Q&A

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

～Thread Materials～

Q1: What is the significance of Young's modulus when selecting thread materials?

Ans: In the case of metal materials, Hooke's Law, which insists that stress is proportional to strain, holds in the range of small displacements. The proportional constant is called Young's modulus. Young's modulus of carbon steel materials is around 200GPa. Although Young's modulus of austenitic stainless steels is slightly smaller, but there is no significant difference. The important point about Young's modulus is that it does not represent the material strength but the stiffness, i.e., the extent of difficulty in deformation. For instance, there is not much difference in Young's modulus between low-strength low carbon steel and high-strength alloy steel. The moduli of titanium and titanium alloy are about 110GPa and that of aluminum alloy is around 70GPa, both of which can be called low stiffness materials.

Q2: Is there any other material constant similar to Young's modulus?

Ans: Young's modulus represents the extent of ease to elongate or shrink when the material is subjected to the load perpendicular to the surface. On the other hand, including twisted bars, the stress caused by the load along the surface is called shear stress. Shear stress is proportional to shear strain (surface inclination angle) caused by shear load. The proportional constant is called modulus of transverse elasticity. Incidentally, when a round bar is pulled, it elongates in the axial direction and shrinks in the diameter direction. The ratio between the strains in the diameter and axial directions is a material constant called Poisson's ratio. In addition to those constants, there is a material constant called bulk modulus. In any event, if the values of any two of the above material constants are given, the remaining material constants can be calculated by relating mechanical expressions. This is a convenient property that makes it possible to obtain material constants that are hard to measure.

Q3: What are the material constants representing the characteristics of thread materials?

Ans: Material constants are classified into two categories that represent mechanical properties and thermal properties. A typical constant of the former is Young's modulus. Among the latter constants, coefficient of linear expansion and thermal conductivity are representative ones. Regardless of high or low temperature environments, it is necessary to note the amount of these constants when bolted joints are subjected to thermal loads. Coefficient of linear expansion represents the amount of strain generated by the temperature change of one Celsius degree. It is a constant representing the extent of ease to elongate or shrink. If the temperature of a carbon steel round bar of 1m in length is raised by 100 degrees Celsius, the bar elongates a length of 1.2mm. Comparing to this, the coefficient of austenitic stainless steel is 1.5 times larger, that of aluminum alloy is about 2 times larger, and titanium/titanium alloy is about 75%. On the other hand, thermal conductivity is a material constant representing the extent of ease for heat flow. Comparing to the thermal conductivity of carbon steel, the conductivity of austenitic stainless steel is about one third, that of aluminum alloy is 2.5 times larger, and those of titanium and titanium alloys are as small as about 40% and 17%, respectively. When material surface is heated, the surface temperature does not rise too much in case of high thermal conductivity because the heat easily dissipates into the object. Conversely, if thermal conductivity is low, heat is less likely to diffuse; hence, attention must be paid because the surface temperature may significantly rise.

Q4: What are the characteristics of austenitic stainless steel?

Ans: Compared to carbon steel, austenitic stainless steel has somewhat lower Young's modulus and the coefficient of linear expansion is 1.5 times larger. In contrast, the thermal conductivity is one third of carbon steel. Thus, we can say it is a material that is hard to conduct heat and is easy to elongate. When using austenitic stainless steel in a bolted joint subjected to thermal loads, axial bolt force is likely to vary and large bending stress tends to occur due to large temperature gradient to be generated. Additionally, in the tightening process of bolts, the heat generated at thread surface and bearing surfaces is unlikely to diffuse inside. Therefore, the temperature of the contact surfaces rises, making seizure more likely to occur.

Q5: What are the characteristics of titanium and titanium alloy if used for thread materials?

Ans: Young's modulus of titanium and titanium alloy is somewhat larger than 50% of the modulus of carbon steel. Hence, when using titanium and titanium alloy as the materials for bolts and nuts, it is found from simple calculation that they tend to elongate nearly twice as much as the screw threads with the same specification made of carbon steel. From a mechanical perspective, if the thread specification and axial bolt force are the same, the longer the bolt, the higher the fatigue strength and the less the loosening is likely to occur. From that point of view, screw threads made of titanium and titanium alloy can be said to be excellent. Meanwhile, they have small coefficients of linear expansion. Accordingly, using them while noting the small value of thermal conductivity, they possibly work well as anti-loosening threads against thermal loads. ■