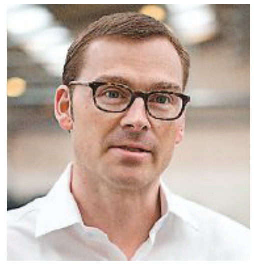
Testing

Vibration testing: A step-by-step guide to testing fasteners to determine self-loosening behavior



Morten Schiff,
CEO
Vibrationmaster
www.vibrationmaster.com

Fasteners in bolted joints subjected to transverse loading conditions will loosen, unless the correct torque, a locking element or both are applied. Understanding the self-loosening behavior of fasteners under vibration conditions is an essential element of the fastener and locking element product design process undertaken by fastener manufacturers. Downstream fastener users such as original equipment manufacturers (OEMs) require an understanding of how bolted joints will perform during actual service, which may include transverse loading conditions. Here Vibrationmaster CEO Morten Schiff uses an example to provide a step-by-step explanation and demonstration of how to perform a vibration test.

"Fasteners and bolted joints are subjected to transverse loading in a huge variety of end-user applications. For example, the automotive sector is the single largest consumer of fastener products and, from an engineering perspective, the average car is a highly efficient vibration machine," explains **Morten Schiff**, CEO of **Vibrationmaster**. "A correctly conducted vibration test will demonstrate at what point a bolted joint will fail. Vibration tests can also be used to develop and test the effectiveness of locking elements such as wedge washers and locknuts."

Schiff notes that vibration testing has become synonymous with the 'Junker Test': "It was the pioneering work of **Gerhard Junker** in 1969 that led to the understanding of why fasteners self-loosen under vibration conditions. This in turn led to the first international standard for vibration testing, *DIN 65151*[1], which was replaced by *DIN 25201*[2] in 2010. A new aerospace vibration testing standard is currently under development by the **International Standards Organization (ISO)**[3] and is likely to come into force during 2015. These standards highlight the importance of conducting fastener vibration tests."

Vibration Test Equipment

Schiff says the first step is to identify and acquire suitable test equipment: "If testing to a standard such as *DIN 25201*, the vibration test equipment that must be used is specified by the standard. Vibration test rigs are commonly referred to as Junker Test benches, or Junker Test machines. It is possible for a well-equipped test laboratory to build a Junker Test bench, and there are commercially available machines. For our test demonstration, we will be using a Vibrationmaster J100 Junker Test Bench Demonstrator."

Ideally, the vibration test machine should apply transverse loading in as close to actual operating conditions as possible. This is a requirement of *DIN 25201*. **Figure 1** shows a cross section through the vibration test fixture in a J100 Junker Test bench. The bolt head end of the bolted joint is stationary and secured from rotation by the sleeve, which is held in a load cell to measure the clamp force. The test nut and locking device end is moved up and down using an eccentric gearbox to simulate vibration.

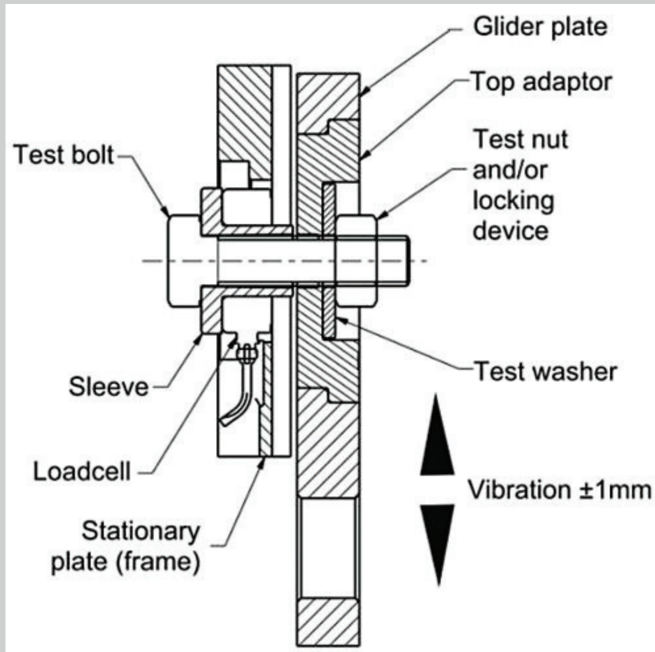


Fig. 1 — Cross-section of vibration test fixture subassembly.

Fig. 2 — Junker Test machine to simulate transverse loading.

Figure 2 shows a J100 from the test nut and locking device end. The threaded bolt and test nut can be seen protruding from the top adaptor. The final element of the test equipment is the tablet computer that controls the Junker Test machine (**Figure 3**). The device being used for this demonstration includes proprietary software that is used to set the test parameters, record test data and then conduct analysis of the test data once the test is complete. The data can also be exported in CSV format for use in other analysis software.

Before the Test Starts — Setting Up

"The complexity of setting up the equipment for the test varies according to the test machine being used," says Schiff. "The J100 includes straightforward adaptors, into which the bolt and nut and washer, plus the locking element if used, are inserted."

Figure 4 shows the bolt being inserted into the sleeve and load cell (the top adaptor can be seen in **Figure 1**).

To satisfy *DIN 25201*, the test equipment used must also be able to vibration test fasteners of varying sizes. And from the operator's perspective, it should preferably be able to do so without extensive reconfiguration. The small and portable J100 addresses this challenge by having adaptors in all main fastener sizes up to ½" UTS and M12 ISO metric.

Figure 5 shows adaptors for M5 and M12. This figure also shows the face of the glider plate, which will vibrate to generate the transverse loading. **Figure 6** is a close-up of the head of the bolt resting in its anti-rotational sleeve in the stationary plate (see **Figure 1**). The load cell that measures the clamp force can be seen below the test bolt.

Figure 7 (on next page) shows an M5 adaptor being inserted into the glider plate. This is the side where the washer and nut are located as well as any locking element. The bolt is inserted through the test machine's stationary plate, through the adaptor and then the washer is added before the nut. The use of a washer and lubrication is compulsory when conducting a test to the *DIN 25201* standard.

The test machine operator simply sets the vibration frequency and the number of cycles. These will be set according to the standard being applied and/or according to the service environment that the test is designed to simulate.

The bolt is then tightened according to the required clamp force/preload, holding the bolt firm with a standard wrench and using a torque wrench (on next page in **Figure 8**). It is essential that the clamp force/preload is accurately achieved according to the test parameters. In addition to achieving the clamp force/preload using a torque wrench, the VM Test software, which is installed on the tablet computer controlling the J100 Junker Test machine, uses the load cell to measure the clamp force. This is shown on next page in **Figure 9**.

The clamp force/preload reading, shown in kN or lbf, will go green when the nut is tightened and the clamp force is sufficiently within the required test parameters. Once the nut has been tightened to provide the required preload, the test is ready to run.

Running the Vibration Test

"It is possible with very little technical knowledge to use a J100 to successfully test fasteners," says Schiff. "Using the control software on the tablet, the technician operating the test machine does not need to take any action until the test has completed. The vibrations are induced by the

Fig. 3 — Tablet computer with test software.

Fig. 4 — Fastener adaptors.

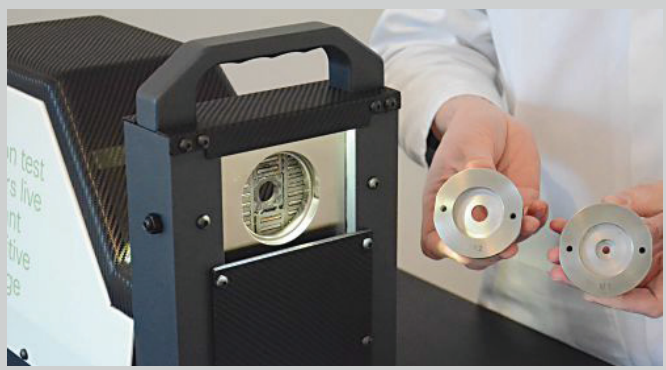


Fig. 5 — Different adaptor sizes and the view of the glider plate.

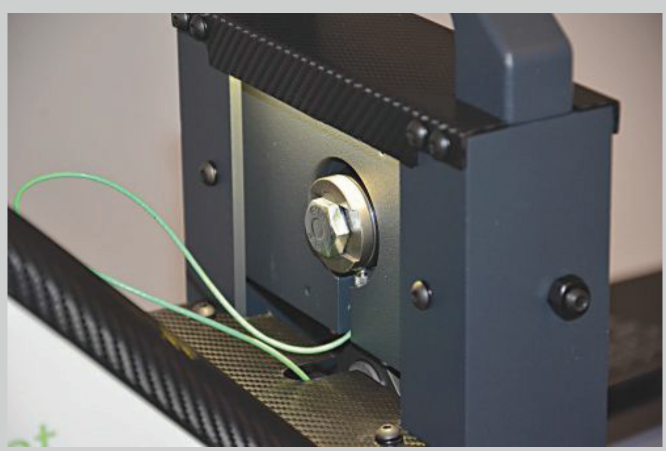


Fig. 6 — Close-up of test bolt in its anti-rotational sleeve by the load cell.

Fig. 7 — Adaptor being inserted into the glider plate.

Fig. 8 — Applying torque to the joint using a torque wrench to generate clamp force/preload.

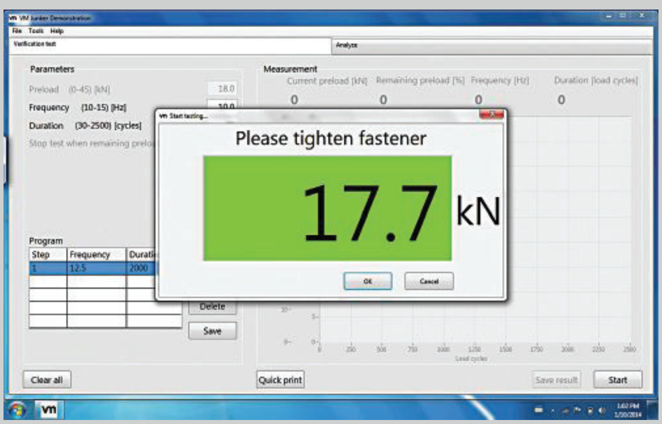


Fig. 9 — Screenshot from tablet computer – the clamp force can be shown in kN or lbf.

glider plate moving up and down by a displacement and a frequency that can both be varied according to the test requirements."

When the test is conducted on bolts without a locking element, the bolted joint will typically lose its clamp force and preload and the joint will fail, or it will stabilize usually at a reduced preload. "It is possible to visually inspect the bolt

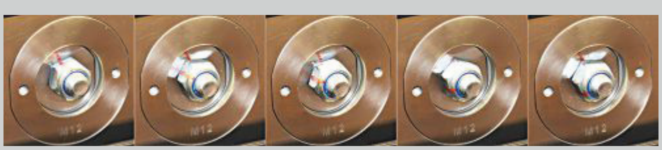


Fig. 10 — Time delayed photos of the nut as it loosens.

while it is being vibrated, and depending on the test conditions, you can actually watch the nut as it loosens," adds Schiff.

Figure 10 shows a time lapse sequence of photos of the nut as it loosens, as can be seen by the red marker on the nut moving around from the red marker on the adaptor. The test is complete when the maximum number of cycles set during test set-up has been reached, or if the bolted joint loses its preload and fails completely.

Interpreting the Results

As the test progresses, software on the J100's tablet computer displays the loosening curve in real time, so the loss of preload caused by the transverse loading can be clearly seen. **Figure 11** shows the loosening curve for the fastener tested as part of this demonstration.

There was no locking element, so within just a few load cycles (vibrations), the preload had dropped to 11 kN, where it stabilized briefly before falling to less than 3 kN after 78 cycles. This is equal to approximately six seconds, which shows how quickly a fastener can fail under transverse loading with no locking mechanism. This screenshot in **Figure 11** also shows how the operator sets the parameters, such as the preload, frequency and duration, onscreen before the test begins.

Fig. 11 — Loosening curve for fastener without locking element.

"The ability to plug the test parameters into the software and have it run the same test again and again is perfect for standards such as *DIN 25201*, which require 'reproducibility' over reference tests and 12 subsequent verification tests," notes Schiff. "Using the J100, the results of the reference and verification tests can be displayed on the screen simultaneously."

Figure 12 shows the results of multiple vibration tests performed on bolted joints, this time with different types of locking mechanisms that have distinctive loosening curves. It is possible to compare and contrast the loosening curves of different fasteners and of different locking mechanisms.

This technology is an invaluable tool for fastener manufacturers testing the effectiveness of their locking element against competing products. Additionally, it is a powerful development tool for Design Engineers in downstream

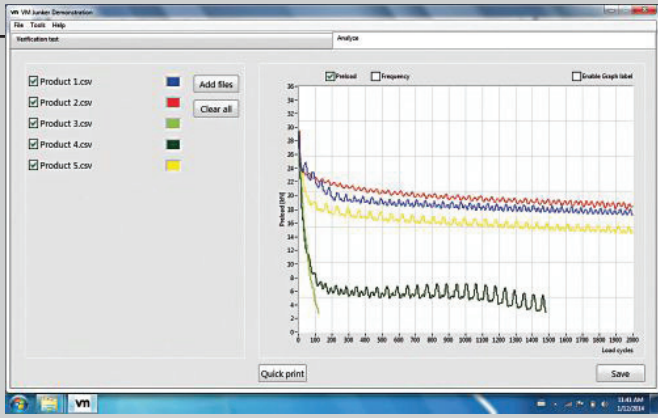


Fig. 12 — Comparing multiple fastener tests simultaneously.

OEMs when evaluating different fastener and locking mechanism products.

To learn more, visit: ***www.vibrationmaster.com*** **FTI**

References:

[1] DIN 65151: 2002-08 Dynamic testing of the locking characteristics of fasteners under transverse loading conditions (vibration test), Deutsches Institut für Normung cV, Berlin 2002.

[2] DIN 25201-4: 2010-03 Annex B Test specification for demonstrating the resistance to self-loosening of secured bolted joints, Deutsches Institut für Normung cV, Berlin 2010.

[3] ISO/DIS 16130 Dynamic testing of the locking behaviour of bolted connections under transverse loading conditions (vibration test), International Standards Organization, Geneva 2013 [DRAFT].

About Vibrationmaster...

Vibrationmaster designs and manufactures advanced testing technology and delivers specialized test services. Our products include Junker Test machines to analyze and demonstrate the self-loosening behavior of fasteners and bolted joints to *DIN 65151* and the new *DIN 25201*. We also perform contract testing to assist our customers with product development and certification. With a head office, R&D function and advanced manufacturing facilities in Luxembourg, we operate globally. Our customers span the commercial, academic, research, public, government and not-for-profit sectors. We offer highly reliable test solutions to organizations seeking innovative, market-proven and cost-effective technology to test and prove the reliability, consistency and safety of their products. ***www.vibrationmaster.com***