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By Jozef Dominik, owner, FERODOM s.r.o

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For engineers involved in the design and maintenance of bolted joints there is one very important maxim: 'There is no universal remedy for loosening of bolted joints'.

Although correctly proportioned and tightened bolted joints do not need any special locking, many dynamically loaded structural nodes do require it. The unlocked bolted joint represents a latent risk of loosening, which makes the choice of locking method one of the most important constructional decisions. A wide range of locking bolted joints is available on the market nowadays. It is up to the constructor's erudition which variant they select. To have credible data is an important condition.

The aim of this article is the analysis of current testing methods for locking bolted joints and, in particular, to disprove any assertion about the universality of any specific solution.

Theoretical analysis of the issue and discussion

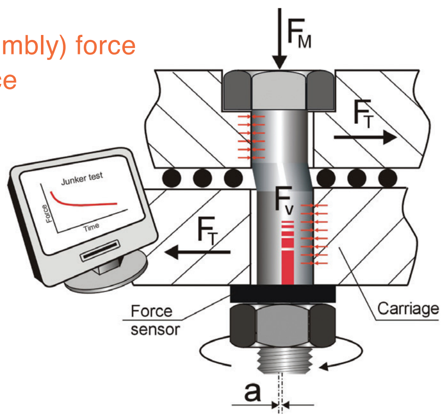
Vibration and shock resistance of bolted joints is tested using special laboratory devices of various types. The best known is the so-called Junker test, which was first published by Gerhard Junker in the magazine SAE Trans, Vol. 78, 1969. Soon this method became popular in Germany but also spread all around Europe, the USA (National Aerospace Standard 3350/3354 is the exception) and in many other countries.

In the course of the time, it has been adopted into international fastener standards such as DIN 65151 (Dynamic testing of the locking characteristics of fasteners under transverse loading conditions) and its replacement DIN 25201-4.

Nowadays, many research and development departments, technical universities, manufacturers, and even distributors of fastening systems, have Junker test equipment at their disposal.

The Junker test is the method used for testing the self-loosening behaviour of threaded fasteners under transverse loading conditions by vibrations. The principle is simple (Figure 1). The tested bolted joint is, having been exactly tightened, cyclically stressed by means of eccentric alternate transversal force (F_T) at a specific amplitude and frequency. The frequency 12.5Hz and the amplitude ±0.3mm are generally effective for screw sizes M8 and M10. Observation is aided through the use of a force sensor and then the decrease in the assembly force is graphically recorded on the screen. The following criteria is acceptable: A bolted joint will be safe if its preload force (F_V) does not fall by more than 20% during operation.

Figure 1:
F_M – montage (assembly) force
F_T – transverse force
F_V – preload force
a – amplitude

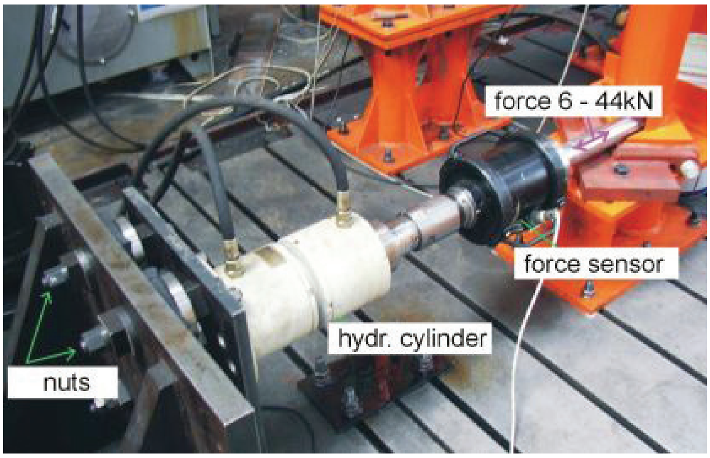


Today, there are several producers of these testing devices for sizes from M8 to M16. The devices for M8 and M10 are portable and they are used especially as a marketing tool for promotion of leading locking fastener systems. Testing bigger sizes than M16 is more problematic and this method is hardly ever adopted.

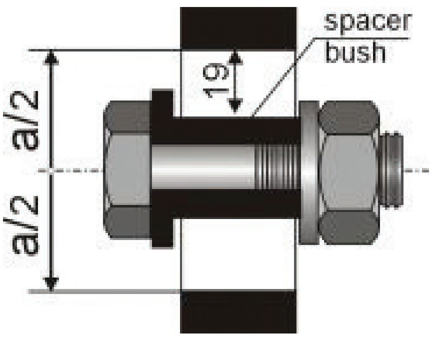
With this exception the following statement is important: The Junker method is based on alternating cyclic loading of the bolted joints in a radial direction, i.e. perpendicularly to the bolt axis. A good example of this kind of loading can be found in wheel fastening.

However, a lot of structural nodes are dynamically loaded not only in transversal but also in axial direction or in a combination of both. A winding machine (pictured below) is a typical example. Repeated starts of a locomotive, train braking and mutual pounding of the wagons cause alternating loading of the load-bearing fasteners in an axial direction. Their loosening could have catastrophic consequences.

Testing of the fasteners by the Junker system would not provide relevant results in this case. The only correct testing method is such that corresponds with the loading type of the real structural node in operation conditions. For this reason, an appropriate pulsator has to be used for an accurate loading simulation. For example EDYZ (pictured below) could be used. This is able to generate relevant force impulses in the axial direction.



Its advantage is in the size variability of the alternating tensile forces, ranging from 6kN to 44kN, and the loading frequency. Similarly to the Junker test, this method also uses a force sensor, which records the changes of the original assembly force and the number of the loading cycles until the total loosening of the tested fasteners.



There are also some other vibrations tests. It is worth remembering the already mentioned test according to the National Aerospace Standard 3350/3354. This is a very radical method because it is based on high frequency vibration loading at the amplitude ±19mm in horizontal or vertical direction (pictured above).

A bolted joint enduring the conditions of the NAS 3350/3354 endures everything. This is demonstrated indirectly in the graph in Figure 2, where the efficiency of the popular locking wedge washers according to the tests Junker, EDYZ and NAS is compared.

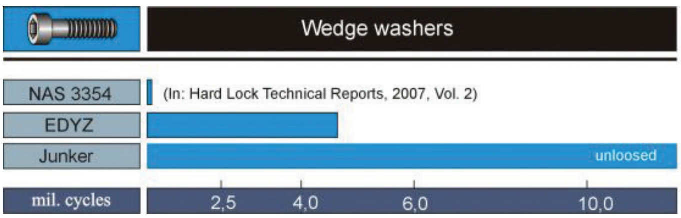


Figure 2: Efficiency of popular locking wedge washers according to Junker, EDYZ and NAS tests

From the graph it is evident in which circumstances the selection of wedge washers is appropriate:

- According to the conditions of the radial alternating loading (Junker) it is an excellent locking element.
- According to the conditions of the axial loading (EDYZ), depending on the amplitude it is a quite good element.
- According to NAS 3354, however, it is an unsatisfactory solution.

This kind of comparison would also be possible and useful for some other locking systems and the results would be analogous. All of them would show their dependence on the type of loading.

Conclusion

Choosing the way bolted joints are locked is an important construction decision. As has been shown, there is no universal solution. It is, therefore, essential to be critical and cautious in the interpretation of vibration test results – an incorrect decision can cause serious problems.

It is not that the mentioned methods of vibration testing are in any way bad. The reverse is the case. They provide valuable information about individual locking fastening elements but they do relate to specific testing conditions.

The competence of the fastener supplier extends to providing clear information. That is the Rubicon they should not cross. The correct interpretation of the results must be the domain of the designer and constructor, who has an intimate knowledge of the application.

Where it works, a bolted joint repays with the reliable and safe operation. However, disrespecting the rules can have undesirable consequences.

About the author

Jozef Dominik is a certified engineer, PhD, educated at the Technical University VŠB Ostrava (CZ) with an academic degree from Technical University Žilina (SK). His career includes the position of metallurgist at ZTS Martin; 25 years as head of heat treatment at the Research Institute of Antifriction Bearing Parts VURAL; and 10 years at Bossard AG Schrauben.

Currently he manages his own company: Ferodom s.r.o., based in Žilina, Slovakia, which aims to deliver "Just the Best" fastening solutions for its customers. Ferodom works in conjunction with technical universities and institutes across Europe, to develop new higher utility fastener elements and technologies. The company supplies a range of locking solutions for threaded joints including its own IstLock® locking nut system, which received a Fastener Technology Innovator award at Fastener Fair Stuttgart 2009.

In addition Jozef has written books including: 'Technologie der Gewindeverbindungen' and 'Illustrated Fastener Dictionary DE – EN – SK'.

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