Structures Security in Terms of Bolting

Motto: "Any chain is only as strong as its weakest link."

螺栓接合的結構安全 *by Jozef Dominik*

General Construction Principles of Secure Products

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

As A. Neudörfer writes in his book "Konstruieren sicherheitsgerechter Producte" (Springer Vieweg 2016), "Product security is the external demonstration of a company's culture." If we do not count the stochastic cases of crash, then the general criteria in ***Figure 1*** on the right are valid for the secure structure.

Fig. 1

As it is shown in the figure, it is not only the security but also the impact on the environment which have to be factored in each structure by the constructor. A successful and competitive product has to offer the required technical and economical parameters. Product reliability is always a compromise between costs and technical parameters. The constructor has an irreplaceable role to find an optimal solution in confrontation of these two opposing factors. Besides these, there are other significant construction criteria, such as a technology oriented 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 CE mark (European Conformity) as a symbol of free marketability in the European Economic Area (Internal Market). 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 – Inspection types documents. The bolted joints are not an exception in this respect. Quite the opposite, they do not have to be the weakest part of the structure. The reason is simple. Any kind of the failure could result in the destruction of the whole structure with possible catastrophic consequences. The trailer hitch in ***Figure 2*** serves as an example of it. In this case the used locking system 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. You can easily guess what can be caused by 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 did not meet the requirements of the "fail-safe" principle.

Fig. 2

Security of Bolted Joints

As it has been already mentioned the bolted joint must not be the weakest part of the structure and therefore this topic should be discussed in more detail. The consequences of bolted joints failures have become the subject matter of many companies and relevant theoretical departments. The SKF company has worked out an analysis which implies that the most often cause of these failures is an assembly (ca. 45%) followed by production, construction, heat treatment, material and surface treatment. In the further lines the attention is devoted to some of them.

Assembly

This, seemingly simple, technological operation used to be the biggest source of bolted joints failure and the cause of the whole construction crashes. The role of the 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 obligatory

production. The essential precondition of the secure product is the application of the controlled assembly which assures necessary screw pre-stress. The exactness of the 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 ***(Fig. 3)*** are important. The higher friction coefficient μ, the more energy is consumed while tightening to overcome it and the less is used to create the 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 to below the specific values to prevent damaging the joint and they must not overcome steel solidity. Popularly said: "Security Force Rubicon".

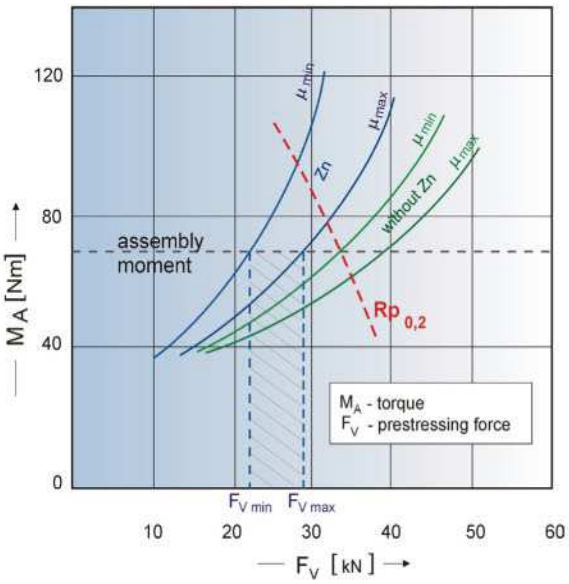


Fig. 3

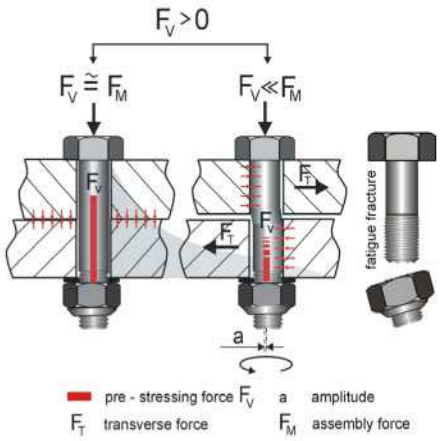


Fig. 4

Fig. 5

Fig. 6

Construction

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

1. Eliminating dangerous sources/causes

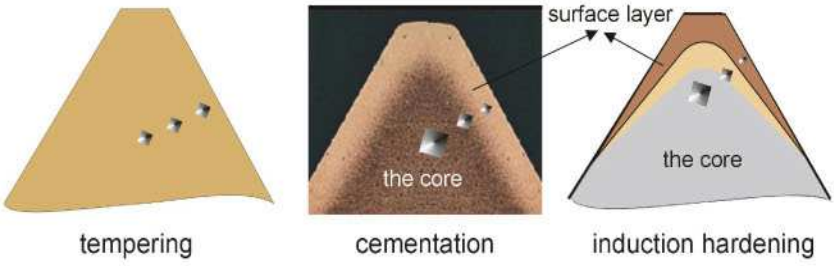
2. Crash security

It is clear that the crash of the trailer from Figure 2 was caused by insufficient bolted joint security with effective locking system. By the alternating dynamic stress, the pre-stressing force value has decreased to zero, which has caused the joint to stop fulfilling its function and the fatigue fracture has occurred ***(Fig 4)***. In this case it was not possible to eliminate the source of danger, i.e. to prevent dynamic stress. On the other hand, it was possible to prevent the deformation of the tightening screws on the automobile wheel ***(Fig. 5)*** which has loosened during the drive. It would be enough to respect the allowed vehicle loading. A good example of cause elimination is the application of fitted hardened pins, e.g., according to EN ISO 8736 ***(Fig. 6)*** or screws with fitted shaft according to ISO 7379. Their role is to intercept transversal dynamic impacts. This measure is often used for pressing tools.

Heat treatment

Principally, there are two ways of steel heat treatment for screws and nuts production ***(Fig. 7)***. The most frequent way is tempering, characterized by uniform martensitic structure in the whole section of the part. The reached solidities 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 the defects can occur. These defects are hardly ever identified without appropriate laboratory equipment.

Fig. 7



The refinement is characterized by low solidity, the cracks or the decarburization of the surface caused by inappropriate constitution of the protective 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) are 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 the screws and nuts production are unacceptable in practice.

Fig. 8

Surface treatment

It is often mistakenly supposed that surface treatment serves only as the protection against corrosion (Fig. 8) or to improve the appearance due to the higher credibility and marketability of products. However, the fact that the character of screws and nuts surface significantly determines the friction of coefficient, is marginalized. As it is shown in Fig. 3, different surface treatment influences the final pre-stressing force FV. Therefore, the constructor should have at disposal the correct data on surface characteristics in order to prescribe the right parameters of tightening. The bolted joint in Fig. 8 is a typical example of the incorrect combination of galvanized and untreated surface.

Conclusion

The security of products and the whole construction units is a difficult process in which the constructor has the most significant role. The constructor is responsible for construction security and whether it meets all technical requirements, economic and ecological criteria, etc. Naturally, that is true if the assembly fully respects the construction prescription. 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 the current technology of mechanical joining.

The Importance of 緊固接合控制的重要性 *by Laurence Claus*

Controlling Joint Tightening

On December 23, 2016 a fatal crash occurred on a busy Chicago highway. A large tractor trailer truck hit a car, flipping over, and crashing through the center median hitting on-coming traffic. What could have been a horrendous holiday tragedy was limited only to the driver of the truck. Unfortunately, even one fatality is too many, especially if it is due to an entirely preventable cause.

Figure 1: December 23 Chicago Truck Crash Linked to Separated Wheel

Early reports claimed that the crash was caused by a wheel separating from the truck. It was believed that this caused the driver to lose control resulting in the subsequent chain of events. After accident reconstruction, however, it was determined that the truck driver actually hit a wheel (tire and rim) that had separated from another truck and was lying in the roadway.