Products Safety as the External Demonstration of Corporate Culture

產品安全作為企業文化的外在體現

Design Principles for Safety Products

As shown in **Table 1**, there are five reasons why screw connections must be secured and safe. Their disintegration is due to vibrations and dynamic stress, mechanical overload, theft and vandalism:

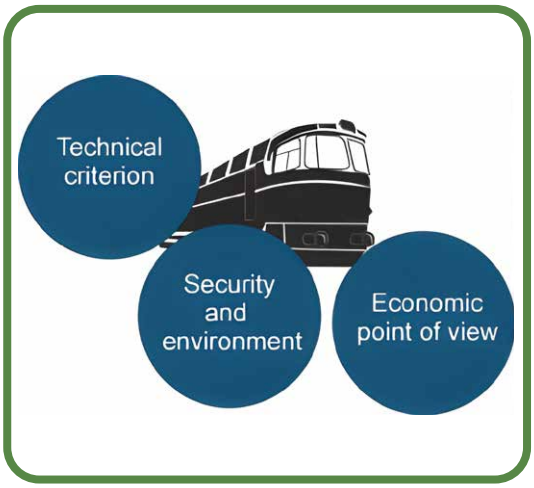
Table 1. Reasons for secure screw connections

SECURITY/SAFETY Against:				
Disintegration	Mechanical Destruction	Corrosion	Theft	Vandalism

To provide secure products is a complicated and demanding process. The observing of regulations itself does not give a guarantee of the secure and commercially successful product. It is not possible to prescribe safety and security, or to program it. It has to be constructed and designed.

If we do not count the stochastic cases of the crashes, then the following general criteria are valid for the safe structure **(Fig. 1)**:

▲Fig. 1. General criteria for safe structure



As shown in **Figure 1**, it is not just the security and the impact on the environment which have to be factored in each structure by the designer. A successful and competitive product has to offer the required technical and economical parameters. **Product reliability is always a compromise between the costs and the technical parameters. The design and manufacture have an irreplaceable role to find an optimal solution in confrontation of these two opposing factors.** Besides these, there are other significant design criteria, such as a technology-oriented design and construction and last but not least the product appearance.

In the EU conditions, various legislative regulations have been approved, especially the standard ISO 13849-2015: "Safety of machinery, Part 1: General principles for design". This standard provides safety requirements and guidance on the principles for the design of safety-related parts. The quality assurance is the mark - (European Conformity) as a symbol of free marketability in the European Economic Area. Of course, there are many other legally binding regulations which have to be accepted not only in the EU conditions. The most important one is the EN 10204 standard "Metallic product – Types of inspection documents" with four levels of inspection reports:

(1) Type 2.1 Declaration of compliance with the order

(2) Type 2.2 Test report

(3) Type 3.1 Inspection certificate - Statement of compliance with the order, with indication of results of specific inspection

(4) Type 3.2 Inspection certificate with indication of results of specific inspection. The manufacturer's authorized inspection representative independent of the manufacturing department and either the purchaser's authorized inspection representative or the inspector designated by the official regulations.

The CE-marking (and the declaration of conformity) is the signal to the public and the market supervisory authorities that manufacturers believe their products meet all basic safety requirements.

Bolted joints are not an exception in this respect. Quite the opposite, as already said, they do not have to be the weakest part of the structure. The reason is simple. Any kind of failure could result in the destruction of the whole structure with possible catastrophic consequences. The trailer hitch serves as an example of it. In this case the locking system used was not effective enough and therefore the joint is being progressively loosened and by the influence of the repeated alternating dynamic stress, a fatigue fracture has occurred **(Fig. 2)**. You can easily guess what can be caused by an automobile trailer which is torn off and being rushed at high speed in an uncontrolled way down the road. It is clear that the given structure hasn't met it.

Everything is governed by the cause-and-effect principle. Assuming correct assembly and a defect-free product, there are two levels of design measures against the risk of a crash:

(1) Crash protection

(2) Eliminating the cause (source) of danger which is the requirements of the "fail-safe" principle.

▲Fig. 2. Fatigue fracture

Obviously, the accident of the towing device from **Fig. 2** was caused by insufficient securing of the screw connection with an effective insurance system. Due to the action of alternating dynamic stress, the prestress dropped to zero value, and as a result of which the joint ceased to fulfil its function and a fatigue fracture subsequently occurred. In this case, it was not possible to eliminate the source of danger, i.e. to prevent dynamic stress.

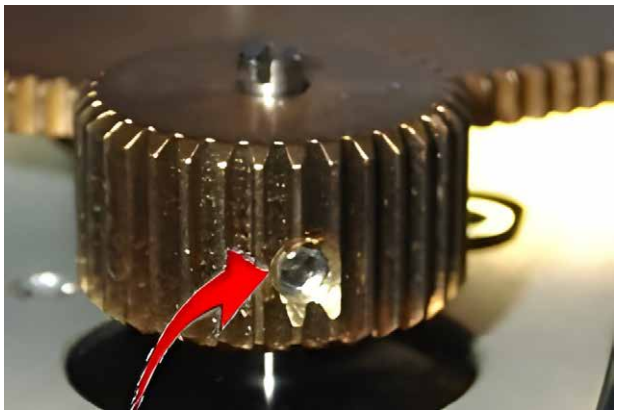
On the other hand, the deformation of the fastening screws of the car wheel **(Fig. 3)**, which came loose during driving, could be prevented by respecting the permissible load of the vehicle. This relatively common ailment of drivers has already resulted in more than one serious accidents with fatal consequences. The safety screws in **Fig. 4a and 4b** only protect against theft, but not against free loosening.

▲Fig. 3. Car wheel screw

▲Fig. 4a. Safety screw

▲Fig. 4b. Safety screw

Despite the driving lever position of the water jet drives FULLS BACK, no effect of this maneuver was noticed - Consequences: 6 seriously injured, 43 slightly injured people. The cause was a loose small screw on the steering system **(Fig. 5)**. For the same reasons, the doors on the expressway fell out while driving **(Fig. 6)**.



▲Fig. 5. Steering system

▲Fig. 6. Expressway door

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.

Impact parameters:

• Assembly

This, seemingly simple, technological operation tends to be the biggest source of bolted joints failure and the cause of the whole construction crashes. The role of a constructor is not only to construct the product but also to prescribe the way and parameter of assembly. The prescribed assembly procedure is for the production obligatory. The essential precondition of the secure product is the application of the controlled assembly which assures necessary screw pre-stress. The exactness of tightening tools defined as the maximal and minimal assembly force ratio and the intensity of friction between the threads under the nut head and under the nut are important. The higher friction coefficient μ, the more energy is consumed while tightening to overcome it and the less is used to create pre-stress FV.

Most producers and distributors state the recommended tightening values of the specific bolted joints in relation to the friction coefficient in technical documents. There is only approximate information without the influence of operating forces. It is a competence of the constructor to consider these forces and to evaluate their influence. **The rule is that the pre-stress forces must not decrease under specific values to prevent damaging of the joint and they must not overcome steel solidity.**

• Construction and Design

On condition that the assembly is correct, and the product is immaculate, there are two construction measures against the danger of crash:

1. Elimination of the danger source/cause

2. Crash security

It is clear that the crash of the trailer from **Fig. 2** was caused by an insufficiently bolted joint security with an effective locking system. By the alternating dynamical stress, the pre-stressing force has decreased to zero, causing the joint to stop to fulfil its function and the fatigue fracture occurred. In this case it was not possible to eliminate the source of danger, i.e. to prevent dynamical stress. On the other hand, it was possible to prevent the deformation of the tightening screws on the automobile wheel **(Fig. 3)** which had been loosened during the drive. It would be enough to respect the allowed vehicle loading. A good example of the cause elimination is the application of fitted hardened pins, e.g. according to EN ISO 8736 or screws with fitted shaft according to ISO 7379. Their role is to intercept transversal dynamical impacts. This measure is often used for pressing tools.

• Heat Treatment

Principally, there are two ways of steel heat treatments for the screws and nuts production. The most frequent way is tempering, characterized by uniform martensitic structure in the whole section of the part. The reached strength degrees are from 8.8 to 12.9/14.9. The other group comprises cementation and inductive surface hardening, characterized by the solidity gradient along the section of the part. The aim of this article is not to compare these methods. It is important to state that in both cases defects can occur. These defects are hardly ever identified without appropriate laboratory equipment.

The refinement is characterized by low solidity, cracks or decarburization of the surface caused by an inappropriate constitution of the protection atmosphere. During cementation or inductive hardening the small thickness of the hardened surface layer or material overheating in the area of sharp edges are the most often occurring problems. Austenitic stainless steel (A2, A4) is characterized by the fact that their increased solidity is not reached by heat treatment but by mechanical cold surface firming. It quite often happens that the declared strength valued at 700 or 800 N/mm^2 does not correspond to reality. All the mentioned cases of screws and nuts production are unacceptable in practice.

• Surface Treatment

It is often mistakenly supposed that surface treatment serves only as the protection against corrosion or a way to improve the appearance due to the higher credibility and marketability of the products. Whereas the fact that the character of screw's and nut's surface significantly determines the friction coefficient is marginalized. Different surface treatments influence the final pre-stressing force. Therefore, the constructor should have correct data of surface characteristics at his disposal in order to prescribe the right parameters of tightening.

Conclusion

The security and safety of products and the whole construction units is a difficult process in which the designer and constructor has the most significant role. The constructor is responsible for construction safety and whether it meets all technical requirements, economic and ecological criteria, etc. Naturally, that is true if the assembly fully respects the construction prescript. Unfortunately, it is not rare that correctly calculated and precisely dimensioned bolted joint is finally tightened manually, i.e. in an uncontrolled way. It is one of the persisting bad habits of current technology of mechanical joining. ◘