

About the Author/WAYNE WALLACE

Wayne Wallace is the president of Applied Bolting Technology Products. The company provides bolting consulting services and manufactures direct tension indicating washers from its base in Ludlow, Vermont. Wallace is a member of the Research Council on Structural Connections, a director of the Bolting Technology Council, and author of numerous papers on the practical aspects of quality assurance in structural bolting.

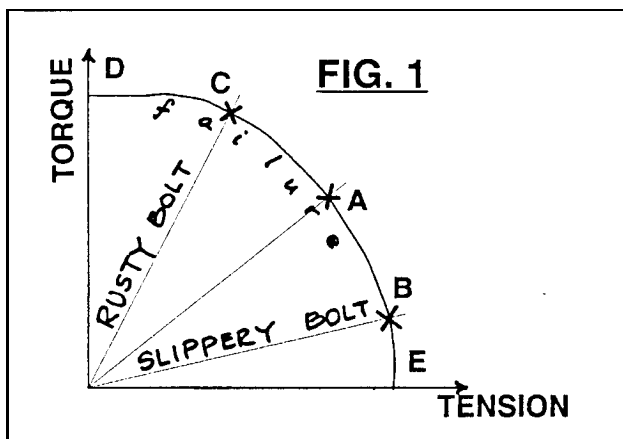


DTI's Do More, Often, For Less

Torque and Tension are very often confused, as most of us know. Take away the confusion and it quickly becomes apparent that paying a little for a compressible washer, called a DTI, actually saves money, and helps the connection stay together, too.

A simplified combination torque/tension curve illustrates the difference between them (Figure 1).

Consider what happens when you turn a nut and break off a bolt. For this bolt assembly, when the TORQUE (rotational turning effort or resistance) is plotted on the vertical scale, against TENSION (axial "stretch" in the bolt) plotted on the horizontal scale, the failure ("X") of the bolt occurs at a certain torque and at a coincident tension (point "A", Figure 1). For a different bolt assembly which has been better lubricated, and hence has a lower torque resistance, failure occurs at point "B" on Figure 1. For yet another bolt assembly which is less well lubricated, possibly even quite dry or rusty, the torque resistance is higher and failure occurs at point "C" on Figure 1.

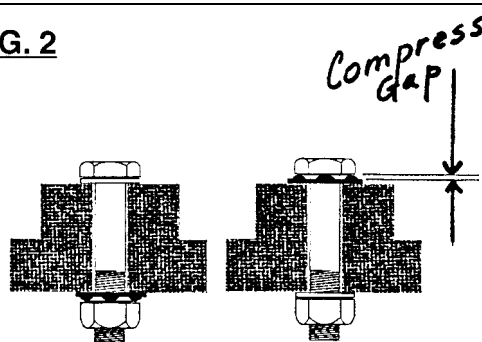


The "failure envelope" of combined torque and tension is marked on Figure 1 as a definite line, but is, in reality, a fuzzy line which is roughly elliptical. Although they're difficult to model in the lab, at its extremes, the failure envelope can be all torque and no tension ("D"), or all tension and no torque ("E").

The point of this illustration is to position clearly what Direct Tension Indicators (DTIs) actually do. As they

compress under a bolt head (Figure 2), they ONLY measure tension not torque. And it's bolt tension that creates the clamping force that holds connections together. DTIs are said to be very stupid — they only know bolt tension. Compress the DTI bumps using a lot of rotational energy (lots of torque) or just a little rotational energy (very low torque) and the clamping force will have been reliably generated.

FIG. 2



Some designers try to solve bolt loosening problems by using some form of locking washer or locking nut, such as Anco locknut. But bolts loosen because they were probably never tightened properly in the first place, not because the nuts suddenly and magically rotate counterclockwise¹. So ensuring a high and consistent initial tension will usually, if not always, prevent loosening of the bolt. And the good news is that, using DTIs, this can be accomplished no matter what the torque resistance, and it's never more expensive and often less expensive, as shown in Table 1¹¹.

Some designers feel that twist-off bolts can be installed correctly to high consistent initial tension, thereby reducing the probability of loosening. While this can be true, twist-off bolts depend on keeping the installation torque resistance in the same range as when they were manufactured, and construction site conditions conspire against this of course. Once the torque resistance of the twist-off bolt increases due to dirt, moisture, time, etc., as can be appreciated from Figure 1, the tension achieved during installation becomes lower and lower. And it's the low-tension bolts that feel external applied

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loads most directly, and therefore "shake down" to a "loose" condition most quickly. Again, the good news is that, as shown in Table 2, regular hex head bolts and DTIs can be less expensive than using twist-off bolts anyway.

ⁱThere are some forms of high frequency lateral vibration loads which can cause certain nuts to counter-rotate and therefore the bolts to loose clamping force. These situations are rare, and usually have to be solved by using a swaged nut such as on a Huck bolt.

ⁱⁱThese cost numbers are our best estimate of what an end user will pay, but obviously they depend on volume, timing, supplier, and country of origin.

TABLE 1

DTIs & Hex Nuts vs. Anco Nuts*

Bolt Dia.	2H Nut & DTI	Anco	DTI Saves \$\$/Bolt
5/8"	\$0.30	\$0.30	(NIL)
3/4"	\$0.40	\$0.40	(NIL)
7/8"	\$0.50	\$0.66	\$0.16
1"	\$0.62	\$0.90	\$0.28
1 1/8"	\$0.82	\$1.50	\$0.68
1 1/4"	\$1.01	\$1.70	\$0.69

TABLE 2

**DTIs & Hex Bolts vs Twist-Off Bolts*
A325**

Bolt Dia. Length	DTI, Hex Bolt, Nut One FW	Twist-Off Ass'y	DTI Saves \$\$/Bolt
7/8" x 3"	\$0.96/\$1.20	\$1.12	\$0.16/(0.08)
1" x 3"	\$1.50	\$1.70	\$0.20
1 1/8" x 3"	\$2.30	\$3.50/\$5.00	\$1.20/\$2.70
1 1/4" x 4"	\$2.40/\$3.30	Not Made	N/A

**DTIs & Hex Bolts vs Twist-Off Bolts*
A490**

Bolt Dia. Length	DTI, Hex Bolt, Nut Two FW	Twist-Off Ass'y	DTI Saves \$\$/Bolt
1" x 3"	\$2.00	\$2.40/\$2.60	\$0.40/\$0.60
1 1/8" x 3"	\$2.70/\$3.10	\$4.60/\$6.00	\$1.50/\$3.30
1 1/4" x 4"	\$4.10	Not Made	N/A