Q&A with Dr. Fastener
Reviewing the Torque Control Method

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Q1: Tell me how to determine the value of tightening torque.

A The value of tightening torque changes with the target axial bolt force and the nominal diameter of the threads. Specifically, we can calculate the tightening torque required for fastening by multiplying the product of axial force and nominal diameter by a coefficient called "nut factor". This expression is the simplified form of an exact equation derived from the balances of the forces and torques on the thread surface and nut bearing surface. The most commonly-used numeric value for the nut factor is 0.2. This value corresponds to a standard value of coefficient of friction, i.e., 0.15, but note that the nut factor greatly changes according to coefficient of friction.

Q2: I don't understand what a nut factor means. How does it affect fastening operation?

A The mechanically exact expression, which shows the relationship between axial bolt force and tightening torque, contains the term pertaining to the friction on the thread surface and nut bearing surface, in addition to the term pertaining to the axial force generated when the male thread climbs up the inclined surface. This is a complex expression involving trigonometric functions, and therefore we usually use the simplified expression (Tightening torque = nut factor x axial force x thread nominal diameter). Consequently, nut factor can be regarded as a coefficient for calculating tightening torque for a given axial bolt force and the size of threads to be used. The value of nut factor K changes because of several reasons, but practically speaking, we can calculate it as the functions of thread surface's COF, μ_{th}, and nut bearing surface's COF, μ_{nu}. This expression is derived by applying a statistical method called least squares method to the exact expression showing the relationship between axial force and torque. The constants in the expression represent the components by which the torque is converted to axial force. It suggests, therefore, that most of the tightening torque is consumed as friction work.

Q3: For the purpose of inspection, I fastened the loosened threads again using the same amount of torque in the initial tightening operation, but it turned out the obtained axial force is insufficient. Why is that?

A This is because "even if you apply the same tightening torque, the value of axial force changes with coefficient of friction". As shown in the above expression, the nut factor is expressed as the function of coefficient of friction. Using the expression and supposing that the coefficients of friction of the thread surface and nut bearing surface are both 0.15 and 0.3, the amounts of nut factor are found to be 0.2 and 0.381. Consequently, when a bolted joint's coefficient of friction changes from 0.15 to 0.3 because of the increase of the surface roughness due to tightening and loosening, only 52% of the target axial force is generated even if you apply the same torque. We can also say that "even if we apply the same torque, the axial force to be generated is almost inversely proportional to coefficient of friction." This is a noteworthy phenomenon in a bolted joint which is repeatedly fastened and loosened. Contrary to the above case, the coefficient of friction could become smaller than the initial value. In that case, we must pay attention to the plastic deformation due to the excessive axial force.

Q4: I feel the loosening torque is smaller than the tightening torque. Is that so?

A That is right. When fastening threads, the male threads move up the thread surface along the helix, thereby generating axial force. The lead angle, which is the spiral angle of thread surface, is usually from 2 to 3 degrees. On the other hand, the male threads move down along the thread surface when being loosened; therefore, the loosening torque is usually smaller than the tightening torque. The ratio of the two torques can be calculated using an expression derived mechanically. For instance, when the coefficient of friction ranges from 0.1 to around 0.2, we can loosen the threads with a torque which is from 70% to 80% of the tightening torque. The ratio of the two torques decreases with smaller coefficient of friction and smaller nominal diameter. In contrast, the ratio gets quite large in fine threads. If you feel the loosening torque is too large, you should suspect the occurrence of "seizure of threaded fasteners". ■

Reference

1. Toshimichi Fukuoka, "Threaded Fasteners for Engineers and Design – Solid Mechanics and Numerical Analysis –", pp.76-100, Corona Publishing Co., Ltd. (2015)