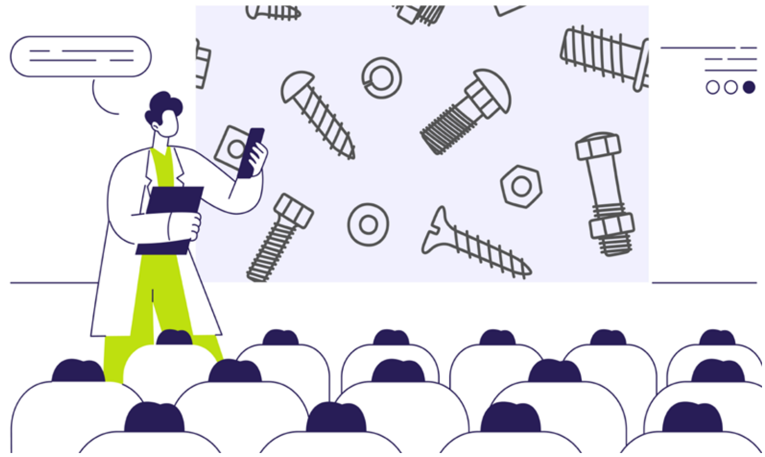
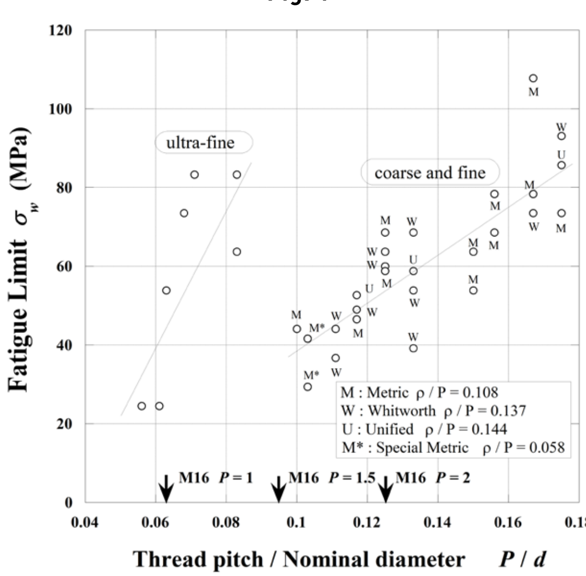
DR. Fastener- Measures to Prevent Fatigue Failure of Threads



<Q1> What factors other than stress amplitude affect the fatigue strength of threads?

Answer: Although threads with high material strength tend to have a high fatigue limit, the rate of increase is not as high as that of yield stress or tensile strength. In fatigue tests in which alternating loads are applied to the bearing surfaces of bolt head and nut so that the tensile load is applied to the bolt, the fatigue limit is reported to be over the range from 20 MPa to a little over 100 MPa. **Figure 1** shows the relationship between: (1) the fatigue limit obtained from the test, and (2) the ratio of pitch *P* to nominal diameter *d*, which represents the non-linearity of threaded parts. The effect of *P* / *d* on fatigue limit is clearly observed. Fatigue limit decreases when the nominal diameter is large and the pitch is small, but it starts to increase sharply at a certain value, and when *P* / *d* becomes further smaller, the fatigue limit drops significantly thereafter. Shown on the horizontal axis are the *P* / *d* values of M16 coarse thread and two types of fine threads. The experimental results given in the figure include the data of different standards of screw threads, thread materials, and thread root radius *r*, but it can be seen that **the ratio of pitch to nominal diameter has a dominant effect on the fatigue limit.**

Fig. 1



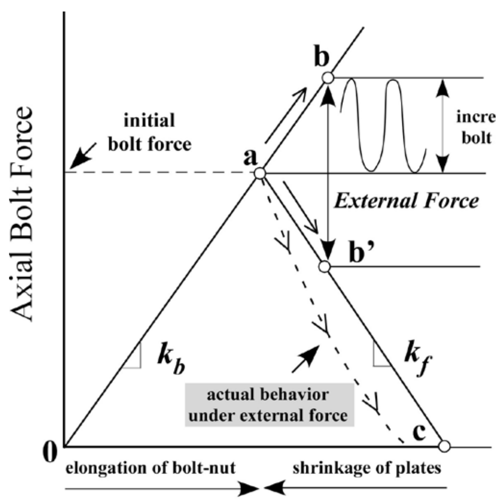
<Q2> Can fatigue failure be prevented by using threads made of high-strength materials?

Answer: With only the previous given answer, it may seem pointless **using high-strength bolts, but using high-strength threads increases the fatigue strength because they can be tightened with a high axial force.** In a simple fatigue test carried out in **Figure 1**, the fatigue limit of high-strength materials is not so high. However, the fastening with high axial force makes the contact surfaces less likely to separate even when an external force is applied, so it reduces the stress amplitude and improves fatigue strength.

<Q3> Can a bolted joint diagram be used to estimate the fatigue strength of threads?

Answer: **Bolted joint diagrams are found in machine design textbooks around the world, but the stress amplitude, which is the basic index of fatigue strength, can be evaluated with sufficient accuracy only in the limited cases.** The bolted joint diagram shown in **Figure 2** represents the relationship among the axial bolt force, the bolt-nut elongation, and the contraction of the fastened plates, using the spring constants of bolt-nut and fastened plates, *kb* and *kf*. The state at "point a" where the fastening is completed is mechanically correct. The problem is the behavior of the fastened plates when an external force is applied. In actual practice, due to the influence of contact surface separation, it deviates from the line c-a during the fastening operation and varies nonlinearly as represented by the dashed line in the figure. When fastened, the plates are subjected to a compressive load. However, since the external force is a tensile load, the spring constant in this case is different from the *kf* value during the fastening operation. On the other hand, the actual stress amplitude is usually lower than that obtained by the bolted joint diagram as long as the interfaces of the fastened plates don't separate greatly, so no problem arises. However, as the separation progresses, the stress amplitude increases sharply, and it increases the risk of fatigue failure. Furthermore, in the bolted joint diagram, it is assumed that the external force acts concentrically. In most cases, however, bending moment acts in actual bolted joints. As the separation develops, the external load acts according to the "principle of leverage" and the stress amplitude can possibly show a very large increase.

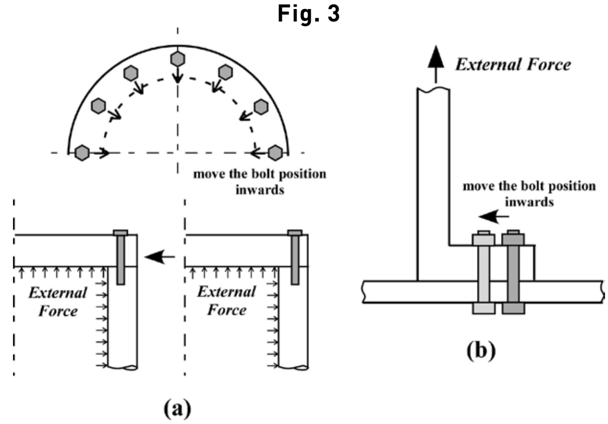
Fig. 2



<Q4> Please tell me an easy way to enhance the fatigue strength of bolted joints.

Answer: **Bolts with thin shanks,** such as crankpin bolts, have smaller stress amplitudes, and therefore increased fatigue strength is expected. Also, provided that there are no problems like plastic deformation of the threaded parts or collapse of bearing surfaces, **increasing the axial bolt force** gives higher fatigue strength. As explained in Q3, this is because the interfaces of fastened plates are less likely to separate even when subjected to an external force. It is also possible to improve the fatigue strength by **devising the shape of the bolted joint.** However, since it is difficult to largely change the shape of the fastened plates, by **designing the mounting position of bolts,** as shown in **Figure 3**, the applied bending moment is lowered and the stress amplitude can be suppressed.

Fig. 3



Reference:

1. Toshimichi Fukuoka, "The Mechanics of Threaded Fasteners and Bolted Joints for Engineering and Design", pp. 173 -215, ELSEVIER. (2022) ■