Counterproductive Effect of Friction on Screw Connections

by Jozef Dominik

When known expert on tribology Prof. Peter Jost wrote his magnificent Jost Report, published in 1966, he had no idea what the contradictory meaning of friction on the screw connections has. He was only interested in global impact of friction and wear on energy consumption, economic expenditure, and carbon dioxide emissions. The friction of the screw connections is very specific and requires separate attention. Without friction, no preloaded screw connection would be possible.

Theory

Friction is defined as the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other. This can be seen in Fig. 1.

Noteworthy in this figure is the contradictory sense of the frictional force F_F when tightening and loosening the screws. This is a specific feature of screw connections. When tightening, friction is undesirable, but after assembly it is necessary not to loosen the screw connection. Friction force F_F depends on the normal force F_N and coefficient of friction μ according to the general equation:

$$F_F = \mu .\ F_N$$

The amount of friction coefficient μ depends on many factors. Except for normal force F_N the most important is surface roughness (Fig. 2) as the arithmetical mean deviation Ra [μm] in assessed profile. The situation worsens the presence of hard non-metallic impurities, corroded surface and temperature.

Roughness plays an important role in determining how a real object will interact with its environment. In tribology, rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces.

Depending on the surface finish technology, the roughness can be exhibited in either direction, or as chaotically arranged undefined projections (Fig. 2). In normal construction practice, the latter is usually calculated that the coefficient of friction is the same in all directions.

The thread friction and friction under the screw head and under the nut must be overcome while tightening a connection. The higher the roughness, the greater the friction, the more energy is consumed to overcome it (Fig. 3).

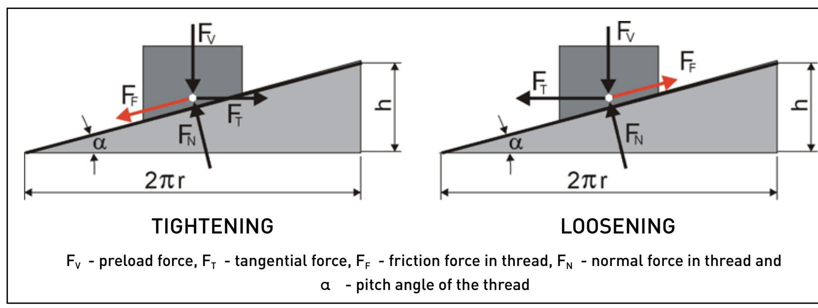

Fig. 1

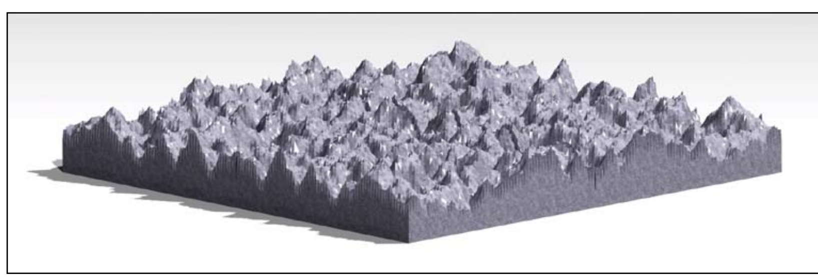

Fig. 2

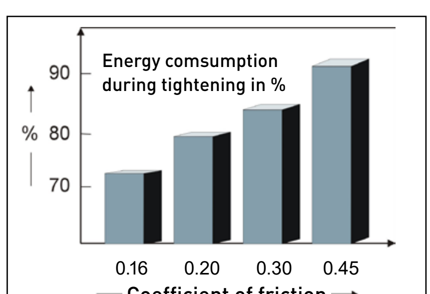

Fig. 3

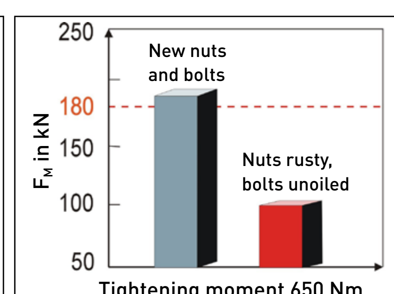

Fig. 4

The influence of friction on the tightening of screw connections is also documented in Fig. 4. The same torque of 650Nm will produce a preload around 180kN for new bolts and nuts, while for corroded surfaces, this is barely 30% only. The rest is consumed to overcome friction and converted to heat.

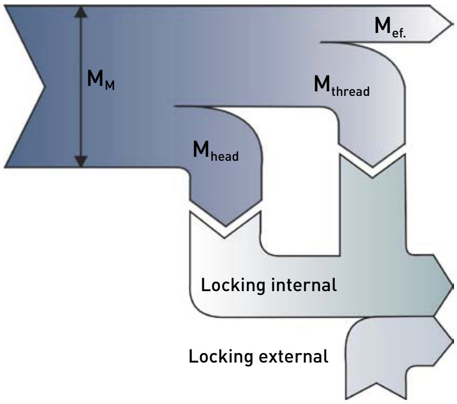

Fig. 5

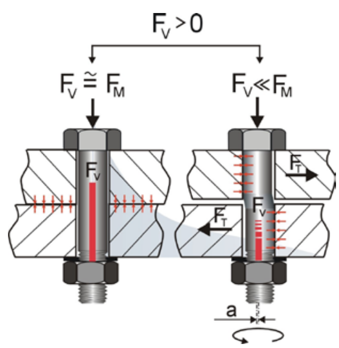

Fig. 6

Friction after the assembly of the screw connections is of other importance. Without friction, the entire structure would fall apart. It is the friction that holds the screw connections together. Without friction, the relevant construction node would be destroyed and ultimately crash. This is illustrated by Fig. 5. When properly assembled and correctly sized, the screw connection usually does not need external, i.e. additional security. In practice, however, there are many cases of extreme dynamic stress (Fig. 6) where simple locking is no longer sufficient, so the screw connection must be secured against spontaneous loosening by external locking.

The current market offers several options for external locking of screw connections. For ethical reasons, the author disclaims their presentation assuming that an experienced designer is able to choose the optimal variant. Here, I will confine myself to the serious statement that the stressing of the screw connections is a complicated process and cannot be reduced to the transverse direction only as shown in Fig. 6. Therefore, the following applies: For each type of bolting stress another locking "dress". Panacea, meaning "all-healing" does not exist for securing screw connections. Each specific case requires an individual approach. Commercial availability and price must not play a dominant role in choosing the optimal variant.

Conclusion

As shown the friction is very important for screw connections. It decides their tightening parameters and is responsible for resistance to dangerous of spontaneous disintegration. Paradoxically, both functions are contradictory. During tightening, friction is undesirable, but after tightening we need it. Otherwise the screw connection would lose its function. Until an effective thixotropic substance is developed, this unpleasant friction property remains to be respected. Relevant research institutes dealing with the development of thixotropic paints and oils may consider this a challenge. ■