Meet Our Expert of the Month: The Fastener Professor, Dr. Toshimichi Fukuoka

Thread Strength & Stiffness

Q1: What is the meaning of thread strength of 10.9?

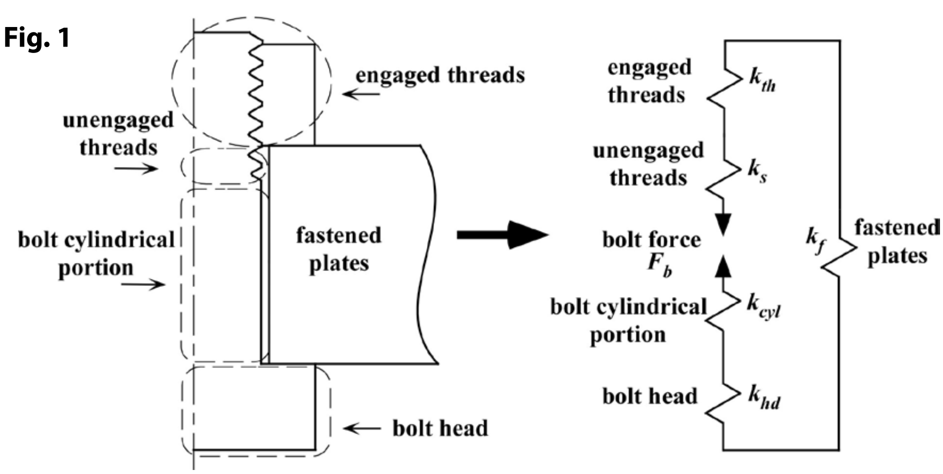
A: With a decimal point, the number 10.9 tells two kinds of strength. Multiplying the whole number 10 by 100, tensile strength of the thread material is obtained, which is 1000MPa in this case. Multiplying this value by the decimal number 0.9, yield stress is found to be 900MPa. If the material is mild steel, the thread strength is usually 4.6 or 4.8. Although the two materials have the same tensile strength, their yield strengths are 240MPa and 320MPa respectively, which means that the latter material is unlikely to deform plastically.

Q2: What is stiffness? I can't understand the difference from strength.

A: Stiffness indicates "unlikeliness to deform". Note that high stiffness and high strength are different characteristics. Let's suppose that tension or compression is applied to a round bar with cross-sectional area of A and length of L. Let Young's modulus of the material be E. The stiffness is AE / L. That is, the bigger cross-sectional area and shorter threads length, the higher the stiffness. Comparing the materials with different Young's modulus for screw threads with the same shape, the stiffness of carbon steel threads is nearly 3 times higher than that of aluminum alloy threads. In the case of the same thread materials, the lower the stiffness, the higher the fatigue strength and loosening resistance.

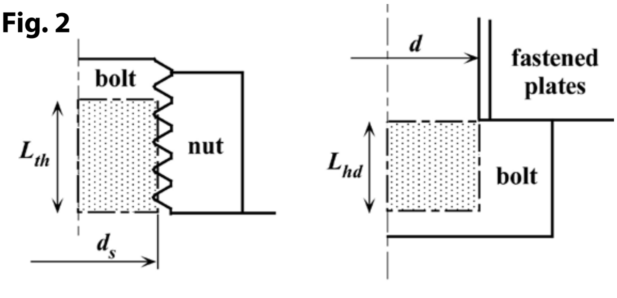
Q3: Tell me a concrete method to evaluate thread stiffness.

Fig. 1



A: Figure 1 shows one way to evaluate the stiffness of a bolted joint. The whole joint is replaced with 5 springs connected in series. Bolt cylindrical portion is regarded as a cylinder (round bar), and the stiffness (spring constant) can be evaluated with the nominal diameter and the cylinder length using the equation presented in the previous question. The stiffness of unengaged threads is calculated by regarding it as a cylinder whose cross-sectional area is equal to the stress area. The portion where male and female threads are engaged (engaged threads) is wholly replaced with a cylinder whose cross-sectional area is equal to the stress area. In this case, the height of the cylinder is called "equivalent length", whose value is about 0.85 times the nominal diameter according to finite element analysis. Bolt head portion is regarded as a cylinder whose cross-sectional area is equal to that of the cylinder portion, and the equivalent length is around 0.55 times the nominal diameter. The stiffness of fastened plates is the most difficult to evaluate because the regions around nut and bolt head bearing surfaces deform into complex shapes. There exists an equation derived from advanced solid mechanics theories. Meanwhile, in the author's laboratory, focusing on the bolted joints with widely used shapes, simple graphs are published to show the stiffness obtained by finite element analysis for the purpose of practical use.

Fig. 2



(a) engaged threads (b) bolt head

Q4: What do we learn of bolted joints from thread stiffness?

A: We can understand various mechanical properties of bolted joints. For instance, we can draw joint diagrams for evaluating fatigue strength, or diagrams for estimating the amount of axial force reduction resulting from non-rotation loosening which occurs without rotation of threaded fasteners. In the author's laboratory, using simple spring models shown in Figure 1, numerical approaches are proposed to predict how much initial tension is required to obtain the target axial bolt force when using a hydraulic tensioner, to obtain the relationship between the axial bolt force and heating time when using a bolt heater for fastening, etc.

Q5: What is the ratio of flank loads?

A: When a bolt-nut pair is fastened, bolt threads elongate and nut threads shrink. Additionally, the axial deformation of the nut bearing surface is restrained by the fastened plates. Therefore, each thread does not equally sustain the axial bolt force. The ratio of axial bolt force sustained by each thread is called "ratio of flank loads". In general, the ratio of flank loads of the thread nearest to the nut bearing surface becomes fairly high (ranging from 20% to 30% or above, for instance). Therefore, excessively increasing the number of engaged threads only gives limited improvement of strength. ■

Reference:

- *Toshimichi Fukuoka, "Threaded Fasteners for Engineers and Design – Solid Mechanics and Numerical Analysis –", pp.33-52, Corona Publishing Co., Ltd. (2015)*