A Small Screw, A Giant Value

by Jozef Dominik

Once upon a time there was one quite a little screw which together with the others held two giant steel plates together. During the long cruise across the Indian Ocean this little screw felt a bit cramped therefore it tried to release. There was a real thread of falling off.

Even the other screws turned to it: "If you fall off, we will do it as well."

When the giant steel profiles had heard it, they started to complain:

"God! Stay! When you stop holding, what will happen to us?"

A tiding about the intention of the little screw has been spreading as quickly as a streak. It didn't take too long and all beams, futtocks, steel plates and other construction parts have decided to send the common message to the little screw to persuade it to stay otherwise the whole ship will sink. At last, the little screw, flattered by such an attention, submitted and stayed with the feeling of its own importance.

Rudyard Kipling (*1865 – †1936) the first English Nobel prize winner for literature. (loosely adapted by the author)

Introduction

Although a layman, Rudyard Kipling, almost 100 years ago, depicted precisely the importance and the role of bolted joints. Practically, any technical work could not exist without them. They are everywhere. Not in vain it is said that the screws are holding our civilization together. Without a doubt, the bolted joints are the most commonly used assembly systems not only in mechanics.

A lot of things have been changed from the times of Leonardo da Vinci, referred to as a father of bolted joints, and a lot of things will also be changed into the future. In current times there are a lot of specialised research departments and study fields at technical universities focused on the bolted joints and related issues in the world. These central departments together with the development ones of some significant local producers of bolted joints are the guarantee for further development. It is valid: Development= improvement. Where the application of the latest results of the development into the practice has become natural part of the company strategy, there are also better results achieved. On the other hand, remaining on the position of standard production of common bolted joints pushes the producers to calculate with the price without the added value. The orientation to low cost products has not got the perspective from the long-term point of view.

Quite a few producers of bolted joints paid for their development neglecting especially in the countries of Central Europe. Even Leonardo da Vinci claimed that practice without theory is like a ship pilot without a compass or a helm. Nobody knows where it will sail.

This rule was understood by many current companies and they earmark considerable sums of money for the research and development in order to achieve the answers on these fundamental questions:

- how to reduce the weight of the product preserving security and quality,
- how to save costs,
- how to join hybrid materials effectively,
- how to rationally ensure simple assembly in the condition of mass production,
- how to reduce impacts on the environment

The European leader in this field is Germany. For instance by the application of light Mg-alloys for new six-cylinder petrol engine BMW the weight was decreased by 10 kilograms with relatively positive impact on the consumption of propellants. It also goes for screws. The common steel materials have not been satisfying any more due to the risk of the contact corrosion and different thermal expansion coefficient; therefore BMW company used extra-firm Al screws for this purpose.

The car producers require the high quality of the bolted joints. If the market is not able to provide it to them just in time, they will have to turn to so called premium manufacturers with string development base who will be able to respond flexibly to specific requirements especially of the automatic production. The example can be the screw production for automotive industry in Chinese Jinxi eco-industrial park which was established by Nedschroef Fasteners Kunshan in 2013. However, it is not only the automotive industry which dictates the trends in the development of mechanical joining. Electrotechnics, electronics, engineering, furniture industry and also orthopaedics or dental technology have their own specifics which are necessary to know, respect and devote them appropriate attention.

The Development Trends

The categories to which the biggest concentration of research-development capacities is expected in the future, are illustrated in **Figure 1**.

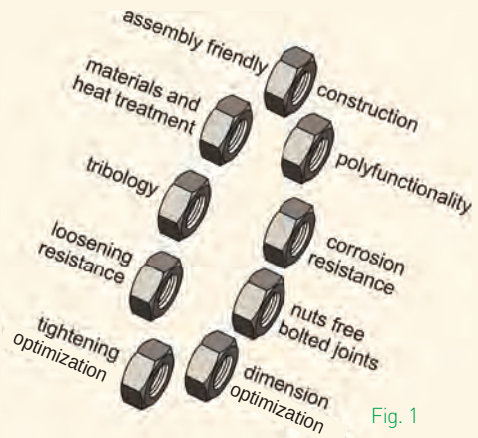
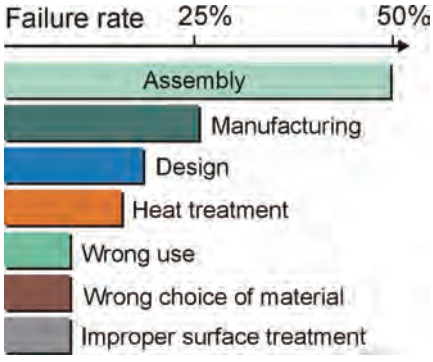


Fig. 1

The mentioned trends are also related to the current quality of mechanical joining. As the Swedish company SKF states, the most frequent mistakes of bolted joints have their origin in the incorrect assembly (almost 50%), in production process, in construction and in heat treatment **(Fig. 2)**. Of course, the developments cannot ignore this knowledge.



Assembly Friendly Construction

The common bolted joints which are produced in a world scale way are not usable for automatic production **(Fig.3)**. This was already mentioned in the previous issue of Fastener World No. 147, where possible solutions were indicated.

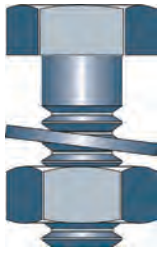


Fig. 3

Materials and Heat Treatment

Probably the biggest growth will achieve the development of new materials and their heat treatment. As it was stated, light Mg-Al alloys were developed which are lighter in sufficient solidity; they tolerate high temperatures better and they are more resistant to corrosion than common steels. The increased attention to these materials is devoted, e.g., at Technical University Darmstadt, DE.

The perspective also has plastics and ultralight composites. Mainly the Swiss company Icotec contributed to it. It developed special screws of Icotec material for orthopaedics and dental technology. This material is also used in production of microlight planes and bicycles, and the screws are not the exceptions.

Of course, the significant part of bolted material will be further produced in steel and stainless steel. Regarding the heat treatment, the quenching in protected atmosphere and case-hardening of self-tapping and self-drilling will remain the basic methods. In special cases, partial induction quenching or laser or electron beam will be spread.

Tribology (Science of Friction)

The friction of bolted joints is a strange phenomenon because during the assembly it is a hindrance but after finishing the assembly it is required in order to prevent the bolted joint from the damage caused by vibrations.

As it is known just about 25% input tightening moment is used for pre-stress of the screw and the rest is consumed to overcome the friction under the head and in the threads. Concurrently it is highly important to have the friction constant otherwise it will come to great pre-stress dissipation while tightening. The next task of the development will be to secure stable tribological conditions at bolted joints. The latest knowledge will be used from the field of nanotribology.

Loosening Resistance

Fig.4

The bolted joints loosening resistance caused by vibrations and dynamic loading is closely related to friction. The direct proportion is valid and it means that the friction is higher on the contact surfaces where the bolted joint is stabler. There are several ways of external locking of the bolted joints but only a few of them are also appropriate for the conditions of automatic assembly. Especially various types of the washers increase uselessly the number of partition lines and assembly parts. Only the screws or the nuts with integrated profiled flange proved successful **(Fig. 4)** and the development will probably turn in this way. In well-founded cases the various kinds of glues, e.g., LockTite will be asserted.

Tightening Optimisation

As it is shown in **Fig. 2**, the assembly is the most frequent source of bolted joints defects. The cause is in the inaccuracy of applied tightening method **(Tab. 1)** and in the dissipation of friction coefficient.

Tab. 1 Accuracy of the Tightening Load for Various Tightening Methods Using Torque (by French Standard NF E 25-030)

Tightening Method	Accuracy on Pre-load	γ
Calibrated torque wrenches power tightening tools with regular calibration on application (measurement of elongation of the bolt or measurement of torque value using a calibrated torque wrench)	± 20 %	1.5
Impact wrenches with stiffness adjustment and periodic calibration on application (measurement of torque value using a calibrated torque wrench per batch)	± 40 %	2.5
Hand tightening shock wrench (non-calibrated)	± 60 %	4

γ = Uncertainty factor on tightening load = Fo max./Fo min.

The high uncertainty factor on the tightening load γ. together with the huge dissipation of the friction coefficient results in uncontrolled tightening with its all negative impacts. In some cases even γ=1,5 is not sufficient; therefore hydraulic torsion-free tightening has to be used, as it is in the case of the high-pressure cleaning machine in **Fig. 5** in which γ is approaching to 1.

Fig.5

The regular calibration of tightening tools is necessary in all types of them.

Fig.6

The tightening accuracy does not only depend on the features of the tools but also on the form of tightening. The standard hexagonal shapes are being consecutively replaced by more advantageous internal or external shape Torx **(Fig. 6)** which is able to carry higher torque moment.

Polyfunctionality

By this term we understand the ability of the screws to fulfil also some other functions not only the joining. The self-tapping screw in **Fig. 7** is a typical example. It is able to drill a hole under the thread, cut the thread itself and then it fulfils the washer function.

Fig.7

It is a modern, highly sophisticated and in practice frequently used fastening part because it saves costs significantly. Such screws are made of cementation and also martensitic stainless steel with excellent corrosion-proof resistance.

Corrosion Resistance

As long as the screw exists, it copes with corrosion problems. It is a serious social phenomenon because the fight against corrosion consumes substantial amount of the national income. Despite the development in the field of corrosion-proof protection significantly progressed, we cannot say that it was sufficiently finished. The problems are caused by the fact that the universal cure for corrosion does not exist. What is valid in one case needs not be valid under other conditions. The constructors have an irreplaceable role. They have to know the mechanisms of corrosion process, and the conditions in which the future construction will work. They also have to be able to choose an optimal protection system.

In connection with corrosion-proof protection we cannot forget to mention the protection of the environment. As the harmful coatings comprising a hexavalent Cr were prohibited in the EU and it is supposable that a trivalent Cr will also be soon prohibited. It is an appeal for the development of new ecologically appropriate methods of surface treatment. The latest knowledge from nanotechnology can also be used during that.

Nuts-Free Bolted Joints

This topic is connected especially with the automatic assembly. Nut bolted joints represent two assembly trends and it would be a significant handicap for robotic systems.

Besides, nuts require washers in most cases. This situation not only complicates logistics but also increases the number of undesirable contact surfaces. The modern constructions of the automobiles hardly ever use the nuts. Similarly it is in electrotechnics and electronics.

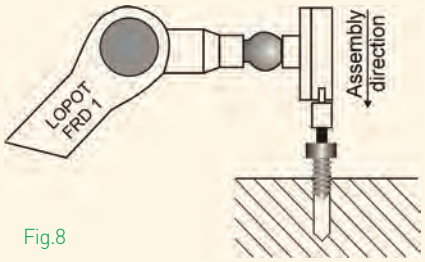


Fig.8

Dimension Optimisation

Professionals agree that the weakest part of the current technology of mechanical parts joining with the help of screws is their useless excessiveness. On one hand it is a natural consequence of the constructor's fear of responsibility and on the other hand it is insufficient use of the virtual simulation possibility and strength calculations by the FEM (finite elements method). The newest construction programs have already included elaborated FEM modules, so it is not a problem for a skilful constructor to use them. The problem can be to assign the correct marginal conditions for calculation because no program can supply the role of the constructor in any way. The weak aspect of most FEM programs is the incapability to accept the anisotropy of mechanical features of the material.

Conclusion

Bolted joints are the most significant and widespread type of mechanical parts joining. Seemingly simple construction parts are and will also be the object of the permanent interest of research institutes and development centres of prominent producers. In this contribution there are implied the trends of future development. The fastener industry will not be developed on its own but parallelly with the development trends of the automobile industry and electronics as the most dynamically developing branches of economics. These branches are characterised by high level of automatisation to which the bolted joints and assembly technology have to be subordinated.