AMTI BOLT -3 Application Note

The BOL T -3 is a specially designed multi-component torque/force transducer used for the accurate evaluation of installed screws, bolts and other threaded fasteners. This is done using a pair of nested multiaxis load cells. Although each of the load cells can be provided with up to six independent outputs corresponding to the three orthogonal forces and moments, a total of only three channels is needed for most applications.

The three channels of output provided in the standard BOL T -3 correspond to the following variables:

1. The tension in the fastener, FB
2. The torque applied to the fastener, TA
3. The torque transmitted through the fastener to the mating female thread, TT.

The difference in torque indicated by the TA and TT channels is the amount of friction torque under the head of the fastener. This torque does not produce any axial tension. An identical torque on both the T A and TT channels would indicate a frictionless bolt head/mating surface.

In most applications the distribution and resultant tension of the applied torque between the thread and the bolt head is an important and unknown factor in bolted joint design. Critical applications calling for joints tightened to a particular torque are subject to wide variations in clamping force due to changes in geometry, materials, and lubricants. In addition, cycling the fastened joint significantly affects the torque/tension curves due to lubricant squeeze out. This effect can be seen even on the first loosening and retightening cycle; a 10% reduction in tension is typical with anti-seize lubricants.

An approximate empirical formula[1] for determining the torque-tension value of a bolted joint is:

$$T = KDP$$

where

T = torque (in lbs)
K = friction factor
D = nominal screw diameter (in)
P = induced screw tension (lb)

It may appear that this equation is an oversimplification because the pitch of the screw thread is not shown. A finer pitch thread may produce more tension per unit torque, but in practice, the effect of screw pitch is small when compared to the large variation in K. F or example, a dry stainless steel screw can have a K of more than .30 while the use of anti-seize screw lubricants can reduce K to .05. Typical oiled parts have K values between .13 and .25, producing a factor of two difference in screw tension for a given torque. High K values often lead to highly undesirable galling, which is actually cold welding of portions of the mating threads.

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[1]From Holokrome Data Card

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It is possible to accurately determine a specific K value for any given geometry and set of conditions, but this must be done empirically. The BOL T -3 transducer allows such testing to be easily performed. In addition, the actual strength of a fastener can be determined by tightening it to failure. This then allows the accurate application of one industry practice of tightening a screw to 75% of yield.

The three signals provided by the BOL T -3 can be used to measure the effect of lubricants, pitch size, thread form, material, and contact pressure. Thread-locking compounds and self-locking inserts or threads can also be evaluated. Typical test specimens are standard screws or bolts with a mating female thread. Backup washers are needed at the fastener/transducer interfaces. These simple parts are generally user supplied for particular applications. Extended backup washers allow testing of short bolts; contact the factory for more details. The same bolt, nut and contact surface materials that will be used in the final assembly should be tested.

The torque/thrust characteristics of power lead screw and nut combinations can also be accurately determined. External preloading springs such as belleville washers can be placed under the head of the lead screw to provide torque as a function of axial load. One single test can provide data from zero to maximum load. Although most lead screw systems utilize rolling contact bearings to reduce the head loss torque, with the BOL T -3 it is not necessary to provide a bearing to test the nut torque/thrust characteristics. The use of a bearing, however, will provide additional useful information concerning the torque/thrust characteristics of the bearing itself. Relying on the manufacturer's published torque/thrust data for lead screws can be an expensive mistake in servo systems where drive torque cannot be over specified in order to provide a comfortable factor of safety due to cost or other requirements.

Use of a torque wrench is not required with the BOL T -3 because it measures the applied torque. Standard wrenches or mechanical or electromechanical drivers can be used. The BOL T -3 force and torque outputs are not affected by the side load components of unbalanced torques (as obtained from standard wrenches). The measurement of the X and y forces applied to either or both fastened members can be provided as an option. The BOLT -3 can be used to calibrate or check torque wrenches.

In general, the very high (several kilohertz) resonant frequencies of the BOLT-3 make it suitable for most applications; however, the use of impact wrenches should be reviewed by AMTI due to possible dynamic vibration effects.

Additional useful data can be obtained with the optional ROT -1, an angle of rotation attachment for the BOL T -3. This is an easily adjustable rotary position sensor which mounts to the top of the BOLT-3. The input rotation is transmitted, without backlash, to a sprocket on the sensor through a small flexible no-slip drive belt. A sprocket with three setscrews 1200 apart is also provided for attachment to a socket or the driver. The center hole on this sprocket can be bored to any size.

The sensor is a servo potentiometer, which provides a high level analog signal corresponding to the input rotation of the screw. It is very easy to use in conjunction with the other BOLT-3 analog signals. The ROT-1 is provided with an in-line plug, which attaches to the output of AMTI's MCA amplifier. A precision supply voltage for the ROT -1 and its output signal are, therefore, automatically wired into the output cable.

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