The Risk of Hand Tightening Screws

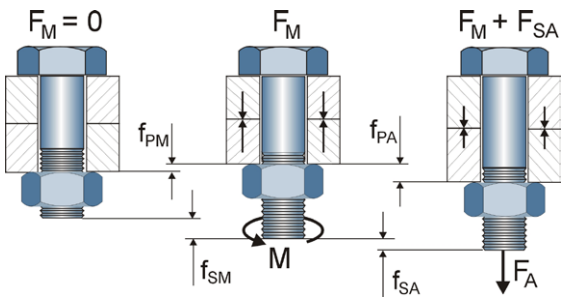
"He who relies solely on practice without science is like a sailor who embarks on a ship without a rudder and without a compass, so he never knows where he will swim." —Leonardo da Vinci

Introduction

According to DIN 8593 "Manufacturing Process Joining", screwing is the most widely used method of joining in the mechanical engineering and in the automotive industry. This is also the reason why the reference from Leonardo da Vinci is current in the technique of mechanical joining of parts using threaded fasteners. Leonardo's compass and rudder in this case is the exact tightening of screw connections.

As will be seen from the following text, the correct pre-stressing force can only be achieved by controlled tightening. Hand-tightening by feel, so often preferred in practice, is burdened with a subjective factor that cannot be predicted, and therefore it represents a latent danger of disintegration of the entire structure.

★ Fig. 1. Mechanical Forces Acting on the Screw Connection



Theory

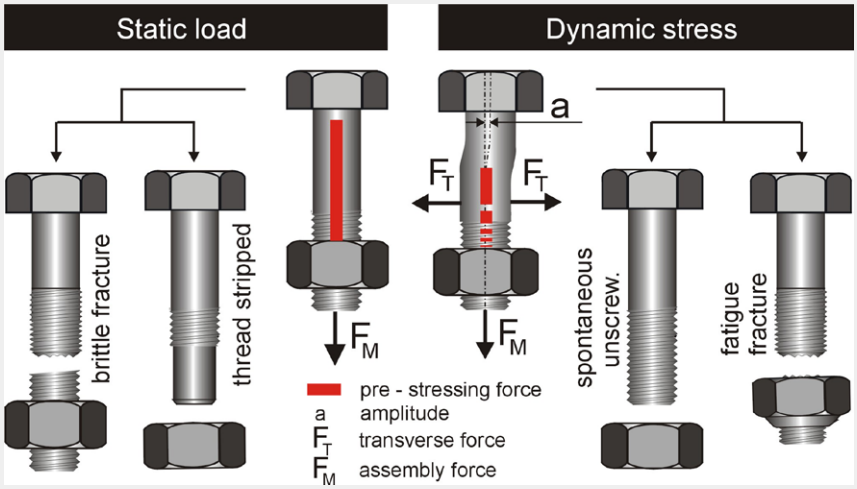
The mechanical forces acting on the screw connection can be divided into two groups:

(1) Internal or assembly forces F_M caused by the applied tightening torque.
(2) External forces F_A caused by additional static operating stress **(Fig. 1)**.

Internal or assembly forces are purposely introduced during assembly either through the tightening torque M_M or in a torsion-free manner, e.g. hydraulically to create a basic assembly preload.

These forces either support each other proportionally or disproportionately, or they work against each other and they may not exceed the elastic zone. We are therefore talking about the superposition of internal (assembly) and external (operational) forces, which then determine the resulting stress of the screw connection. Due to the predominant axial load, it is essentially a system of springs, with the screw representing a tension spring and the connected parts a compression spring. As follows from **Fig. 2**, static load is not the only type of stress on bolted joints. Much more careless is the dynamic stress which leads to material fatigue. Both cases differ in the nature of the violation of the integrity of the system. Characteristic cases are shown in **Figs. 3** and **4**.

★ Fig. 2. Bolted Joint



★ Fig. 3. Characteristic Case 1

★ Fig. 4. Characteristic Case 2

Assuming tightening to 90% Rp0.2, the assembly preload force F_M is:

$$F_M = 0,9Rp_{0,2}A_S$$

while the tension cross-section A_s according to DIN 13 is equal to:

$$A_S = \frac{1}{4}\pi\left[\frac{d_2 + d_3}{2}\right]^2$$

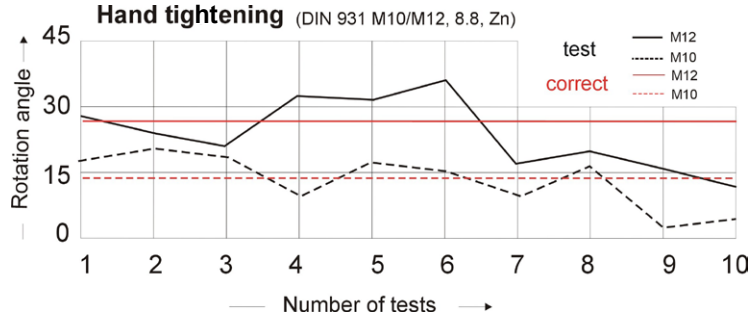
where d_2, d_3 - is the medium and small diameter of the screw.

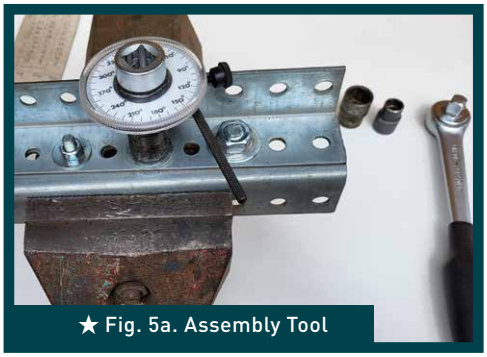
It follows from the above that the assemble force F_M is an exact value that can only be achieved with a controlled tightening system. The following test shows how inaccurate manual tightening is.

Test Methodology and Results

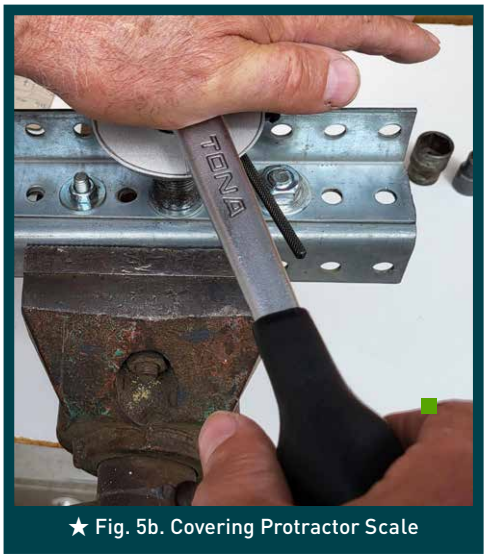
The angle of rotation of the assembly tool was evaluated by hand according to feel **(Fig. 5a)** in 10 tested persons aged between 30 and 65 years. In order not to influence the results, the protractor scale was covered during the experiment **(Fig. 5b)**. M10 and M12 screws with a strength of 8.8, galvanized, were tested. The result is summarized in **Fig. 6**, where the correct values according to the standard are also given.

★ Fig. 6. Correct Values According to the Standard





★ Fig. 5a. Assembly Tool



★ Fig. 5b. Covering Protractor Scale

This picture clearly shows the unreliability of hand tightening. The deviation of precision for the M10 diameter is about 45% and for the M12 diameter even ca 48% which is too much. It can also be read from the graph that about 54% of the tested people tightened the screw connection to a lower value than the regulation for the M12 diameter, and about 32% for the M10 diameter. However, no one has exactly hit the required value. The result can be either destruction of the connection due to excessive load or loosening of the connection due to insufficient tightening. Both are dangerous.

Conclusion

The conclusion is very easy: it is not recommended to tighten by hand, especially for high-stress structural nodes. This applies in particular to screws or nuts for fixing of car wheels. If it is necessary to change the wheels on the road, visit an authorized service center as soon as possible. ■

Remember! The choice of the tightening methods is one of the most important construction decisions.