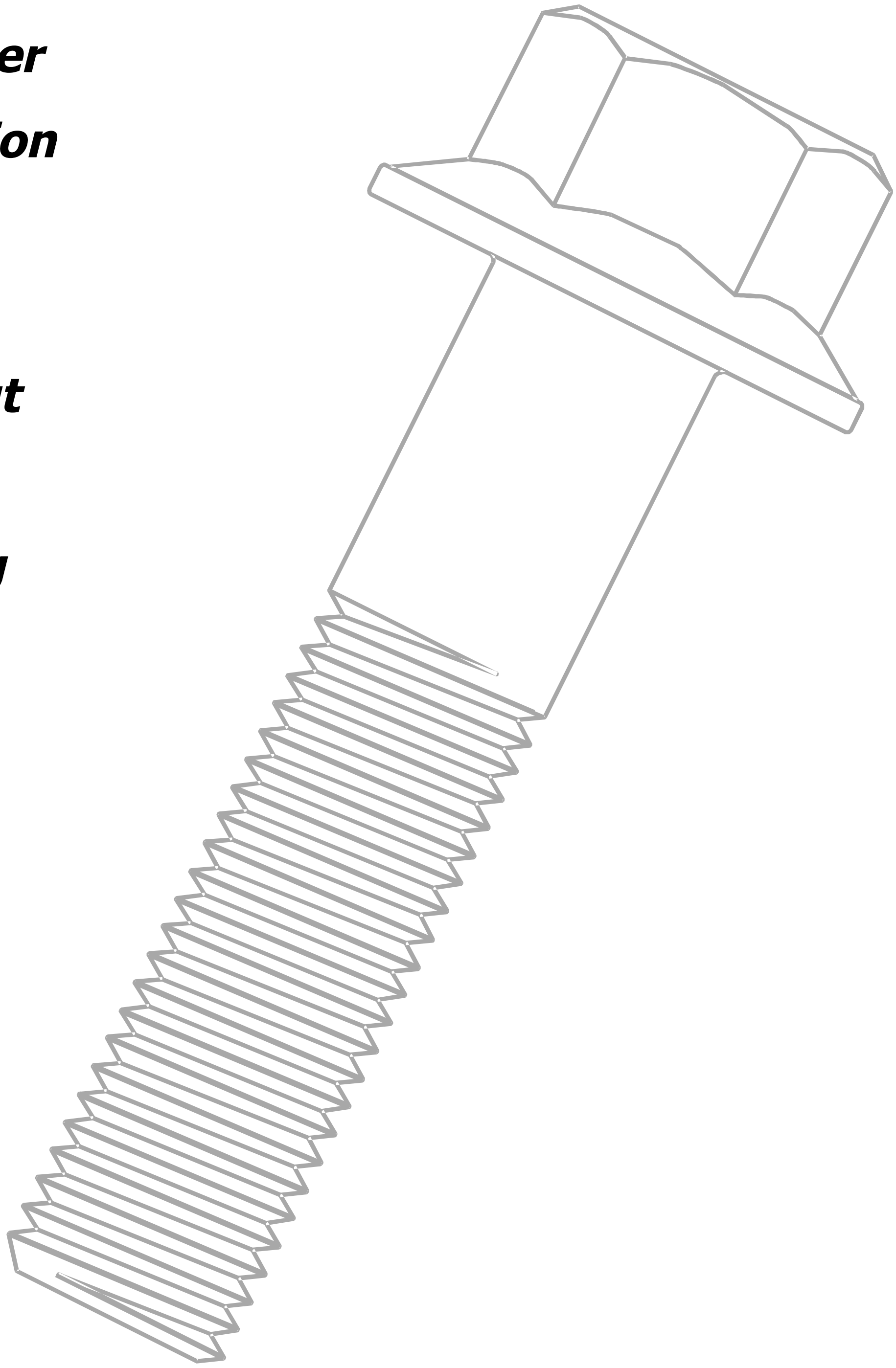
Report on Junker Fastener Vibration Tests on the Under Hole Nut and the PLB Fastening System



Report completed for:
T.H.I. Sarl

Report completed by:
William Eccles PhD
Bolt Science Limited
(www.boltscience.com)
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BOLT SCIENCE

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Abstract and Introduction

It was requested that a series of Junker transverse vibration tests be performed on M8 Under Hole Nuts[1] and M10 PLB[2] fasteners. The Under Hole Nut is made from a non-metallic material shaped like a wing nut. The PLB (Perfect Lock Bolt) is locked by tightening two nuts. The first nut, referred to as the power nut, has a course thread (1.5 mm) and provides the clamping force. The second nut, referred to as the lock nut, has a pitch (0.75 mm) which is half that of the power nut and provides a locking function. The bolt that is used in conjunction with the two nuts has threads of both pitches formed into it.

The Junker test assesses the loosening characteristics of fasteners. Junker published his research in the late 1960's [1][3] which showed that plain non-locking fasteners will self-loosen when subjected to transverse vibration. The machine used is based upon his findings (and that of later researchers) on the causes of self-loosening of threaded fasteners. The DIN 65151 standard [2] provides a definition of the key features of this test. The target number of test cycles was 1000, (the fastener preload will usually have stabilised after this number of cycles or the fastener will have come loose).

Self-loosening is when the fastener self rotates under the action of external loading. Non-rotational loosening is when no relative movement occurs between the internal and external threads but a preload loss occurs. A significant amount of non-rotational loosening occurred in these tests. The likely cause of this preload loss is embedding loss. The short screw grip length results in a small extension to the screw when tightened. In such circumstances, embedding loss will cause a larger preload reduction than is the case with a fastener with a large grip length. Embedding is localised plastic deformation that occurs under the nut face, in the joint faces and in the threads as a result of plastic flattening of the surface roughness.

The preload that can be achieved by hand tightening the Under Hole Nut was relatively small (typically 3 kN). In no instance during any of the 10 tests was rotation of the Under Hole Nut noted. At the end of 1000 cycles the retained preload was between 0.3 kN and 0.8 kN. A test was completed using a plain nut to allow a comparison to be made with the Under Hole Nut. In this test the plain nut came completely loose in 110 test cycles.

In no instance was any rotation of either of the PLB nuts noted during the 10 tests completed. The tightening procedure adopted resulted in a preload of typically 12 kN. The retained preload was between 4.7 kN and 6.3 kN at the end of 1000 test cycles, the majority of the loss occurring as a result of embedding immediately at the start of the test. A test was also completed using just the power nut without the lock nut attached to allow a comparison to be made with the PLB. The nut came completely loose in 400 test cycles indicating that without the lock nut, self-loosening of the main nut would occur.

[1] Under Hole Nuts are made by Aoyama Metal Industry Co. Ltd. of Japan
[2] The Perfect Lock Bolt is made by Nissei of Japan.
[3] See bibliography at the end of the report.

Test Arrangement

A diagram of the test arrangement is shown in Figure 1. The test machine consists of a fixed lower base and an upper moving section separated from the lower base by needle roller bearings. The bearings are used to eliminate friction between the two parts of the machine so that any transverse loading is sustained solely by the test fastener that secures the two sections together. A load cell is fitted in the lower base to allow the fastener preload to be monitored continuously during the test. The output from the load cell is fed, via a load cell transmitter, into an analogue to digital converter that is subsequently connected to a computer. The computer logs the preload values continuously during the test allowing graphs of preload versus number of cycles to be produced. Such graphs are often referred to as preload decay curves.

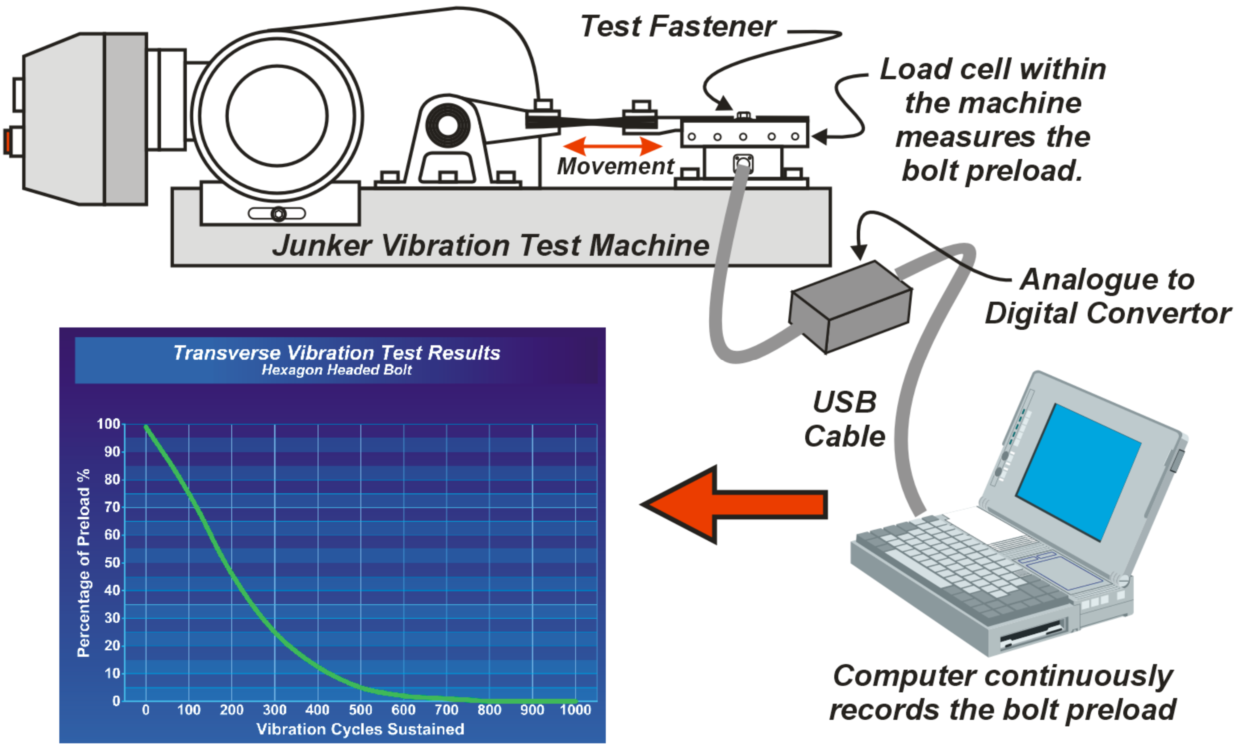

Figure 1 – Test Arrangement

The test machine produces a relative movement between the upper and lower section (cross movement) of ± 0.65 mm. The test frequency was 12.5 Hz. The duration of the test can be varied but typically a test of 1000 cycles duration is used.

Figure 2 shows the Under Hole Nut being tested and figure 3, the PLB.

Figure 2 – Under Hole Nut being tested

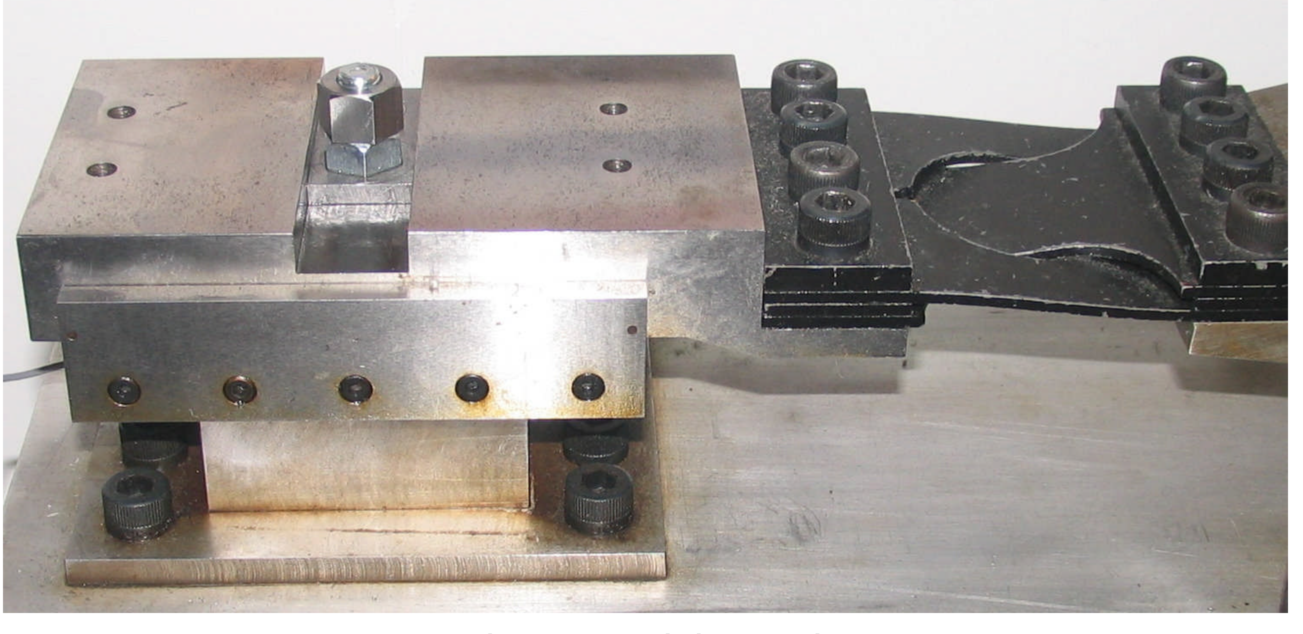

Figure 3 – PLB being tested

Test Results

Under Hole Nut

An M8 electro-zinc plated bolt was used with the Under Hole Nut. The nut was tightened by hand using the wings on the side of the nut. The maximum preload that could be achieved using hand tightening alone was typically 3 kN. Figures 4 and 5 shows graphs of the results. No rotation of the Under Hole Nut occurred in any of the tests. In total 10 tests were completed.

At the end of 1000 cycles the retained preload was between 0.3 kN and 0.8 kN.

A test was completed using a plain nut to allow a comparison to be made with the Under Hole Nut. The result for this test is shown in figure 8, the nut came completely loose in 110 test cycles.

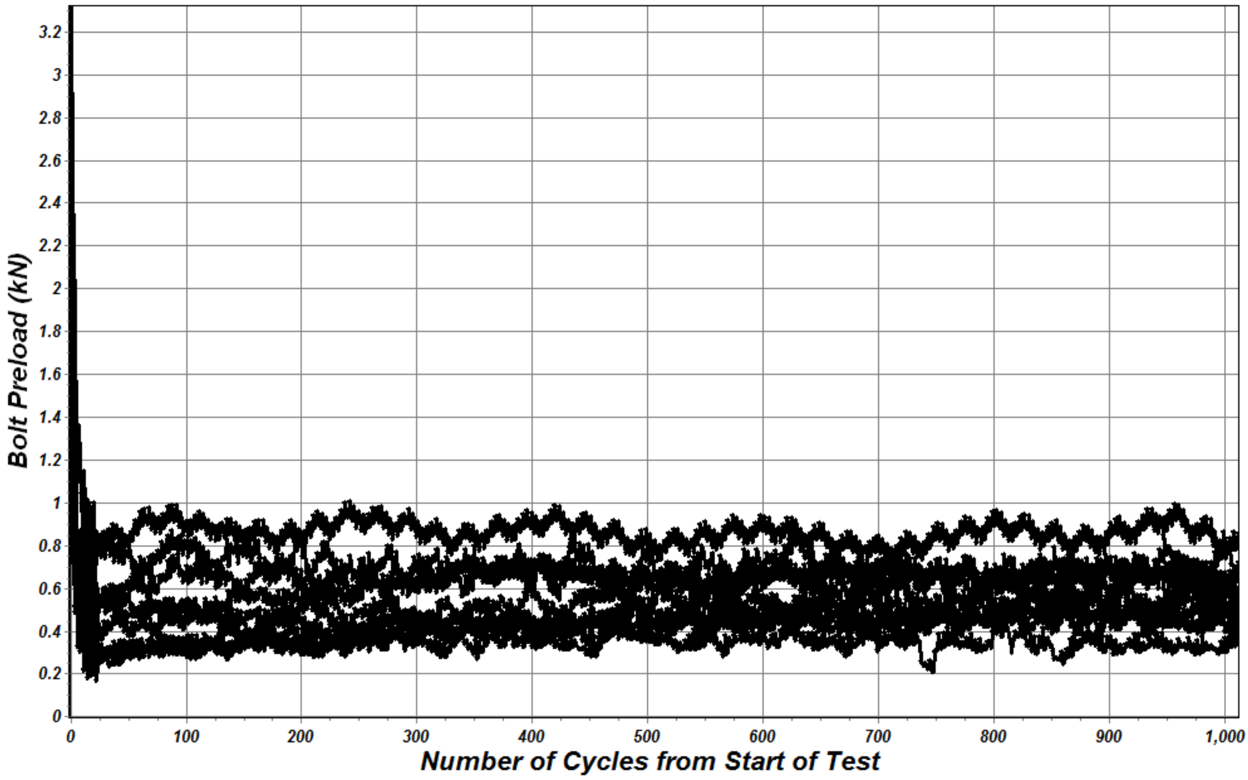

Figure 4 – Under Hole Nut - All Results

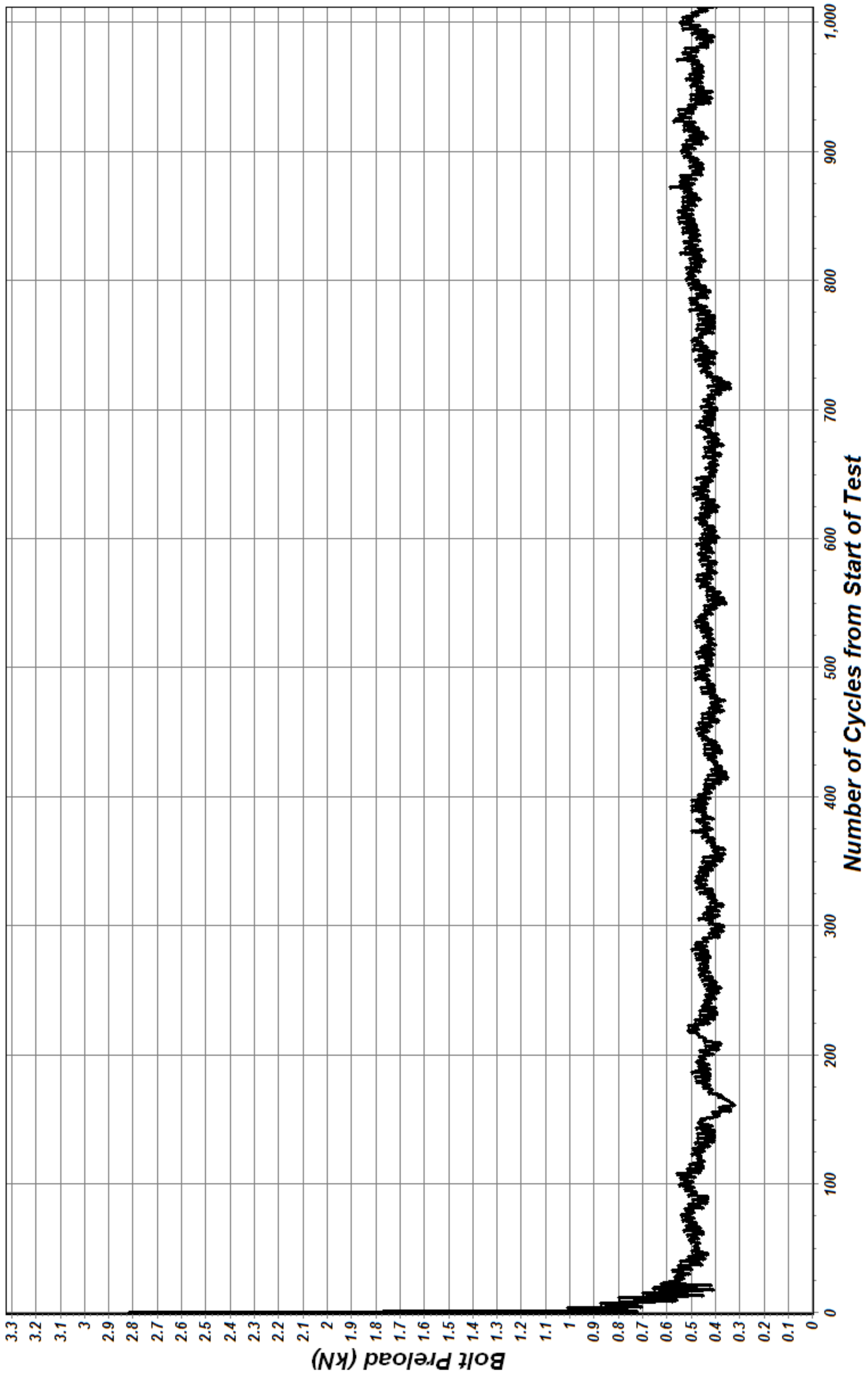

Figure 5 – Under Hole Nut - Typical Test Result

Perfect Lock Bolt (PLB)

The PLB bolt had the head marked indicating that it was property class 4.8. In total 10 tests were completed. The following procedure was used to tighten the PLB:

1. The M10 power nut was tightened onto the bolt so that a nominal preload of 16 kN was achieved.

2. The M10 lock nut was then tightened on top of the power nut using a tightening torque of 20 Nm.

3. The power nut was rotated in the loosening direction through an angle of approximately 20 degrees whilst holding the lock nut stationery using a spanner.

Some difficulty was experienced in applying this procedure due to the power nut seating on a plate that is recessed into the machine. In no instance was any rotation of either of the nuts noted during the tests.

The retained preload was between 4.7 kN and 6.3 kN at the end of 1000 test cycles.

A test was completed using just the power nut without the lock nut attached to allow a comparison to be made with the PLB. The result for this test is shown in figure 9, the nut came completely loose in 400 test cycles.

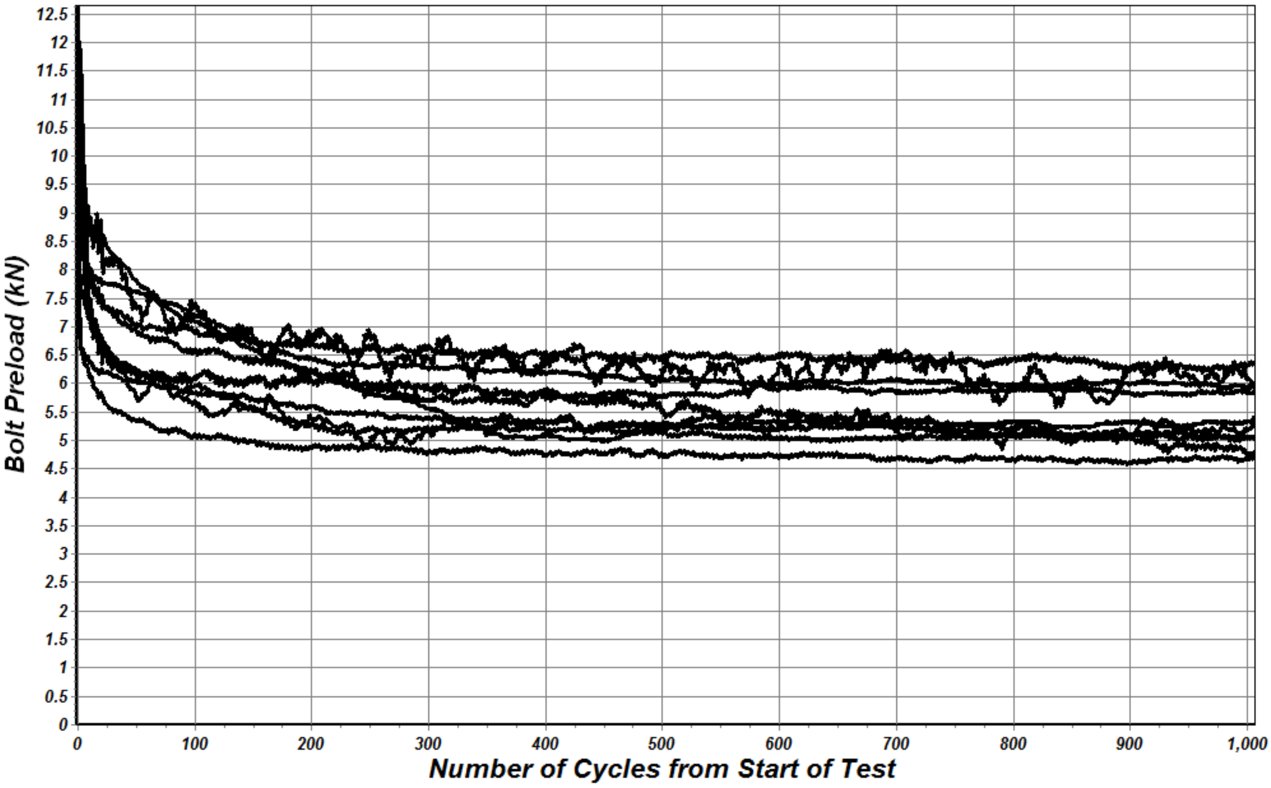

Figure 6 – PLB - All Results

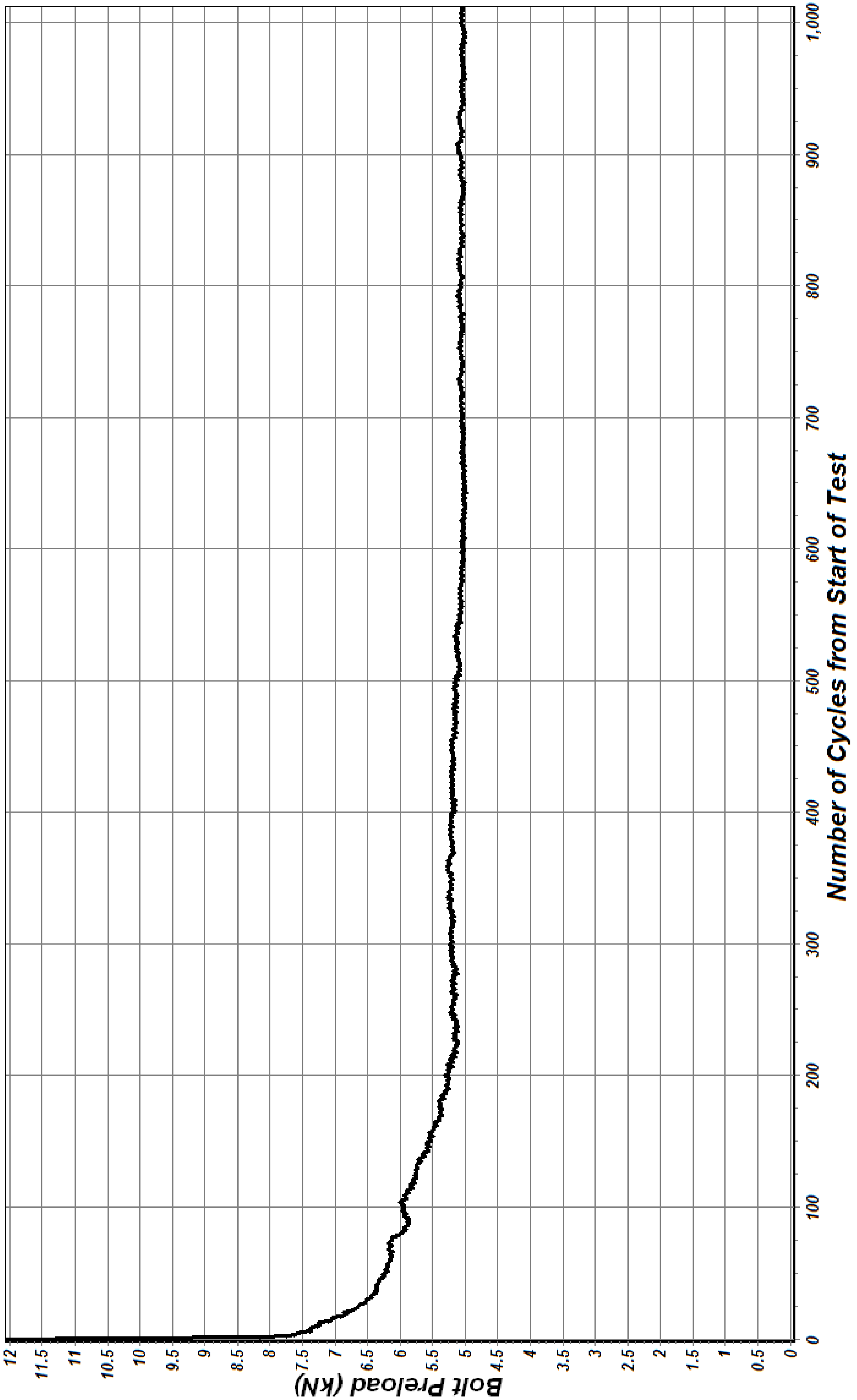

Figure 7 – Typical Test Result for the PLB

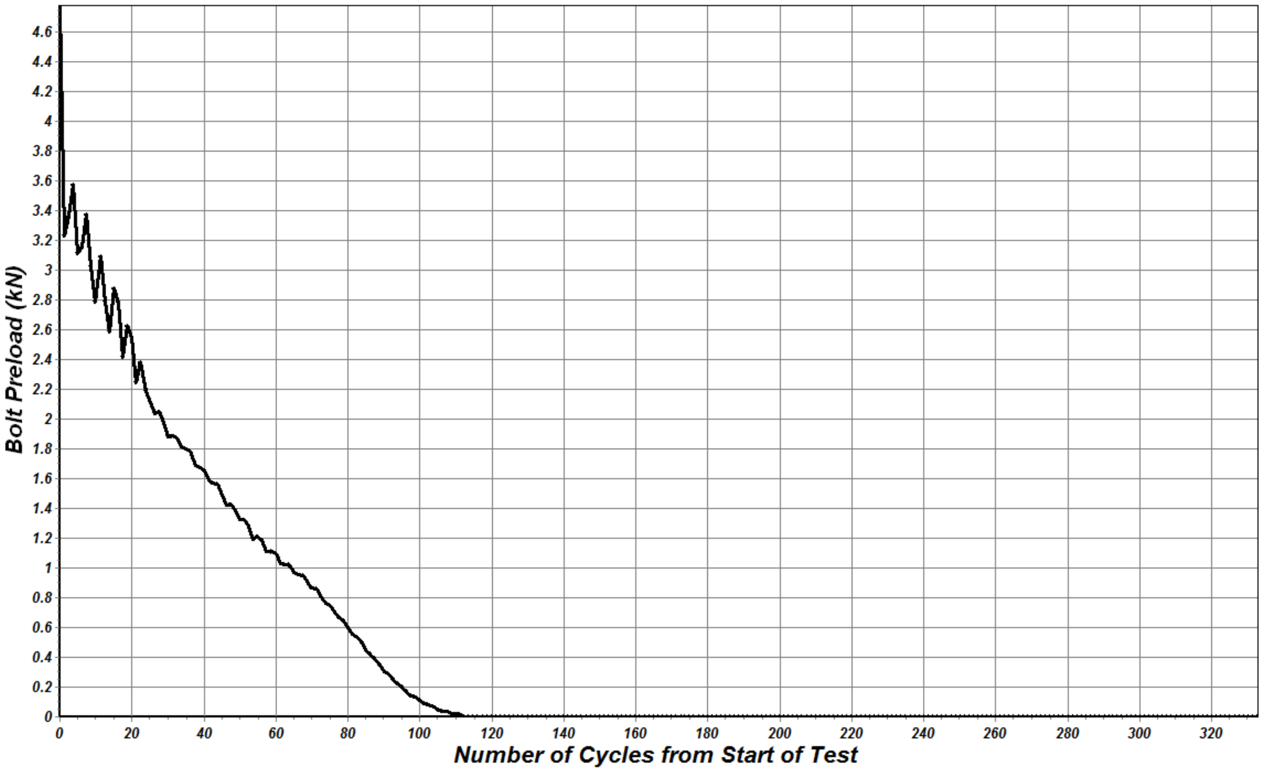

Figure 8 - M8 Plain Nut

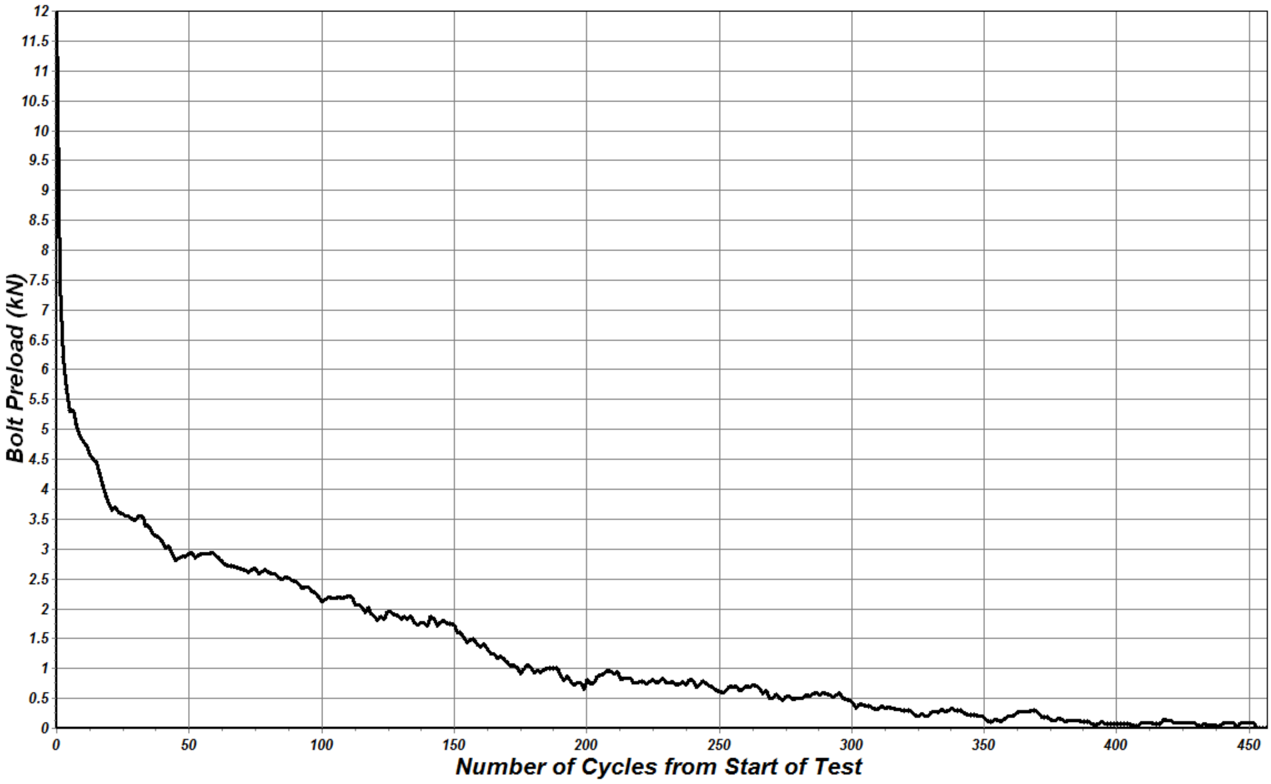

Figure 9 - M10 Power Nut without the Lock Nut

Conclusions

Self-loosening is when the fastener self rotates under the action of external loading. Non-rotational loosening is when no relative movement occurs between the internal and external threads but a preload loss occurs. A significant amount of non-rotational loosening occurred in these tests. The likely cause of this preload loss is embedding loss. The short grip length of the bolt used results in a small extension to the fastener when tightened. In such circumstances, embedding loss will cause a larger preload reduction than is the case with a fastener with a large grip length.

Embedding is localised plastic deformation that occurs under the nut face, in the joint faces and in the threads as a result of plastic flattening of the surface roughness. This occurs even when the loading is below the yield point of the bolt or limiting surface pressure of the joint material, and is the result of the real area of contact between surfaces being less than the apparent area. See [3] for a discussion on this topic. It is known that the majority of embedding losses arise when the working load is first applied to a joint, changing the contact pressures. Guideline values for embedding loss per interface for steel have been published [4]. Research into this phenomenon [5] indicates that, once tightening has stopped, approximately 80% of the embedding loss occurs on first loading by a static or dynamic service load while the remaining 20% is caused by further loading of the joint.

The preload that can be achieved by hand tightening the Under Hole Nut was relatively small which makes preload loss from embedding more significant. In no instance during any of the tests was rotation of the Under Hole Nut noted.

In no instance during any of the tests was rotation of the PLB noted. Tests completed on the power nut alone indicated that without the lock nut, self-loosening of the main nut would occur.

William Eccles CEng BSc PhD MIMechE
Bolt Science Limited

References

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