped to a work surface in front of a backdrop showing lines angled off perpendicular. This guide allowed measurement of the drive angle used during testing. To assist the operator in maintaining a constant in-line drive in the plane 90° to the plane established by the backdrop, a flexible guide was set up to contact the driver on either side of its centerline. This setup is shown in Figure 6.1.1.

Figure 6.1.1 Test 3 setup. The flexible support shown to the left was used to assist the operator in maintaining an in-line orientation along the axis of the nut member.

Each screw was inserted multiple times at increasing angles until the limit was reached. At that point 6–12 additional screws (depending on the consistency of the results) were run to establish the point at which the fastener could not be driven without the bit spinning out of the drive feature. This angle is the value reported in Figure 6.2.1.

Figure 6.2.1 Test 4 Results

	DRIVE	HEAD	ANGLE
◆	Phillips	Pan	2°
◆	Slotted	Pan	4°
◆	Hex Socket	Cap	4°
◆	Hex Socket	Button	6°
◆	Hex	Hex Washer	10°
◆	Torx Plus®	Button	12°
◆	Torx®	Pan	14°
◆	Hex	Cap	17°[1]

[1] The angle is reduced to 11° during the final portion of the drive

The maximum angle that each tested fastener can be reliably driven in a prevailing torque locknut

6.3 Data Interpretation

The poor performance of the Phillips drive was due to the angled drive surfaces and rapidly diminishing contact area when driven at even small angles. The failure mode of the slotted drive was that it cammed out laterally before enough angle could be achieved to cause axial release. This lateral cam out is present when driving slotted fasteners completely in-line, so the maximum drive angle is not distinct in this case. The angle reported was one at which the prevalence of cam out was significantly more noticeable than it was during in-line driving. The wide variation in results between the plain and washer head external hex drive was due to the washer flange limiting the bit position on the acute side of the drive angle. The plain hex head allowed the bit to fall below the screw bearing plane, thus allowing drive angle to be increased without raising the bit on the obtuse side of the drive angle. This means however that the drive cannot be completed at this angle because bit contact will prevent the fastener from being fully driven. At this point the driver must be rotated upward to an angle similar to the hex washer head. It should also be noted that at the reported 17° maximum angle some discontinuity could be felt during the drive as the bit rode over the tips of the drive surface. An additional 1° to 2° drive angle could be achieved with these relatively soft screws but this would result in rounding the tips of the head.

The internal contain fairly close fitting surfaces. The small increase in angle for the button head over the standard cap head is the result of the smaller engagement depth, which in turn allows a greater bit angle for the same clearance. The ball head drivers available for hex socket screws permit greater off-axis driving angles, but at the penalty of reduced contact area with the bit. When used for tightening rather than rundown, as is common when using a hex key, this reduction in contact area increases the potential for rotation between bit and screw, particularly with button heads where insertion depths and key sizes are smaller to begin with.

In a simple hex drive, stress is concentrated at the intersection of each plane (the tips of the drive or bit). As clearances are increased, stress concentrations rise quickly and rounding of the fastener and wear of the bit result. The lobed geometry of the Torx® and Torx Plus® drives allow greater clearance between the bit and drive surfaces because the shape allows more contact area to be maintained. This results in greater possible drive angles. A small drive angle difference between the Torx® and Torx Plus® drives may be influenced by the greater engagement depth of the pan head relative to the button head. As opposed to the internal hex drive, the Torx® drive allows a small axial movement that doesn't result in cam out. This may explain the difference, as a static angle measurement (a good indicator of dynamic performance for most drives) for the two drive systems was identical.

The fact that three of the fasteners were high strength did not add an unwanted variable to the test, as in each case the limiting factor was the initial disengagement of the bit and screw. This was not accelerated by the yielding of the lower strength machine screws. However, once the bit disengaged and continued spinning, the softer screws were damaged to a greater degree than the hardened types. This is particularly true of

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Table 8.0.1 Summary Comparison

	DRIVE	COMMENTS
1	Phillips	The reasons to specify Phillips drive: cost; availability for a desired head style; and user's tool assess are not based on performance. There are several variants of cross drive that improve the Phillips performance, but they are not nearly as widely available.
2	Hex	The value of the hex drive's high level of torque reaction capacity is of less value the smaller the fastener size, while the disadvantage of greater tool clearance becomes greater. Good for niche applications like scheduled removal in potentially corroded environments.
3	Hex Washer	Similar comments to hex. In most small fastener applications, washer head is more desirable than use of hex and separate washer. Commonly combined with slotted or Phillips drive which provides drive flexibility (Phillips preferred).
4	Socket Cap	The assembly flexibility of the hex key is particularly beneficial for full manual assembly, although this benefit is reduced in smaller screws where a screwdriver can comfortably provide the required installation torque. Application is defined more by the high-strength fasteners with which it is generally utilized.
5	Button Cap	Similar comments to Socket Cap. Lower head and smaller key greatly reduces torque reaction capability, while larger bearing area lessens the occurrence of embedment. Embedment is often an unrecognized problem when manufacturers attempt to gain the full tension potential of socket head cap screws against non-hardened components.
6	Torx®	A drive with a good range of performance properties. Use is limited more by issues such as availability in a wide range of sizes and head styles, and the consumer's limited ownership of Torx® drivers than by performance.
7	Torx Plus®	The primary enhancements of lower bit wear and breakage are not drivers for the target of these recommendations, and therefore it is hard to justify the added expense and lower availability relative to Torx®. Note that a Torx® driver can be used in Torx Plus® screw, while the reverse is not true.
8	Slotted	As the other low cost and widely available drive, the only performance benefit over Phillips is the ability to apply greater torque for removal of frozen screws.

license a drive style, thread form, or other feature to manufacturers for a fee, or if they are the manufacturer, to charge a premium price for this exclusivity. The only drive style tested in this study that is still under patent is Textron's Torx Plus®, as their Torx® patent has expired.

8.0 Concluding Comments

Final comments will first cover the results summarized in this report, and then discuss some of the elements that were not covered.

Regarding Test 1 and Test 2, the data developed provides the basis for the general conclusions made. More detailed conclusions and more accurate measurement of the gaps between drive styles would require a much larger number of test runs performed with a greater number of operators to increase statistical certainty.

Test 3 was a confirmation that locking patch or insert fasteners of this size with initial on torque values within IFI specifications do not significantly impact driving relative to free running fasteners when driven with a powered driver in-line.

The off-axis test run as Test 4 could be enhanced by a more sophisticated slide system with a pivoting driver attachment and adjustable end load. It is not, however, certain that this sophistication would significantly alter the results. The point of disengagement is distinct and repeatable, so more sophistication would simply provide reading accuracy more easily. In this study, multiple readings for each fastener were substituted for a sophisticated setup.

Screw length, a variable not included in Test 1, would significantly influence start times. However, for a given joint there is often not much flexibility in fastener length. Also, with its primary impact on starting, length is not a prime point of drive style differentiation.

Another measure of drive performance very important to manufacturers of high volume and automated products is bit wear and the ability to engage a rotating bit on a static head. These considerations were not included and do not necessarily correlate with the results of Test 4.

Finally, can an overall winner be identified? The range of joint requirements makes a single best answer difficult to offer, but the field can certainly be narrowed. Recommendations made in Table 8.0.1 are based on the following assumptions.

1. Recommendations are for fasteners smaller than 1/4" in diameter
2. Factors specific to automation and high volume production are not included.
3. Availability is assumed limited to what is widely available in standard fastener distribution, as described in the introduction. This means, for example, that the two socket cap and the Torx Plus® screws are assumed only available as more costly high-strength fasteners.
4. The relative cost of the fasteners is the same as shown in Section 7, although cost range may not be as great. ■