Dr. Fastener: Static Strength and Fatigue Strength of Screw Threads

Q1: Which part of the screw thread is subject to a large force?

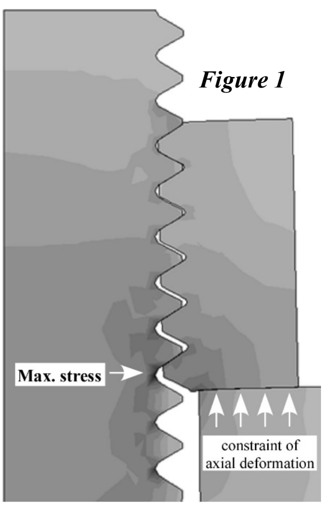


Figure 1

A: *Figure 1* shows the distribution of Mises stress that generates in the engaged threaded portion when an axial force (purely tension) is applied to the bolt. Mises stress is a stress by which various stress components acting on the target portion are replaced into a single component, and is used to judge the yield of the target material. Generally, the maximal stress occurs at the bolt thread root closest to the nut bearing surface. This portion is normally under plastic deformation, but the high stress area shown in black is concentrated in a narrow area around the thread root, so it does not immediately affect the strength of the bolt. In addition, high stresses are also observed at the thread runout and the root radius under the bolt head; hence, please pay attention to the machining accuracy and material defects in these parts.

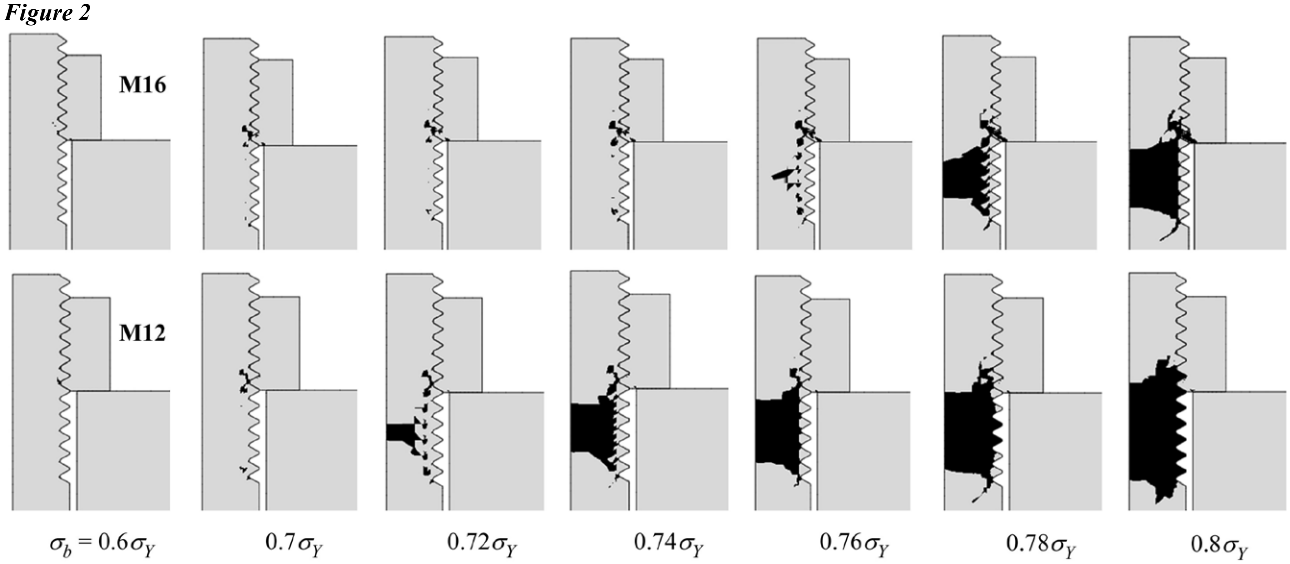
Q2: Although the thickness of nut is specified by standards, does the strength of the thread portion increase if it is manufactured higher?

A: The thickness of nut is usually about 0.8 times the nominal diameter of the threads. Increasing the nut thickness reduces the maximal stress at the bolt thread root, shown in *Figure 1*, but the effect is limited. As explained in Q5, "ratio of flank loads " in my third serial article, the reason for this is that the first engaging thread sustains a large load, which is the basic mechanical properties of threads. Therefore, considering the negative aspects such as increased weight of threaded parts, the specified nut thickness is judged reasonable.

Q3: Is it better not to generate the plastic deformation in the threads?

A: Plastic deformation of a bolt usually initiates around the root of the first thread, but as long as the area of plastic deformation doesn't spread significantly, it will not affect the strength of threaded fasteners. *Figure 2* shows the progress

Figure 2

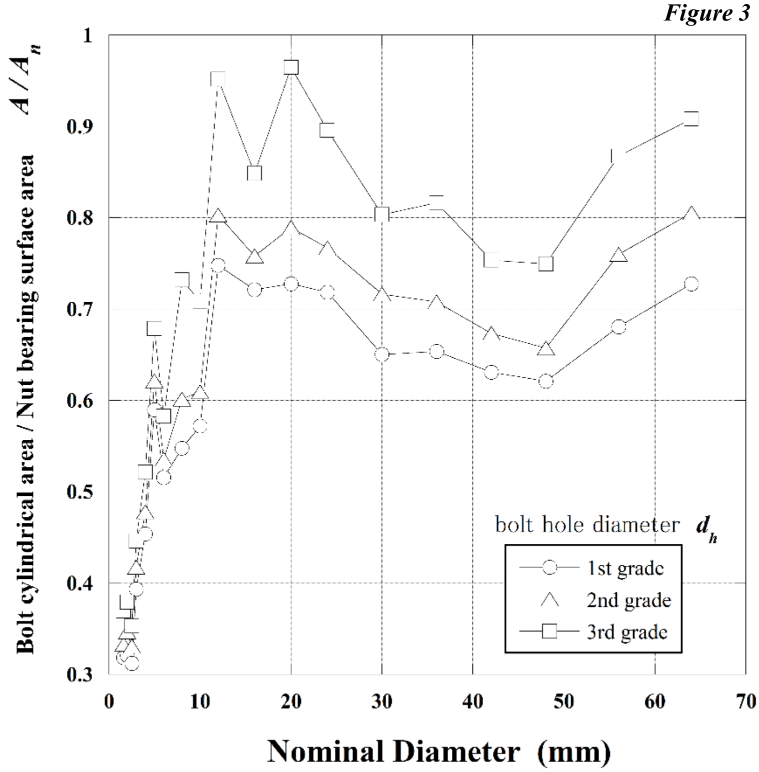


of plastic deformation as the axial bolt stress σ_b is increased against the yield stress σ_Y of the bolt material. It can be seen that when the ratio exceeds 0.7, the plastic region suddenly expands. If the axial stress is further increased, the cross section near the center of the unengaged threaded portion wholly reaches the yield state, and it seems that the rupture due to the over-tightening often occurs around this area. Regarding the fatigue strength under alternating loads, there is no particular problem as long as the plastic deformation stays within a certain range, because the behavior is similar to that in the elastic deformation. Please refer to the reference for details.

Q4: Please tell me about the depression of bearing surface, which becomes a problem when fastening low-strength materials with high-strength bolts.

A: The depression of bearing surface is a phenomenon that the axial force decreases over time, when a bolt is tightened with high axial force, due to the progression of plastic deformation occurred around the nut bearing surface and the bolt head bearing surface. To prevent this, it is necessary to suppress the bearing surface pressure below a certain level. The ratio of the critical contact pressure to the tensile strength of the fastened material is: 70 to 85% for carbon steel, 35 to 50% for stainless steel, and about 80 to 95% for aluminum alloy. On the other hand, gray cast iron, equipped with high compression resistance, has high critical contact pressure that is two to three times higher than the tensile strength. Another point to note is the ratio of the cross-sectional area of bolt cylinder to the nut bearing surface area. ***Figure 3*** shows the relationship between the ratio of the two areas and the nominal diameter. For example, if the ratio is 0.7, the contact pressure on the nut bearing surface becomes 70% of the axial bolt stress. As seen from the figure, when the nominal diameter and bolt hole diameter increase, the ratio of the two areas increases, which means that the bearing surface area decreases relatively, and a large contact pressure acts on it. So please be careful in those cases.

Figure 3



Q5: How does the thread fatigue failure occur?

A: Various factors affect this, but the most critical factor is stress amplitude caused by alternating loads. Fatigue failure occurs when the stress amplitude exceeds a critical value called "fatigue limit". Even if the shape is the same, the fatigue limit varies greatly depending on the type of applied load, such as tension, bending, or shear, and is also affected by the dimensions and the material of threads. All of them make it difficult to evaluate the fatigue limit of threads, and that is the reason why the accidents due to fatigue failure continue to occur.

References

1. Toshimichi Fukuoka, "The Mechanics of Threaded Fasteners and Bolted Joints for Engineering and Design", pp.81-86, pp.93-96, pp.143-215, ELSEVIER. (2022)