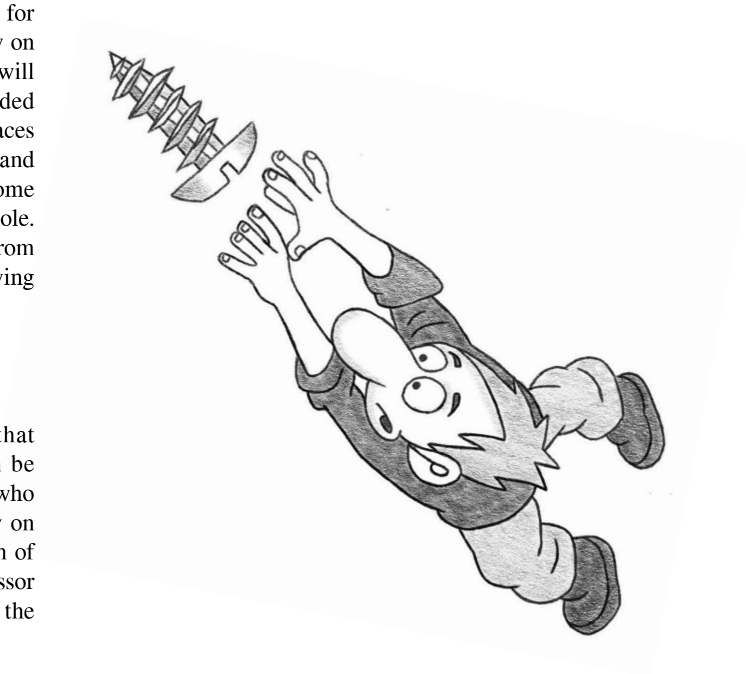
Science Friction isn't for Screw Connections Fiction

科学摩擦：螺丝接合非虚构之谜

Readers may forgive a slight excess, but a parable from Shakespeare's Othello characterizes this article well. Even the Nobel Prize winner for literature, Rudyard Kipling, wrote a short story about a naughty screw on a ship. Of course, this is not the only reason for writing this article. As will become clear in the following text, friction plays a key role in threaded joints. That's what this is about. From the moment of interacting surfaces in relative motion and associated subjects, in this case of an internal and external thread and the contact surfaces, threaded joints have become an important tribological node in which friction plays a dominant role. Contrary to other structural pairs, threaded joints have their specifics from the point of view of friction. These will be specified within the following text.



"You too, Screwtus?"

(A playful twist on Shakespeare's famous line "You too, Brutus?")

About Friction Itself

Despite the fact that friction as such is a property of matter that is independent of intelligence and it cannot be eliminated, it can be influenced to a certain extent. Leonardo da Vinci understood this, who in his experiment found that the magnitude of friction depends only on the pressure force and the surface roughness characterized by friction of coefficient μ. In his magnificent work Jost Report, the English professor Peter Jost, the father of the scientific discipline of tribology, developed the issue of friction.

Friction is the force that slows down movement over a surface. It is calculated using the formula:

$$F_t = \mu . F_N, \text{ where}$$

F_t - shear friction force in - [N]

F_N - perpendicular pressure force between the bodies in [N]

μ - coefficient of friction (dimensionless number)

The Importance of Friction in Bolted Joints

The life cycle of a threaded joint unfolds in two stages:

1. assembly
2. a work process that continues until the end of its useful life, either through destruction, spontaneous release, or disassembly

While tightening by torque moment, which is a dominant way of assembly in common use of screwing, only a part (Me_f) of the exerted moment M_M (Fig. 1) is effectively used for making needed prestressing. The rest, i.e. M_{fr} is consumed for overcoming the friction within threads and under the nut and the head of a screw and it changes in the heat.

$$M_M = M_{fr} + Me_f$$

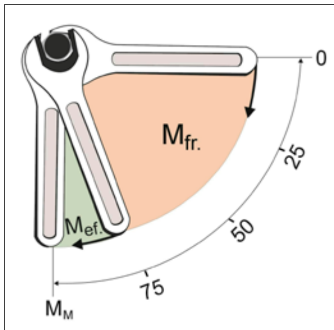


Fig. 1 Torque distribution

The stronger friction, the higher consumption of energy is, and the more heat is created, as well. In extreme cases, for example, the plastic ring in the locking nut DIN 985 may melt (**Fig. 2**).

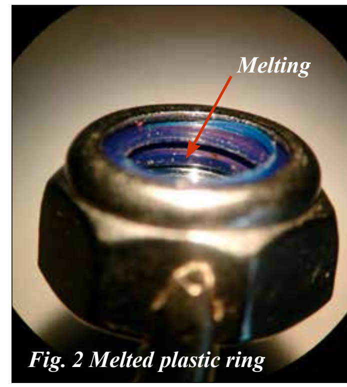


Fig. 2 Melted plastic ring

The counterproductive effect of friction on screw connections is evidenced by **Fig. 3**. Note the different direction of the force F_R when tightening and during operation when loosening tendency. **Friction is undesirable during tightening (Fig. 4), but during operation it protects the joint from spontaneous loosening. This contradictory effect of friction has never been solved. Some hope is offered by so-called thixotropic lubricants.** At the same time, it is a challenge for tribologists.

$$M_A = F_M \left[0{,}16P + \mu_G 0{,}58 d_2 + \frac{D_{kM}}{2} \mu_K \right]$$

According to VDI 2230 for 60° angle of the thread this formula is valid:

M_A – a torque moment for overcoming friction,

F_M – assembly prestressing force

μ_G – a friction of coefficient within threads,

μ_K – a friction of coefficient under the head,

P– lead of a helix,

D_{km} – an effective diameter under the head, M_G, respectively

M_K – moments for overcoming the friction within threads and under the head

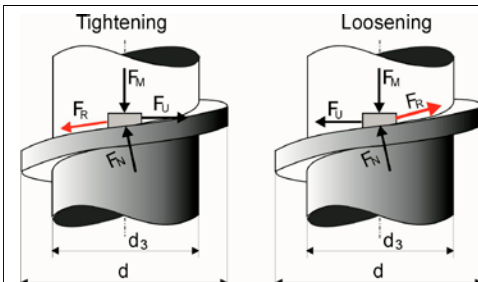


Fig. 3 Decomposition of forces

This relationship clearly shows the effect of friction on the tightening torque.

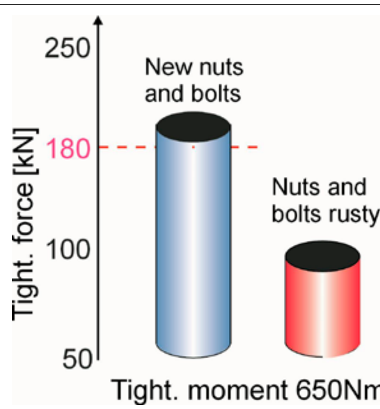


Fig. 4 New and rusty

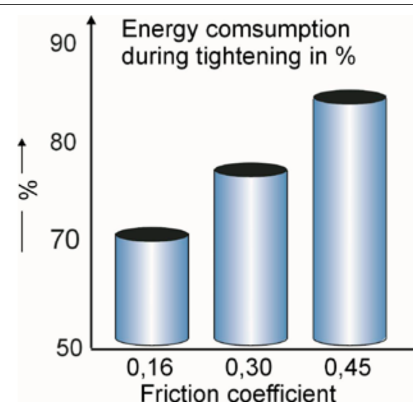


Fig. 5 Energy consumption

Conclusion

Threaded joints represent a difficult tribological system when friction plays a contradictory role which is necessary during operation but undesirable during assembly. In contrast to other structural elements such as toothed wheels, bearings and similar tribological pairs, in this case the friction is not so important from the service wear and energy consumption point of view but from the aspect of the exact assembly and safety of construction. Despite this, professor H. P. Jost is right. It is important to pay increased attention to tribology of threaded joints. Investment in that will pay off in the form of reliability of products and credibility of producers.