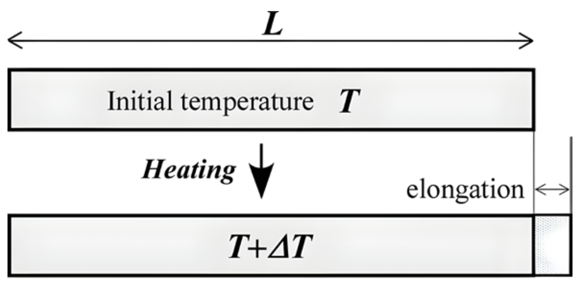
DR. Fastener-

Behavior of Screws Under High/Low Temperature Loads

Q1: Why does the axial bolt force decrease when the temperature of the fastened plates changes?

A: When the temperature of a bolted joint changes from its initial state, the axial bolt force may decrease or increase. Metals elongate when the temperature rises and contract when it drops. **Figure 1** shows how to calculate the elongation. The elongation of a round bar with length L due to the temperature increases of ΔT can be calculated by multiplying the product of L and ΔT by the coefficient of linear expansion α. **Considering the case where the temperature rises, if the elongation of the bolt and nut is greater than that of the fastened plates, the axial bolt force decreases, and vice versa. On the other hand, when the bolted joint becomes low temperature, the entire joint contracts. In this case, the axial bolt force decreases if the contraction of the fastened plates is greater.**

Fig. 1



Elongation $= \alpha \times \Delta T \times L$

Fig. 2

$$\Delta F_b = -\frac{\left(\alpha_b \Delta T_b - \alpha_f \Delta T_f\right) L_f}{\dfrac{1}{k_b} + \dfrac{1}{k_f}}$$

ΔF_b : variation of axial bolt force

α_b , α_f : coefficient of linear expansion (bolt & nut, fastened plates)

ΔT_b , ΔT_f : variation of temperature (bolt & nut, fastened plates)

Q2: How much does the axial bolt force change when the temperature of the bolted joint varies?

A: **The amount of change in the axial bolt force can be obtained by multiplying the difference in elongation/contraction between the bolt-nut and the fastened plates by the spring constant— which represents the "stiffness of the entire bolted joint" consisting of the bolt, nut and the fastened plates.** For simplicity, considered is the case where the temperature rises and the materials elongate. If the amount of elongation is the same for the bolt-nut and the fastened plates, the axial bolt force should not change. However, as the temperature rises, Young's modulus of the material decreases, so the axial bolt force decreases by the proportion. The calculation procedure of the amount of elongation was explained in **Q1**. For the temperature change, ΔTb and ΔTf are used, which are the temperature increases of the bolt-nut and the fastened plates, respectively, and the grip length Lf is used as the original length. **Figure 2** shows the concrete calculation formula. The numerator of the formula is the difference of the amount of elongation between the two, and the denominator consists of the spring constant kb of the bolt-nut and the spring constant kf of the fastened plates. The reciprocal of this represents **the stiffness of the entire bolted joint. As is clear from the equation, the stiffness of the bolted joint has a large effect on the amount of change in the axial bolt force. Therefore, in order to estimate the change in the axial bolt force with high accuracy, the stiffness of the bolted joint must be accurately evaluated.**

Q3: Why are the bolted joints made of stainless steel likely to cause problems when subjected to heat?

A: Stainless steel has unique thermal properties: its thermal conductivity is about 1/3 that of carbon steel, but its coefficient of linear expansion is about 1.5 times larger. If the thermal conductivity is low, the temperature gradient becomes large because heat does not flow easily, and a large thermal stress is generated in the bolted joint. In addition, when heat flows perpendicular to the bolt axis, bending stress may become a problem if the temperature difference becomes large between the left and right parts of the bolt. Furthermore, care must be taken to prevent the seizure when tightening the screws, because the frictional heat generated on the nut bearing surface is difficult to dissipate to the surrounding area. It is also important to pay attention to the large coefficient of linear expansion. **If the threaded parts are made of stainless steel, loosening is likely to occur because the elongation due to the temperature rise of the fastened plates is large. Conversely, if the fastened plates are made of stainless steel, they expand to push up the threaded parts, so attention must be paid to the increase in the axial bolt force and the depression of the seating surface.**

Q4: What are the precautions when using screws made of a different material from the fastened plates?

A: Since the fastening force may change significantly when subjected to heat load, **attention should be paid to the difference in thermal conductivity and coefficient of linear expansion between the two materials.** If the thermal conductivity is different, the temperature gradient around the bolted joint increases, which may cause thermal stress problems. More attention should be paid to the difference in the coefficient of linear expansion. For example, when a bolted joint made of stainless steel is fastened with a carbon steel bolt, even if the temperature around the fastened plate rises almost uniformly, the axial bolt force increases significantly, because stainless steel elongates about 1.5 times more than carbon steel, as can be seen from the equation shown in **Figure 2**. Conversely, in the case of a combination of stainless steel screws and carbon steel fastened plates, the axial bolt force decreases significantly. In the latter case, even if the temperature rise of the fastened plates is greater than that of the bolt and nut, care must be taken because loosening may occur due to the large difference in the coefficient of linear expansion. ■

Reference

1. Toshimichi Fukuoka, "The Mechanics of Threaded Fasteners and Bolted Joints for Engineering and Design", pp.217-224, ELSEVIER. (2022)