Tension Control Bolts – **Explained**

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Introduction

Tension controlled bolt or TC bolt was first introduced by a Japanese bolt company over four decades ago. It initially came as a proprietary niche product and there were no commonly used standards around the world to cover this product. The Japanese standard JSS II 09 (1) - 1981 'Torsional shear type high strength bolt for structural connection' is the first standard written for this product. This bolt has a reduced section (neck) at the end of the thread followed by a splined end that is sheared off at a pre-calibrated torque. The tension value related to the shearing-off torque will be the final pre-load achieved in the bolt. Therefore it was initially referred to as **'Torsional Shear Type high strength bolt for structural applications'.**

The Tension Controlled Bolt provided many benefits to the heavy construction industry. One-person installation, easy identification of tightened bolts, simple electric tightening tool (Shear Wrench) and assurance of minimum preload made this product widely accepted in the heavy construction industry around the world. During this process, the essentially torque-controlled bolt had its name changed to Tension Controlled Bolt (**TCBOLT**). However, despite the name change, the product still uses torque to control the tension, and it should be correctly identified as a Torque-Controlled Bolt rather than a Tension-Controlled Bolt. The torque-tension relationship is highly dependent on the friction coefficient of the nut and the bolt which in turn depends on the finish and lubrication level.

For correct operation of a **TCBOLT**, these factors should be controlled from calibration to installation. If the lubrication is lost during transport or storage, or the product becomes corroded, thread damaged or additional lubrication is applied, this Torque-controlled bolt cannot control the tension, as the torque-tension relationship is changed. If the product gets corroded or thread-damaged, the resulting tension would be less than the calibrated pre-tension of the bolt assembly whereas if the lubrication level is increased due to additional lubrication the resulting tension would be higher than the calibrated pre-tension. Therefore if the product is changed from its 'as supplied' condition due to any reason, such bolts should be discarded or re-calibrated. It is paramount that **TCBOLTs** should be used in the 'as supplied' condition.

Generally this product is supplied as an assembly (with specific washers and nuts) in sealed containers and the product must remain in these containers until installation. Nuts and washers other than the ones dedicated for the bolt (comes as an assembly or in the same package) shall not be used with this product. **TCBOLT** is an engineered product and should be used and stored with care.

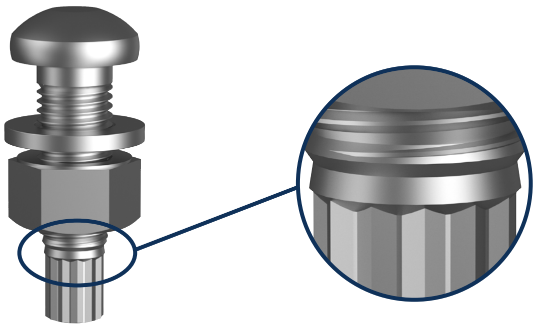

Figure 1. **TCBOLT** Break neck

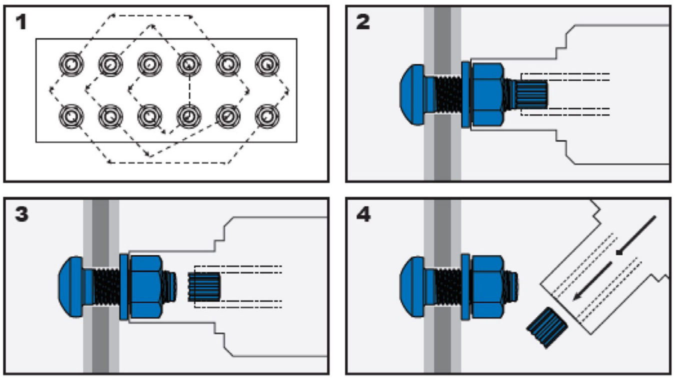

Figure 2. **TCBOLT** installation procedure

Operating Principle

The reduced diameter of the neck section (Figure 1.) between the threaded portion and the splined end is controlled closely in manufacturing. Also the hardness or tensile/shear strength of the bolt is well controlled. The neck diameter and hardness (strength) fix the torque that is necessary to shear-off the splined end. Torque is the rotational effort applied on the splined end while the rest of the bolt is kept stationary. It is measured in Newton-meters (Nm). Depending on the geometry and the frictional characteristics of the assembly (which is kept constant), there is a particular tension related to the shear-off torque. Tension is the bolt load/force due to stretching of the bolt and is measured in Newtons (N) or more widely in kilo-Newtons (kN). When shear-off torque, geometry (tolerances) and frictional characteristics are kept constant, this shear-off torque is related to the calibrated pre-tension or pre-load in the bolt. Typically this is given as the minimum pre-load and hence the final pre-load shall be greater than this minimum value.

If a **TCBOLT** assembly fractures in the threaded portion during installation, additional lubrication applied on the product is indicated. If a **TCBOLT** fails to achieve the calibrated pre-tension, thread damage, corrosion or reduction in lubrication is indicated. The nut should run freely along the threaded section of the bolt, and could be used as a simple test to check whether there is thread damage or any other reason that could alter the torque vs tension relationship. This discussion highlights the importance of maintaining the Torque vs Tension relationship by careful handling and storage of the **TCBOLT** assemblies from calibration to installation.

Installation of Torque/Tension Controlled Bolt (TCBOLT)

Installation steps of a **TCBOLT** are described below.

1. Before commencement of tensioning, all components in the joint shall be fitted together and all bolt assemblies shall be brought to snug tight (Figure 2-1).
2. Shear wrench outer socket is engaged with the nut while the inner socket is engaged with the twelve point spline (Figure 2-2). When the trigger is pressed, outer socket/nut turns clockwise, increasing the tension in the bolt. The inner socket provides the necessary reaction torque. As reaction torque is generated within, the tool operator does not feel any torque while grasping the tool (Figure 2-2). Since the nut torque is reacted by the spline torque, no torsional deformation occurs in the rest of the bolt, making it less prone to relaxation of pre-load after installation.
3. The tightening process continues until the final shear-off toque is reached. At this point, the outer socket stops and inner socket rotates counter clockwise, breaking the spline end. Now the tool can be removed (Figures 2-3 and 2-4).
4. The broken off splined end is retained in the tool and can be ejected into a waste bin. Tightening process is now complete (Figure 2-4).

PART: XT-GH-242EZ
M16, M20, M22, M24

PART: XT-GV-302EZ
M27, M30

PART: XT-GX-362EZ
M36

Figure 3. **TCBOLT** Shear Wrenches

The Shear Wrench is shown in Figure 3.

The electric shear wrench, unlike rattle guns, produces low noise and vibration. The electric motor applies the torque on the nut gradually. Since the spline end is held by the shear wrench no reaction torque is felt by the operator. The tool weighs approximately 6kg (10kg for M36) and one model can be used to install M12, M20, M22 and M24 Assemblies. The electric shear wrench does not cause any occupational hazards associated with rattle guns such as Hand Arm Vibration Syndrome (HAVS). There are cordless versions of the shear wrenches now available on the market

International Standards for TCBOLTs

Due to increased demand from other countries and the need to control the requirements governing the torque-tension relationship, other international standards were later developed to control the production and installation of the **TCBOLT**.

- EN14399-10 'High-strength structural bolting assemblies for preloading - Part 10: System HRC - Bolt and nut assemblies with calibrated preload',
- ASTM F1852 '"Twist Off" Type Tension Controlled Structural Bolt/Nut/Washer Assemblies, Steel Heat Treated to 120/105 ksi Minimum Tensile Strength',
- ASTM F2280 '"Twist Off" Type Tension Controlled Structural Bolt/ Nut/Washer Assemblies, Steel Heat Treated to 150 ksi Minimum Tensile Strength', and
- GB /T 32076.8 - 2017, 'High-Strength Structural Bolting Assemblies For Preloading - Torshear Type Bolt With Cup Head"

As shown, some of these standards use the term **"Twist Off"** or **"Torshear"** type bolt/assembly highlighting the importance of torque in this product.

The Australian standard AS/NZS 1252.1: 2016 nominates EN14399-3 PC8.8 and PC10.9 HR bolts as alternative and additional assembly types respectively. EN14399-10 PC10.9 HRC bolt assemblies will be compatible with AS/NZS 1252.1: 2016 and AS4100 as they use the same bolt thread lengths as EN14399-3.

EN14399-10 HRC product comes with two versions of nuts, namely Style 1 HR nuts and Style 2 HRD (thickness = 1d) nuts. For Australian industry practices, HRD nuts are more suitable due to their larger thickness and higher proof load.

As a properly calibrated EN14399.10 HRC bolt assembly provides a mean value of bolt tension greater than the required minimum bolt tension, it can be used under the definition of a calibrated tension indicator device as per AS4100. These bolts are capable of providing the minimum preload on the bolts as required by the design of the TF/TB joints. The sheared end acts as an indicator that installed bolts have been tensioned correctly.

As full tension (TF/TB) is always achieved with EN14399-10 HRC bolts, they do not self-loosen and no lock nuts are required. Also, these bolts will perform better due to their full tension when the joints are subject to dynamic loading. Furthermore, as discussed earlier, HRC bolts (**TCBOLT**) have less relaxation of the preload due to absence of torsional deformation on the bolt while tightening.

Once the splined end is sheared off, the end of the bolt will be exposed to corrosion. The zinc (HDG) coating will provide some Cathodic protection of the exposed end. However for larger diameters (≥M24) or bolts used in corrosive environments or aesthetically important locations, it may be necessary to apply 'Cold Gal' or other anticorrosive paint on the exposed end after installation. In less corrosive environments (further away from the ocean, enclosed and not exposed to elements) the exposed end may not need any further protection.

Table 1 shows the calibration of EN14399-10 PC10.9 HRC bolts. The surface condition of the product shall be 'as supplied' conditions for this calibration to be valid. This assures a minimum pre-tension of $0.7f_{ub} A_S$ (70% of nominal ultimate tensile load) and a minimum mean value of pretension of $0.77f_{ub} A_s$ suitable for TF/TB fully preloaded bolted joints.

Nominal Size	Nominal stress area of standard test mandrel	Minimum Individual Bolt Tension	Minimum Mean Bolt Tension
	A_s [mm²]	$F_{r\ min}$ $0,7\ f_{ub}\ A_s$ [kN]	$F_{r\ mean\ min}$ $0,77\ f_{ub}\ A_s$ [kN]
M12	84.3	59.10	64.91
M16	157	109.90	120.89
M20	245	171.50	188.65
M22	303	212.10	233.31
M24	353	247.10	271.81
M27	459	321.30	353.43
M30	561	392.70	431.97
M36	817	571.90	629.09

Table 1: Calibrated tension values at the shearing off of the splined end. f_{ub} is the nominal tensile strength of the bolt ($R_{m,\ nom}$). = 1000MPa for PC10.9.