HILTI INSTALLATION SYSTEM PERFORMANCE UNDER VIBRATION LOADS

Abstract: Vibration is often a serious concern for design engineers when using a support system involving bolts, clamps or other removable fastening elements. Vibration can cause loosening of fasteners thus compromising structural integrity or it can become a source of noise pollution (due to rattling sound) thus affecting the serviceability of the facility. This paper addresses the vibration mechanism, its relevance to Hilti MQ support system, relevant tests conducted and their results and validity of the system's performance.

Introduction

One of the most common devices used for connecting different parts together is bolt or devices that work on concepts similar to bolts (threads and nuts). It is one of the most common parts of any modular system, where dimensional flexibility, short installation time and adjustable configuration are important key value propositions. Behavior of bolts and nuts under static tension and shear loading conditions is well known to the construction industry; however, knowledge of their performance under dynamic loads such as vibration is still limited. Many theories have been developed in an attempt to explain interaction between bolting components. However, it is still not adequate to predict bolt loosening phenomenon.

Testing Setup

Past studies and theories state that self-loosening phenomenon depends on several parameters including bolt size and its geometry, lubrication, hole tolerance, initial pre-load, nut locking device geometry and loading direction. In order to study MQ support system's response under vibration, it is recommended to conduct tests specifically on the system. This would eliminate geometrical differences and allows us to focus on reasonable number of other parameters. Five tests were conducted in this regard. Following parameters were selected for the tests.

1) **Geometrical configuration:** The Hilti channel systems (MQ support system) have specific characteristics that would affect the behavior when tested for vibration. Hilti MQ support system uses a special fastener, referred as "MQN Push Button" or simply "Push Button", which consists of a bolt and a special nut with teeth introduced on the surface adjacent to the surface of the channels. Another set of teeth is also introduced on the channels. Hence the two sets of teeth interlock with each other and create resistance by direct compression between faces of the teeth rather than relying only on friction and clamping force. Hence the testing configuration resembles very closely with actual Hilti system configuration (See Figs. 1 and 2).
2) **Loading Direction:** Application of reciprocating load along the transverse direction (perpendicular to the bolt axis) has the most critical impact on bolt loosening mechanism as described by Jiang et. al [1]. Out of two possible transverse directions, load along the length of the channel is considered more critical as the movement along the other direction (perpendicular to the channel) will be restrained by channel walls. Thus, the proposed loading direction is used for the test to understand response under worst case scenario.
3) **Loading Magnitude:** Amplitude of 0.5 mm was selected for the reciprocating load. Amplitude of the loading mechanism was fixed during the test as was also done in experiments conducted by past researchers (Jiang et al [1], Jiang et al [2] and Jenkins et al [3]). This corresponds to the shear load of more than 5kN which is the recommended maximum shear load for MQN push button as per Hilti publications.
4) **Loading Cycles:** The target number of cycles for the test was 50,000 cycles. This is derived from literature (Jiang et al [1] where self loosening phenomenon is compared to fatigue. According to the study conducted by Jiang et. al. [1], It was also found that once the system goes through several thousand cycles it becomes stable and no failure can be observed if the load is low enough.
5) **Loading Frequency:** A frequency of 12 Hz was selected for the test.
6) **Tightening Torque:** Recommended tightening torque as per Hilti publications is 40 m-N. The tests were conducted using the same value. However, one of the tests used half the value, i.e. 20 m-N, to observe its impact on the behavior of the system.

The applied transverse load corresponds to constant amplitude of 0.5 mm and the rotation between the two parts was measured at different number of cycles along the test.

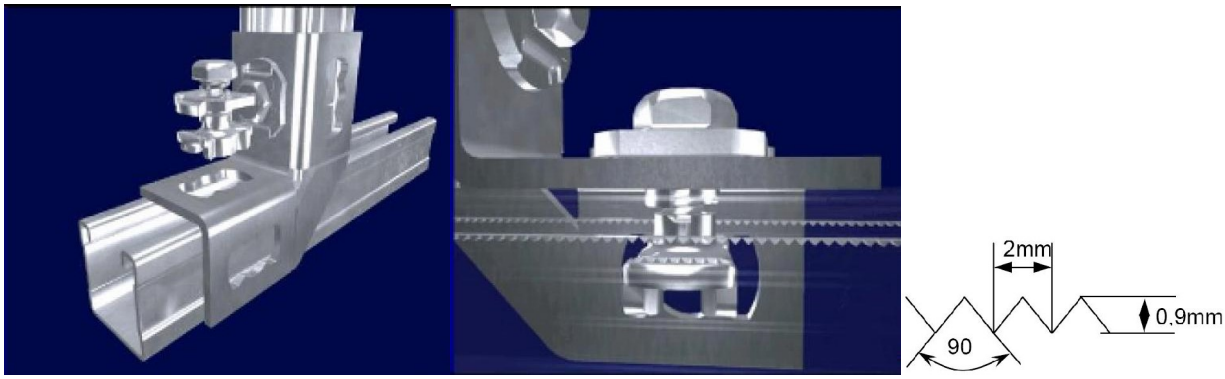

Fig. 1: Typical geometry of Hilti MQ support system connection.

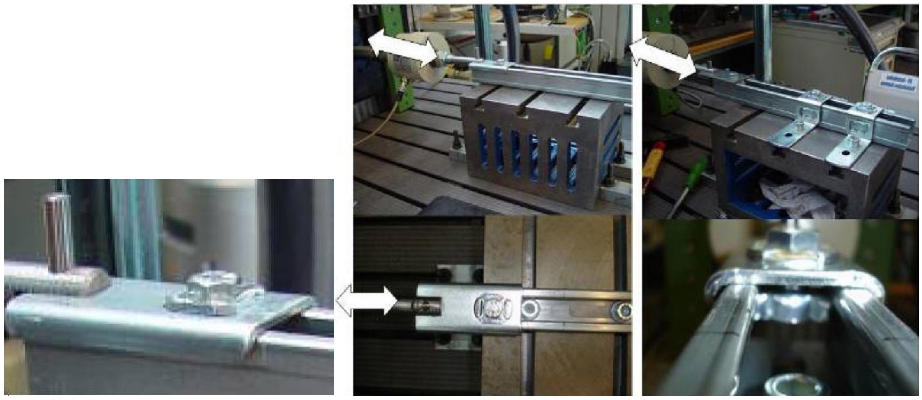

Fig. 2: Test set up to simulate vibration in a typical Hilti MQ support system connection.

Test Results

Table below shows the summary of the test results.

	Torque (m-N)	Bolt Rotation		Load (kN) at number of cycles to generate 0.5mm amplitude						Residual Static Failure load in shear (kN)
		10'000 cycles	50'000 cycles	2'000	6'000	10'000	20'000	40'000	50'000	
Test 1	40	25º	25º	5.8	5.8	5.8	2.3	2.3	2.3	14.0
Test 2	40	20º	20º	8.7	6.0	5.5	5.4	4.2	3.7	14.16
Test 3	40	55º	55º	9.1	2.8	2.8	2.6	2.3	1.9	13.84
Test 4	20	12º	12º	3.8	3.3	3.0	1.8	1.0	0.7	14.48
Test 5	40	0º	0º	5.5	5.0	4.6	4.3	3.3	3.2	N/A*

* Specimen 5 was not tested under static shear load.

Fig. 3 shows the load corresponding to 0.5 mm amplitude at different number of cycles. Fig. 4 shows the surface of push button and connector after passing through 50'000 cycles.

From the results, it is observed that:

- The load corresponds to constant amplitude dropped due to initial settling down between the two sets of teeth on push button and connecting piece. However, the after initial settlement, the system remained stable until end of the test, as expected according to Jiang et. al. [1].

- The failure load capacity under static load after going through the vibration test is within the range of 14 kN which is same as failure load of virgin push button. This implies that vibration loads upto 50'000 cycles doesn't have any impact on the failure load.

- Lesser torque on push button in test 4 shows lesser clamping force but no reduction in ultimate shear load capacity after the test is completed. The system was stable until the end of the test.

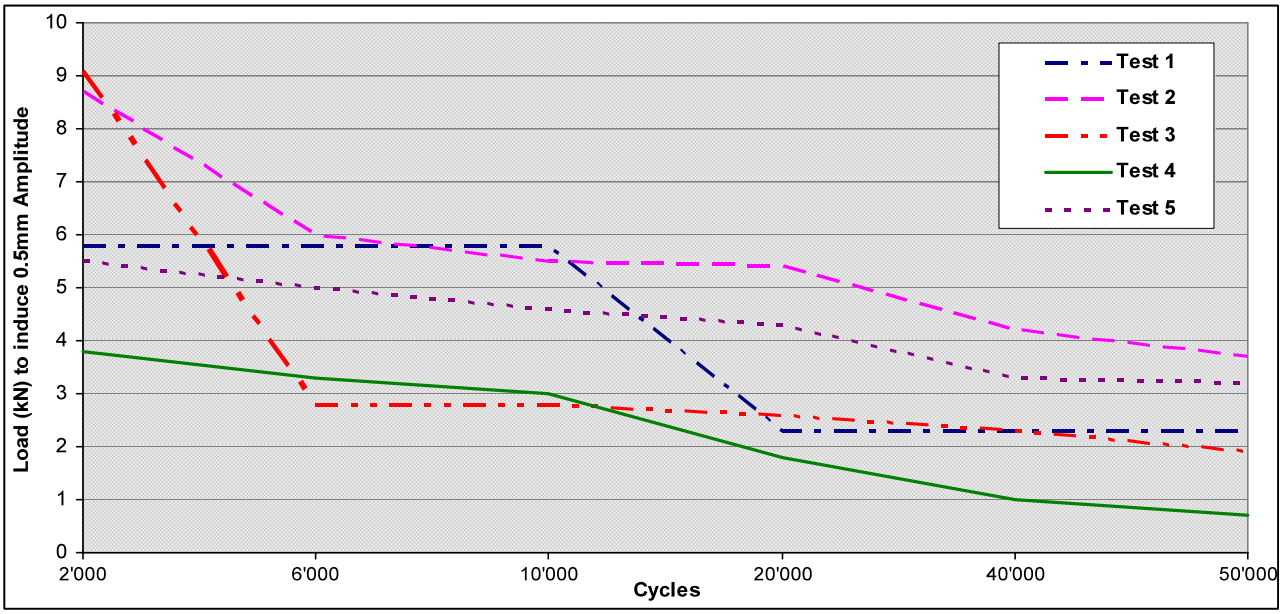

Fig. 3: Graph showing the loads required to produce 0.5 mm amplitude as number of cycles increases.

Fig. 4: Condition of push button and connection after 50’000 cycles.

Conclusion

Push buttons rely on geometrical interlocking to resist shear loads. However, there is some friction between the teeth which causes initial loads of upto 9 kN. With experiencing more cycles, the friction eases up and teeth are well settled in their respective grooves. The initial resistance due to friction depends on tightening torque. Only settling effects (mostly due to geometric tolerances on teeth, and butterfly hole) lead to slight rotation of the bolt shortly after starting the test. The situation becomes stable after a few thousand cycles. Nonetheless, the actual resistance against shear loads comes from interlocking which is not compromised due to vibration. The criterion for the functionality of the pushbutton is the residual shear load which was compared to non-tested (virgin) pushbuttons. These tests showed no reduction in the shear failure load.

References

1. *Ming Zhang and Yanyao Jiang,* “An Experimental Investigation of the Effects of Clamped Length and loading Direction on Self-Loosening of Bolted Joints“, Journal of pressure vessel technology, vol. 128, Aug 2006, pp. 388-393.
2. *Ming Zhang and Yanyao Jiang,* “An Experimental Study of Self-Loosening of Bolted Joints”, Journal of mechanical design, vol. 126, September 2004, pp. 925-931.
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