On the Anti-Loosening Property of Different Fasteners

S. Saha[1], S. Srimani[1], S. Hajra[1], A. Bhattacharya[2], and Santanu Das[1*]
[1] Department of Mechanical Engineering, Kalyani Government Engineering College, Kalyani, India
[2] Department of Mechanical Engineering, Thapar University, Patiala, India

[*] Corresponding author (email: sdas_me@rediffmail.com)

Abstract

Threaded fasteners are widely used for joining different mechanical parts temporarily due to its distinct advantages. However, screw threads have the problem of loosening under hostile vibrating conditions, which leads to decreasing of clamping force and finally failure of the system. To study the anti-loosening phenomenon of the threaded fasteners, a testing rig has been designed and fabricated where the clamping force can be continuously recorded under the application of accelerated known frequency vibration between two plates of nuts and bolt. In the present paper, the results obtained on the anti-loosening property of a number of threaded fasteners are presented, discussed and the effective one is found out.

Keywords: Threaded fasteners, loosening, anti-loosening characteristics, vibratory system, accelerated test.

1 Introduction

Threaded fasteners facilitate some machine parts such that they can be readily assembled or disassembled without making any damage to either of the components. This is needed for the purpose of clamping, setting up, servicing, inspection, overhauling, etc. However, under hostile vibration condition, threaded fasteners often fail to retain the tightening torque, thereby causing its loosening [1][2][3][4][5].

History of evolution of screw fasteners dates back to few thousand years ago. It is learnt [6] that screw fasteners were used in the Tigris–Euphrates region in around 1,000 B.C., mainly, for the purpose of water supply. The plate shaped cross-section of the screw thread was then used. The People of Greece were also supposed to use screws to press olives. The application of screws followed was its use as a feeder. Leonardo da Vinci is credited for creating and sketching different ideas leading to implementation of important usage of screw threads. During that time, square profile screw threads was used [7].

Drastic change followed in its shape of square to triangular thread increasing the reliability of screw threads. Wide ranges of screw fasteners were developed and used in various applications. The advantages realized by the use of threaded fasteners are easy to assemble and disassemble, cheap, widely available, ability to generate very high fastening torque and force by very simple means and its retention for quite a very long time. However, hostile vibration conditions tends to cause loosening of screwed fasteners [1][4][5][8][9][10]. This is a major drawback of screw fasteners. Loosening of the fasteners occur mainly when repetitive forces are applied in a plane perpendicular to the longitudinal axis of the bolt [6][9]. This needs attention to maintain the fastened components to prevent extensive damage to the assembled parts and impending fatal accidents.

To prevent loosening, and its consequent problems, various types of screw fasteners were introduced. Junker [3] tested cap screws, spring washers and free spinning locking screws with respect to its anti-loosening characteristics. Effectiveness of fine screw threads, spring washers, nylon inserted nuts, double nuts and eccentric nuts of few sizes to resist loosening were investigated [2][11]. Test results showed that those popularly known anti-loosening fasteners did not really possess enough resistance to loosening. Applications of adhesives in a fastener can also offer [12] anti-loosening effect in certain applications. However, unscrewing for disassembly often poises problems in this case.

Sase et al [5][10][11] developed a new thread profile of step lock bolt (SLB) to eliminate bolt torsion . This has steps on the helix, hence the name step lock bolt (SLB). The stepped part is of zero lead angle, and the portion with lead angle is the inclined portion. The clamping force is supported by the step part, which, in the conventional threads, has a tendency to push out the nut along the flank angle when friction is overcome. Due to its ability to prevent torsion by itself, a SLB does not loosen even though the bottom surface of the bolt and nut slips.

The anti-loosening property of spiralock internal thread form system [13] is simple and is discussed in spiralock webpage, which uses a typically designed 30^0 wedge ramp. This ramp portion clamps and locks any standard bolt by drawing crests of the bolt thread tightly against the wedge ramp, thereby preventing transverse movement of the bolt thread with respect to the nut. “Wedge locking” of this threaded joint is caused by the increase in contact friction between the materials due to enhanced surface area and total elimination of the transverse motion.

Provision for free spinning systems, metallic friction locking by distorted threads like ‘cleveloc’ and chemical locking of fasteners using adhesives can also offer [12] anti-loosening effect in certain applications. A taper-headed nut has also been proposed by Mondal et al [14].

The present paper contains a report of works aimed at testing the loosening characteristics of several threaded fasteners such as nyloc nut, with serrated washer, standard BSW and metric fasteners, etc., and recommending the scope of developing an anti-loosening threaded fastener in future.

2 Mechanism of Loosening and Desired Anti-Loosening Characteristics

Studying on the loosening mechanism of screwed fasteners revealed that the relative sliding rotation between nut, bolt and components joined is the main reason for loosening [8][9][11][12].

i) The cause for the sliding and consequent loosening is explained by the fact that the lateral displacement of fastened element makes the bolt inclined, and hence increases the tensile stress coming on to the bolt.
ii) Increase of this tensile stress over a limit initiates slip at the engaged flank surface of the screw thread.
iii) The slip takes place not only in the direction of the flank but also in the direction of the axis of the screw thread due to the presence of lead angle.
iv) Differential thermal effects of clamped materials and fasteners may also induce loosening effect.

From the above discussion, it may be summarized that loosening can be minimized [6] if,

i) Lead angle is reduced
ii) Flank angle is made as small as possible
iii) Relative slips between the bearing surface of fasteners and fastened components are reduced by increasing the friction force.

3 Testing for Anti-Loosening Performance

3.1 Details of Experimentation

A loosening test rig has been designed and constructed for performance testing of anti-loosening threaded fasteners as detailed in reference numbers [14][15] published by the corresponding author of this paper and schematically shown in Fig.(1). In this set up, a rocker arm reciprocates, and once in a revolution, it strikes the plate, which is clamped by the nut-bolt assembly. Loosening of the fastener can be detected by the drop in the clamping force, measured by a load cell (model- SLC 302, Sushma make) and a digital indicator.

The end of the rocker arm strikes the clamped plate 280 times a minute generating vibration in a plane perpendicular to the bolt axis for accelerated testing. The testing is carried out for about 9,000 to 11,000 oscillations. Same amount of repeated forces are applied through the mechanism employed, but the magnitude of this force has not been measured.

Two series of experiments have been conducted with applying two different initial clamping forces. For the first case, an initial torque of 1.50 tonnes has been applied, whereas, for the second set of tests, 0.94 tonne of clamping force has been applied. For each test, three repetitions have been carried out for studying the repeatability of each result obtained.

Though a number of bolts and locking nuts, etc. are being investigated, lot of opportunities remains to be there to develop quite effective anti-loosening threaded fasteners with economical viability. With this idea, a number of tests are planned for different innovative threaded fasteners. In this respect, few tests have been conducted first on the existing screw fasteners, results of which are presented in this paper. Bolts, both BSW and metric, are commonly available in the market and made of plain carbon steel; corresponding nuts are also of the same material. However, nylon inserted nuts are made of stainless steel with a nylon ring inserted inside it.

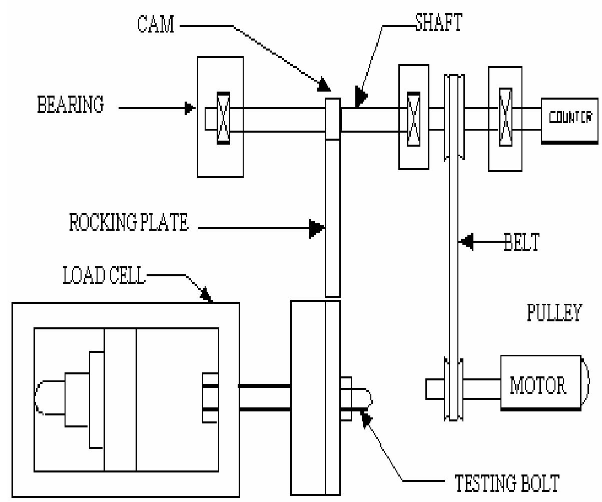

Figure 1: Schematic diagram of Testing Machine

Test results of the fasteners having nylon inserted nut, and fasteners with serrated washers are presented. These results are compared with the results obtained from the tests on standard metric and BSW threaded fasteners. Interesting results obtained from using a metric (M10) bolt fitted with a BSW (3/8") nut are also presented.

3.2 Results and Discussion

From the test results shown in Fig.(2), comparison of the relative effects of loosening in a conventional fastener, fasteners using a nylon-inserted nut, a simple washer and a spring washer are studied keeping the clamping force applied of about 1.50 tonnes. The decrease in the clamping force with the progress in the number of oscillations are shown in Fig.(2). Due to experimental difficulties, tests with 5/8 BSW nylock nut and with M16 inside serrated washer could not be continued more than 1400 and 2100 cycles respectively.

Standard fasteners, such as metric M16 and BSW-5/8, exhibit considerably higher loosening tendency than the others. Again, BSW-5/8 fastener shows slower rate of loosening than the M16 metric one. This may be due to lesser flank angle (55 degree) of the BSW thread than that of the metric thread (60 degree). Nylon-inserted nuts are seen to have higher capability to retain clamping force and hence, clamping torque than the standard fasteners and with both inside and outside serrated washers.

In the case of outside serrated washer, small increase in clamping force is also observed which may be due to some amount of plastic deformation happening during the test causing locking effect. Mark of deformation is also seen on the fastened components. Some of these results are, to some extent, in line with the earlier results obtained by Junker [3] and Sase et al [5][10][11]. While nylon-inserted nuts provide extra frictional gripping, washers provide large preloads to improve anti-loosening characteristics.

Results of another set of tests are shown in Fig.(3). Testing for loosening for M10 bolt with 3/8" BSW nut, fitted with around 0.94 tonne clamping force, along with nylon-inserted nut, M10 nut-bolt set with or without spring washer are presented. In the case of metric bolt with BSW nut, small difference in pitch and nominal diameter become responsible for providing extra contact force on the flank portion of the nut and bolt. This, in turn, causes hike in friction force, thereby resulting in good resistance against loosening under vibration compared to other types of fasteners tested. However, in practice, this may not be used as this may damage the fastener preventing its repetitive use.

In this case also the nylock nut shows higher resistance to loosening than the standard M10 metric fastener and that with spring washer in line with the earlier results obtained through 1.50 tonnes of initial clamping force. However, it is seen from Fig.(3) that the Standard M10 fastener loosens at a faster rate than the M10 nut-bolt with spring washer, showing little effect of using the spring washer. Hence, the popular belief of obtaining good loosening resistance of spring washer is observed not to be very much effective one. Therefore, use the step lock bolt and an organic adhesive may be fruitful to provide desired resistance to loosening.

4 Conclusion

The following conclusions may be drawn from the above results and discussion.

1. The nylon inserted nuts, imparting higher frictional grip, when fitted with a standard metric bolt shows good resistance to loosening compared to the other fasteners tested at both the initial clamping forces of 1.50 tonnes and 0.94 tonnes respectively.
2. The M10 bolt fitted 3/8" BSW nut which have narrow difference in nominal diameter and pitch value exhibits considerable anti-loosening property. High frictional force caused by high contact load between threaded flanks of the nut and bolt may be the reason behind. However, some amount of permanent deformation may damage the nut-bolt mating surfaces.
3. The conventional BSW fasteners have shown lesser tendency to loosen than the metric nut and bolt which may be due to lesser flank angle.
4. Other types of fasteners such as with inside and outside serrated washers have been observed to show small amount of loosening under vibrating condition.

Acknowledgement

The authors acknowledge the AICTE, New Delhi for the financial support for this project vide the sanction Ref. 8018/RDII/BOR/R&D(244)/99-2000 Dt. 24/3/2000.

References

[1] J. N. Goodier and R. J. Sweency, “Loosening by vibration of threaded fastenings”, Mechanical Engineering, Vol.12, 1945, p.798.

[2] K. Hongo, “Loosening of Bolt and Nut Fastening”, Journal of Japan Society of Mechanical Engineering, Vol.30, No.215, 1964, pp.934-939.

[3] G. H. Junker, “New Criteria for Self Loosening of Fasteners under Vibration”, SAE International Automotive Engineering Congress, Paper No.- 690055, 1969, pp.314-335.

[4] K. Koga, “A discussion on screw-fasteners loosening caused by impacts”, Japan Society of Mechanical Engineering, Vol.35, No.273, 1969, pp.1104-1111.

[5] N. Sase, S. Koga, K. Nishioka and H. Fuji, “Analysis of Screw Fasteners Loosening and Development of Evaluation Methods”, Journal of the Japan Society of Mechanical Engineering, Vol.62, No.596, 1996, pp.1527–1532.

[6] H. Fuji and N. Sase, “SLB Concept for Screw fastening and its Anti-Loosening Performance”, Souvenir of the All India Manufacturing Technology, Design and Research Conference, Vol.18, 1998, pp.25-34.

[7] L. da Vinci, Cobex Madrid I Vol. I, U.K., McGraw Hill Book Company Limited. (Facsimile Ed.), 1974.

[8] D. B. Dallas, Tool and Manufacturing Engineers Hand Book, 3rd Ed., McGraw Hill Company, p.27, 1975.

[9] Y. Yamamoto and S. Kasei, “Investigations on the Self-loosening of threaded fasteners under transverse vibration”, Journal of Japan Society of Precision Engineering, 1996, p.507.

[10] N. Sase, S. Koga, K. Nishioka and H. Fuji, “Evaluation of Anti-Loosening Nuts for Screw Fasteners”, Journal of Materials and Processing Technology, Vol.56, 1996, pp.321–332.

[11] N. Sase, S. Koga, K. Nishioka and H. Fuji, “An Anti-Loosening Screw Fastener Innovation and Its Evaluation”, Journal of Materials and Processing Technology, Vol.77, 1998, pp.209–215.

[12] www.boltscience.com/pages/vibloose.htm, 2006.

[13] http://www. Spiralock.com, 2006.

[14] M. K. Mondal, N. K. Peyada, S. Patra, S. Pradhan, S. Banerjee and S. Das, “On the Anti-Loosening

Characteristics of Fasteners", 20th All India Manufacturing Technology, Design and Research Conference, 2002, pp.830-831.

[15] P. Sarkar, P. Mallick, A. Bhattacharya and S. Das, "Enhancing Anti-Loosening Characteristics of Threaded Fasteners- Need of Threaded Components under Vibratory Condition", Proceedings of the All India Seminar on Strategies and Techniques for Maintenance of Equipment and Machinery- Recent Trends, Kolkata, 2004, pp.II18-II22.

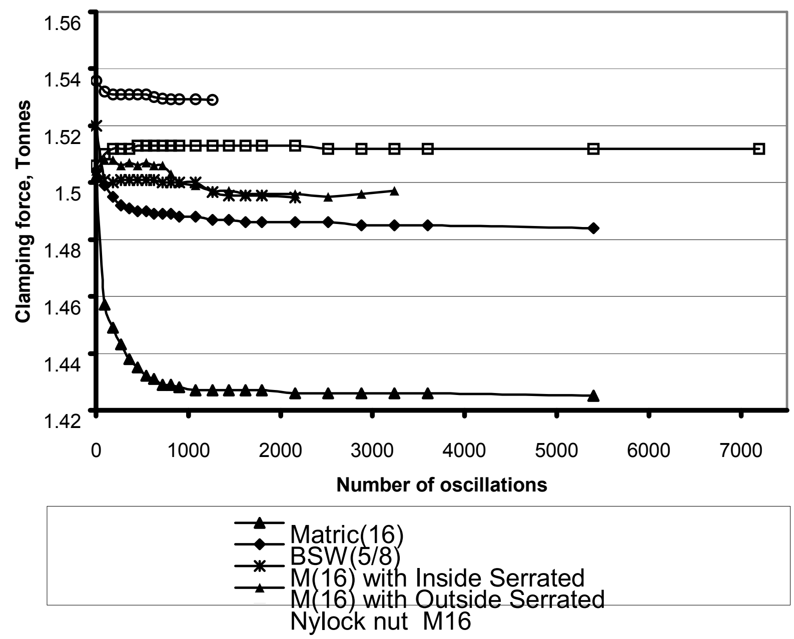

Figure 2: Loosening characteristics of fasteners with about 1.50 tonne clamping force

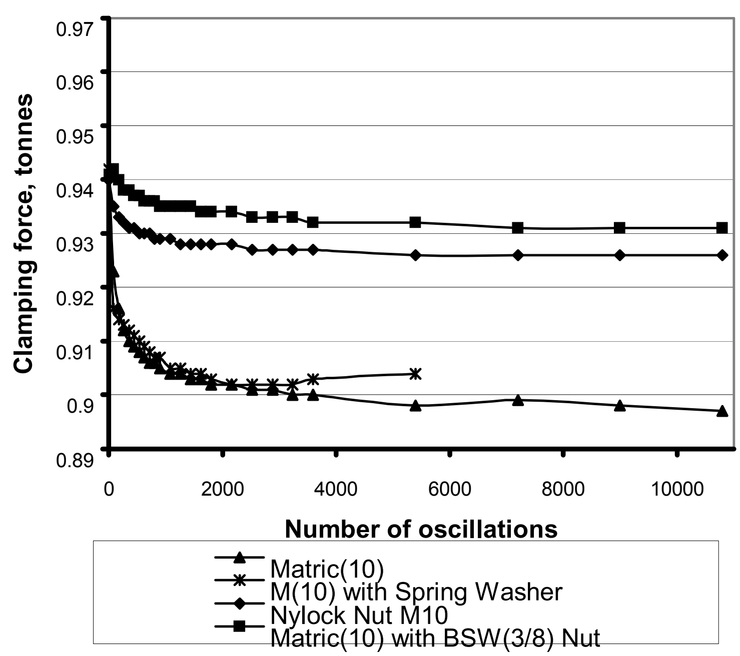

Figure 3: Loosening characteristics of fasteners with about 0.94 tonne clamping force