Advances in Fastener Sector

by Jozef Dominik

Introduction

Despite the fact that bolted joints are generally considered to be relatively conservative structural element, there are still increasing new types, original technological techniques and materials. As Prof. M. Oechsner from TU Darmstadt, DE says, "...it is impossible to stop the development in this field." The special demands on technology of mechanical parts joining, especially related to the space exploring, the automotive industry development, the requirements on light constructions and the automatic assembly force towards further development. However, the constructor has a wide assortment of screws and nuts available; there arises the need for further and further types. The industrial revolution at the end of the 19th century caused not only enormous increase of the amount of the bolted joints but also the demands on their quality. This trend continues nowadays, of course. It concerns not only constructions but also production technology, materials and surface finishes.

Historical Milestones

Modern history of mechanical joining with the help of thread bolted joints began in the 18th century when the first factory for screw production was established in Germany in 1935 (Rudolf Kellermann Fabrik für Gewindeteile). First, they produced simple conical screws into the wood with a square head from steel at strength ca. 400 N/mm^2. These were the forerunners of today's self-tapping screws in a certain sense.

Rudolf Kellermann with Hans-Christof Klein researched the relationship between the friction and pre-stress and they formulated Kellerman-Klein's formula which later became the basis for the current standard ISO 16047. Henry Maudslay and especially an American constructor Joseph Whitworth (1803-1897) contributed mostly in the field of normalisation of bolted joints. Joseph Whitworth's thread with an apical angle 55° is used till now. A metrical ISO version with an apical angle 60° settled down in the European market.

The first automated bolt production is related to the development of "boltmaker" in USA at a solid performance of about 70 bolts per minute.

Technical revolution required the materials with higher mechanical quality. New steels with strength up to 1400 N/mm^2, stainless Cr-Ni (Mo) steels and steels for case-hardening and cementation of self-tapping screws were developed. Nowadays, an intensive development of Al and Mg alloys which at an adequate strength like steel are lighter and tolerates better higher temperatures. Further development was focused on replacement of the washers and extension of contact surfaces with the help of flanges, next on the tightening optimisation but mainly on the measures for preventing spontaneous loosening.

The technological development was in progress parallelly with the construction. Contemporary modern machine centres with CNC control, equipped with sectioning tools with coatings on the Ti basis enabled to increase the section speeds multiply and by that the labour productivity. It caused a fundamental change in the bolts and nuts production where particle machining is a dominant technological operation. The standard lathes (**Fig. 1**) have not already sufficed to fulfil demanding production requirements.

Fig. 1

A similar trend can be detected in the field of forming and pressing. New steels and coated pressing and forming tools by PVD or CVD method enabled to increase significantly the technology of cold-forming. Equally, the surface finishes went through a dominant innovative process. After elimination of hexavalent Cr, progressive elimination of trivalent Cr from the technological process can be expected. In this respect mainly the advances in the area of nanotechnology are used.

The Selection from the Progressive Bolted Joints Portfolio

This chapter does not demand the exhausting list of new bolted joints which were developed in last years. Only a selection from several of these elements is stated without any respect to time sequence of their development. From this list are excluded especially elements on which only small cosmetic finishes were done and they have no significant influence on technology of mechanical joining. In most cases the only concern of the producers is to bypass existing patents and known solutions. It is related to e.g. various modifications of trilobular/triangular bolts Taptite®.

Polyfunctional bolted joints

A bolt ThreadLoc® (**Fig. 2**) is an example of this category characterised by three details: a modern way of tightening Torx® (**Fig. 3**), a chemical way of locking, respectively sealing of the joint and a leading edge which enhances assembly.

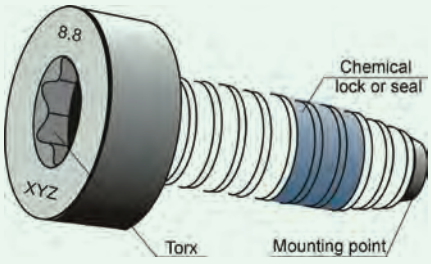

Fig. 2

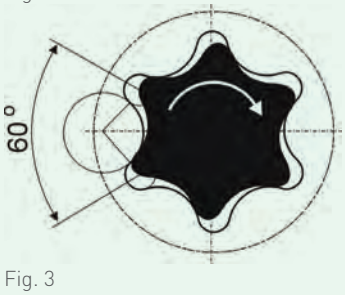

Fig. 3

Typical representatives of polyfunctional bolted joints are mainly various types of self-tapping screws (**Fig. 4**).

Fig. 4

Of course, these highly sophisticated bolts cannot be considered as an innovation, although it is worth mentioning the attempts for combination of the materials for their production. For example, a combination of stainless steel and steel for high-grading. An effort of reaching corrosion-proof resistance at the level of stainless steels, high drilling performance and low costs leads the producer towards such a combination. In all similar cases it is necessary to keep in mind bimetallic corrosion on the boundary of the materials with various electrochemical potential. So far, it has not been overcome by the variant of self-tapping screws made from stainless steel of martensitic type Marutex®.

The screws into the wood and chipboard went through an interesting development. Modern screws with heterogeneous thread (**Fig. 5**) or various types of distance screws (**Fig. 6**) have risen from original primitive shape with square head.

Fig. 5 (Spax)

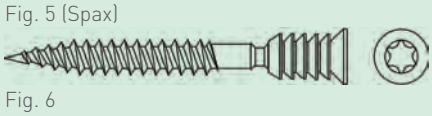

Fig. 6
High-strength structural bolting for preloading

The task is not to present high-strength (HS) structural bolting (**Fig. 7**) as an innovation but emphasize their increasing influence for demanding constructions such as steel bridges, masts, cranes, offshore constructions, wind power plants, etc. The use of HS enables to employ better tensile and shear strength compared to standard bolted joints. This way it is necessary to lower the number of screws during the same loading, from this the economic savings and reduction of construction weight are resulting. The influence of HS was reflected also in a newly designed standard EN 14399. According to this standard HS structural bolting has to allow minimal preloading in accordance with Eurocode 3:

$$0{,}7R_m.A_s,$$

where Rm is nominal tensile strength and A_S is a nominal loading bolt cross-section.

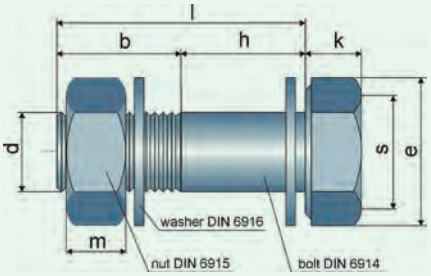

Fig. 7

Accompanying documentation has to consist of important data as mentioned below:

1. Symbols: CE
2. Producer or distributor identification, e.g., Any Co Ltd, PO Box 23, B – 1070
3. Last two digits of the production year, e.g., 14
4. Type or number of Conformity Certificate, e.g., xxx/2014
5. Product identification, e.g., bolt EN 14399

The condition is to have an adequate level of Conformity Certificate which is prepared on the basis of mechanical tests according to the following standards:

- EN ISO 898–1 and EN 10045-1 for bolts
- EN 20898-2 for nuts

- EN ISO 6507-4 for washers

This certificate has to be submitted for request as a part of the accompanying documentation. This way the high quality has to be guaranteed and the responsibility anonymity for possible accidents excluded. The most frequent cause of accidents is hydrogen fragility. Nowadays, the increased attention of the research and development authorities is paid to this problem.

Nuts

Concerning nuts, the development was focused especially on the tightening shape as for example external Torx® and on precautions against spontaneous loosening by the vibrations and dynamic bolt loading effect. The attention of experts is aimed mainly at this serious phenomenon now.

There are three solutions selected from the number of various designs. It is an application of two wedge washers on flange wheel nuts and the newest locking of wheel nuts by the system IstLock® (**Fig. 8**), awarded by Fastener Fair Stuttgart, DE and Fastener Technology International, USA.

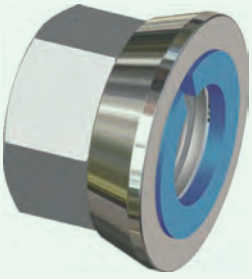

Fig. 8

In connection with the nuts it is needed to say that research and development remained here something to repay. Unmanaged technology of rolling the internal thread is an evidence of it. Even though there are certain solutions indications, the nut still remains the weakest part of bolted joints and it's mentioned handicap has to be compensated by the increased solidity.

Every standard bolted joint represents two assembly trends; therefore the construction of nuts-free and washers-free joints dominates in the automatic assembly. The typical example is the production of automobiles where the nuts and washers are not used at all. Similar tendency can also be applied in electrotechnics. In other cases the nuts are irreplaceable. Their development was in progress approximately according to the general line in **Figure 9**.

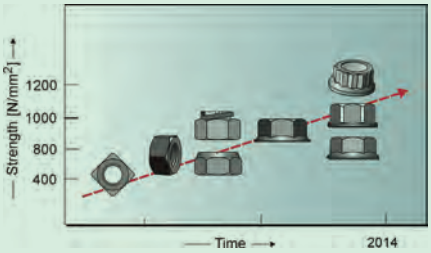

Fig. 9

Washers

The washers are not needed in general from the aspect of the bolted joint function because the number of partition lines increase and they complicate the assembly and logistics. Despite this, in some cases they are inevitable. They serve for extension of contact surface under the nut or under the bolt head and they are not used for external bolted joint locking. For this purpose the ribbed/toothed and wedge-like washers were developed. In recent time no new types have appeared on the market. Definitely, the replacement tendency of the washers with flange bolts (**Fig. 10**) and nuts is prevailing.

Fig. 10

The expected developmental tendencies:

- The level increasing of the screws and nuts poly-functionality.
- The development of nut-free and washer-free bolted joints.
- The screws and nuts with integrated flanges sophistication.
- The methodology improvement of locking against vibrations and dynamic loading.
- Assembly-friendly construction.
- The increasing of resistance against corrosion by ecological techniques with the use of the latest knowledge from the field of nanotechnology.
- The development of new materials, predominantly on the basis of Al and Mg alloys.
- The analysis of stress state of bolted joints with FEM method and the optimization of strength calculations with the aim to reduce their excessiveness.
- The improvement of exact tightening ways with the aim to reach maximal pre-stress with minimal dispersion.
- The stabilization of tribological proportions on contact surfaces.
- The development of thixotropic lubricants which provide differentiated coefficient of friction during assembly and after its finishing, i.e., in working position of bolted joint.
- The methods development and optimization of torsion-free tightening.