Where and Why is the Prestressing Force of Bolted Joints Lost?

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"A screw joint is not a soulless monster, but a living organism with its own colorful inner life."

Introduction

Answering question in the title requires seriously means thoroughly knowing the behavior of bolted joints during assembly and in operation. Does a bolted joint represent a steady state after successful tightening, indicating the exact value of the required assembly force, a fixed status quo? If not, what is actually going on there? Not only the designer, but also the user needs to know the complete truth. What processes take place in threaded joints after their assembly, what affects them, what impact do they have on the safety of the final structure? These are the questions that this article will try to answer.

Analysis of the Behavior of Threaded Joints During Assembly and Operation

Assembly

It is believed that prescribing the correct method and the assembly preload force FM for tightening bolted joints is the most important design decision.

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

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

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

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

where d2, d3 - is the medium and small diameter of the screw.

Regardless of the tightening method, **Fig. 1** logical documents the basic stress state of bolted joints after assembly by force FM. In addition to the distribution of stresses at individual interfaces, the number of these interfaces is also important. In this case, there are 5 of them, including the inter-thread space.

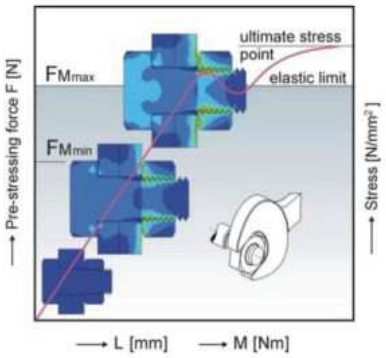

Fig. 3

As can be seen from **Fig. 2** and **Fig. 3**, after tightening with the assembly force FM, certain changes occur in the screw joints. In particular, the joined parts were compressed by the value fPM and the screw was extended by the value fSM (**Fig. 2**). Thanks to the finite element method (FEM), we can observe that the largest change occurred in the area of stress distribution in the steel (**Fig. 3**). The system has entered a non-equilibrium energetic state with a tendency to return to the original state. From a thermodynamic point of view, this state is unnatural. Nevertheless, for the safety of the structure, the goal is to keep it as it is. And that is the greatest screw paradox. The tendency to achieve a state of equilibrium here stands in stark contradiction with the will of man to maintain the status quo.

Operation

However, the consolidation of the condition of bolted joints does not end with their installation. The most important stage in the life of screw joints occurs due to the effect of static or dynamically acting operating forces FA (**Fig. 4** and **Fig. 5**).

The role of screw connections is not only to connect, but also to prevent the disintegration of already connected parts so that the above-mentioned cases of accidents can never occur. Loosening of prestressing force in flanged pipe joints means loss of tightness and leakage of medium into the surroundings. A preventive measure is needed here, which should be considered as a proper investment and not as an expense item.

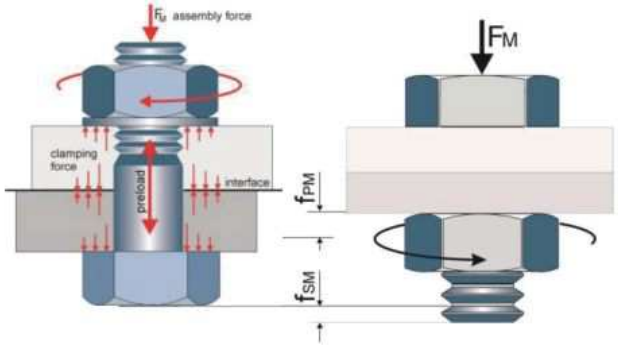

Fig. 1 **Fig. 2**

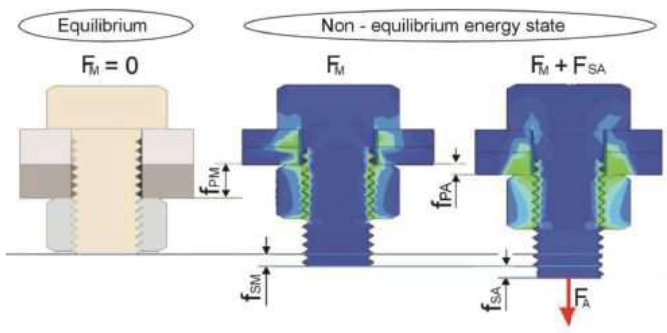

Fig. 4

One possibility is the application of external locking elements. Their effectiveness can be vary significantly. **Fig. 6** shows the course of the decrease in prestressing force FM of three different such elements.

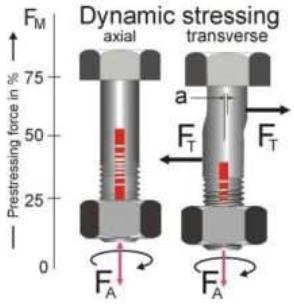

Fig. 5

1. Loosening due microplastic deformation of the unevenness of the contact surfaces. Neither the nut nor the bolt rotates. This stage is independent of the type of locking element.
2. Loosening due to overtightening of the nut and/or bolt due to dynamic stress.
3. Complete decay of the joint when the preload has already dropped to zero, but the nut continues to be overtightened until it finally falls out.

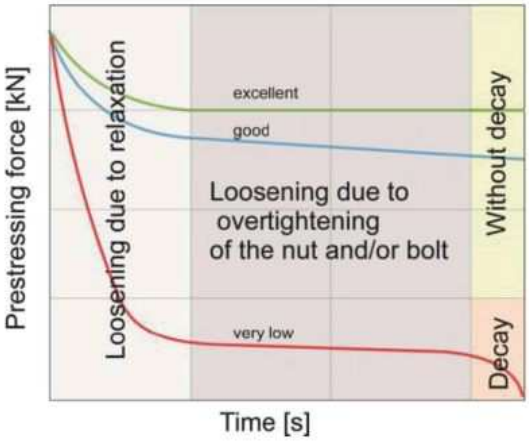

Fig. 6

Prevention

If we do not take into account the chemical methods of protection that make up a separate chapter, then there are only two basic types of external mechanical locking systems:

A. Axial, dependent of the assembly force FM, it means pA → f(FM) (**Fig. 7**).

B. Transverse, independent of the assembly force FM, it means pR ≠ f(FM), for example nuts DIN 985 (**Fig. 8**).

Of course, the basic condition for the proper function of bolted joints is their exact assembly to the prescribed assembly force level. External locking elements are only used in extreme cyclic loading of the structural node.

Very important! It is incorrect to test a bolted joint subjected to axial stress (**Fig. 9**) using a testing method intended for transverse stress!

There is no universal testing method that would be conformable with all types of stress. Just as the Junker test is intended for transverse stress, the axial pulsator (**Fig. 10**) is suitable for testing in the axial direction.

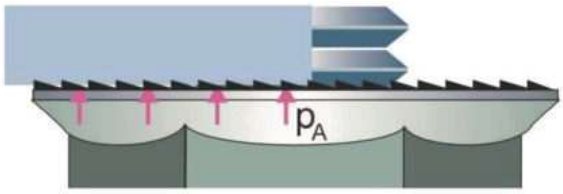

Fig. 7

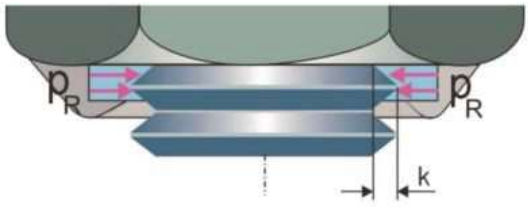

Fig. 8

Fig. 9

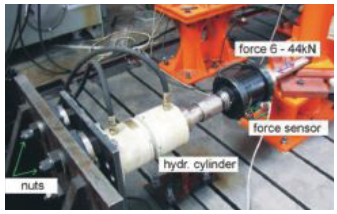

Fig. 10

Conclusion

1. Transition from equilibrium to non-equilibrium state during tightening.
2. Stress state creation and dimensional changes during operational loading.
3. Relaxation so effort to return to original equilibrium state.

All this is the real life of threaded joints. The irreplaceable task of the designer is to prevent spontaneous relaxation of the screw joints so that it does not fall apart during operation. This can be achieved by precise assembly to the required level of assembly force and by applying a suitable external locking system.

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Company Profile:

***FERODOM**, Žilina, Slovakia, was established at the end of the year 2000 as a family enterprise. Selected ware, such as fastening materials and anchor techniques, are the logical culmination of the company founder's effort to make use of his vast experience and knowledge in the area of mechanical fastening of steel and other materials by means of threaded or threadless fastening elements, like screws, nuts, washers, rivets, anchors, etc. The company's activities gradually heightened in scope to include joining elements which found far greater utilities.*

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