# Transverse Vibration Test Rig for Threaded Fasteners

**S.M.Aware**
Department of Mechanical Engineering, G.S.Moze College of Engineering, Pune, India.

**Abstract : The objective of this study is to Develop test rig for vibration loosening of bolts. Design and development of system components for interchangeability of different bolts. Test & Trial on test rig to develop the loosening characteristics of bolts and derive the decay graphs versus cycles. A bolted joint including bolts without washer only nut, bolts with plain washer and nut, bolts with spring washer and nut, bolts with Nyloc washer and nut was considered to carry out the experiments. The same experiment was carried out with Comparative analysis of decay characteristics of individual bots with various end condition and to predict vibration loosening using this study.**

**Keywords: transverse vibration loosening, torque, bolts, washers, nuts.**

## I. INTRODUCTION

**Gerhard H. Junker. Junker (1969** showed that preloaded fasteners self-loosen when relative movement occurs between the mating threads and the fastener bearing surface. **Finkelston (1972)** Tests were completed using a transverse test machine and a range of specific fastener characteristics &. locknuts with a prevailing torque to free spinning nuts . **Pearce (1973)** reports on tests conducted on a small range of fastener locking methods. **Haviland (1981)** showed that transverse joint movement and subsequent loosening can arise from other mechanisms besides direct shear loading. **Sakai (1978)** also made an important contribution in showing that there is an additional loosening torque, besides the torque resulting from the preload acting on the thread helix, due to the movement of the nut thread on the bolt thread. **Yamamoto and Kasei (1984)** established an equation for determining the transverse force required to cause slip on the nut face allowing for bolt bending. **Kerley (1987)** used a structured method, called reproduction, for the analysis and testing of the self-loosening of fasteners. **George C. MSFC, Alabama 35812 NAS8-39 13 1march 1995** Vibration testing was conducted on a shake table with a controlled-random input in the dynamic testing laboratory of the Structural Test Division of MSFC. a percentage of pre-load loss was measured. **Sase et al. (1996)** completed a study to evaluate the effectiveness of anti-loosening nuts. The apparatus they used for the investigation was an eccentric cam driven by a motor that forced oscillations to be applied to a beam that in turn resulted in produced forced transverse movement of the bolt and the nut. **Satoh et al. (1997)** completed some important work on the influence that paint can have on the self-loosening of fasteners. **Jenkintown, PA July 1998** Under the conditions of the subject test, there was a significant difference in the loss of clamp load between fasteners sets with and without DTIs. **Dong and Hess (1999)** used an inertial loaded compound cantilever beam apparatus, similar to that used earlier by **Kerley (1987),** to study the effect that thread dimensional conformance has on the vibrational loosening characteristics of fasteners. **Sase et al. (1998) and Sa e and Fujii (2001)** completed a series of studies into a modified thread form they called a Step Lock Bolt. **N.G. Pai, D.P. Hess (20 May 2001)** This paper presents results of a study on failure of threaded fasteners by vibration induced loosening caused due to dynamic shear loads. **Pai and Hess (2003)** also investigated the ideal location for fasteners in a structure to avoid the tendency for self-loosening. **Antonios et al. (2006)** investigated the ability of a washer made from shape memory alloy (SMA) to compensate for preload loss from loosening. After a certain amount of preload is lost a heater enveloping the washer is activated allowing an axial constrained recovery of the SMA and control of the bolt preload. **Hashimura (2007)** investigated the transition between loosening and fatigue of threaded fasteners when subjected to transverse vibration. **Takemasu and Miyahara (2005)** evaluated a unique product called a double thread bolt. Takemasu and Miyahara used the NASM test (National Aerospace Standard, 1997) to evaluate the design and found that it did not loosen..**Sawa et al. (2006)** evaluated a number of fastener locking devices for effectiveness at different preload levels and found that many were only partially effective. **S S Kadam ,S. G. Joshi(Jan 2010)** In this paper critical analysis using Taguchi method has been carried out for a typical totted joint to determine the factors influencing the resistance of the bolted joint against vibration loosening. **Umesh Dalal 1, Dr A.G.Thakur 2(Mar 2013)** In this paper, relationship between tightening torque and bolt preload and to verify the loosening characteristics of bolted joint under transverse vibration condition by experimental setup under the application of wrenching torque on. single bolt and Multiple Jack Bolt Nut was carried out on a test setup called as Junker's Transverse Vibration Machine.

## II. METHODOLOGY

Design and Development of test rig for vibration loosening of bolts then manufacturing and assembly of test rig .Design and development of system components for interchangeability of bolts namely ( M4 , M5 , M6 , &M8) Test & Trial on test rig to develop the loosening characteristics of bolts and derive the decay graphs versus cycles. Changing the end conditions of bolts i.e. by changing the washers

1. Bolts without washer.
2. Bolts with plain washer.
3. Bolts with spring washer.
4. Bolts with Nyloc washer + nut

Comparative analysis of decay characteristics of individual bots with various end condition and to predict vibration loosening using this study.

## III. Mathematical Formulation

Torque at spindle is given by;

$$P = \frac{2\pi N T}{60}$$

Where;

T= Torque at spindle (Nm)
P = POWER (Kw)
N = Speed (rpm)

$$T = \frac{\Pi \times fs_{act}}{16} \times \left( \frac{Do^4 - Di^4}{Do} \right)$$

Allowable shear stress;
$Fs_{all}$ is given stress;
$Fs_{all} = 0.30$ syt
$Fs_{all} = 0.18 \times$ Sult

$$T_{design} = \frac{\Pi}{16} fs_{all}\ d^3$$

$P = X F_r + Y F_a$
$L = \left(\frac{C}{P}\right)^p$, where p= 3 for ball bearings
$L = 60\ n\ L_H / 10^6$
$T = L \times b \times d/2 \times f\ b_{act}$

$Te = L \times t/2 \times d/2 \times f\ s_{act}$

**PROCEDURE:**

1) Place the bolt & nut in transverse slide.
2) Start motor. Motor rpm is fixed i.e. 1440 rpm
3) Give some torque to the bolt .note down that torque
4) Note down the time required to loosening the bolt.
5) By using torque, time & RPM calculate the no. of cycles.

6) Repeat the procedure for M4, M5, M6 &M8 bolt.
7) Also repeat the procedure by varying end conditions i.e.no washer, plain washer &spring washer.
8) To calculate no. of cycles formula used is,
   No. of cycles= motor rpm x time required = 1440 x Time

Table No 1 Observations for Bolt M5; End condition: No washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 11 | 15840 |
| 2. | 0.2 | 15 | 21600 |
| 3. | 0.3 | 19 | 27360 |
| 4. | 0.4 | 29 | 41760 |

Table No 2 Observations for Bolt M5; End condition: Plain washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 14 | 20160 |
| 2. | 0.2 | 19 | 27360 |
| 3. | 0.3 | 23 | 33120 |
| 4. | 0.4 | 32 | 46080 |

Table No 3 Observations for Bolt M5; End condition: Spring washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 17 | 24480 |
| 2. | 0.2 | 22 | 31680 |
| 3. | 0.3 | 27 | 38880 |
| 4. | 0.4 | 36 | 51840 |

Table No 4 Observations for Bolt M5; End condition: Nyloc washer + Nut

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 21 | 30240 |
| 2. | 0.2 | 27 | 38880 |
| 3. | 0.3 | 32 | 46080 |
| 4. | 0.4 | 42 | 60480 |

Table No 5 Observations for Bolt M4; End condition: No washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 8 | 11520 |
| 2. | 0.2 | 13 | 18720 |
| 3. | 0.3 | 18 | 25920 |
| 4. | 0.4 | 27 | 38880 |

Table No 6 Observations for Bolt M4; End condition: Plain washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 12 | 17280 |
| 2. | 0.2 | 17 | 24480 |
| 3. | 0.3 | 21 | 30240 |
| 4. | 0.4 | 29 | 41760 |

Table No 7 Observations for Bolt M4; End condition: Spring washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 14 | 20160 |
| 2. | 0.2 | 19 | 27360 |
| 3. | 0.3 | 24 | 34560 |
| 4. | 0.4 | 31 | 44640 |

Table No 8 Observations for Bolt M4; End condition: Nyloc washer + Nut

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 16 | 23040 |
| 2. | 0.2 | 21 | 30240 |
| 3. | 0.3 | 27 | 38880 |
| 4. | 0.4 | 34 | 48960 |

Table No 9 Observations for Bolt M6; End condition: No washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 14 | 20160 |
| 2. | 0.2 | 19 | 27360 |
| 3. | 0.3 | 23 | 33120 |
| 4. | 0.4 | 30 | 43200 |

Table No 10 Observations for Bolt M6; End condition: Plain washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 18 | 25920 |
| 2. | 0.2 | 22 | 31680 |
| 3. | 0.3 | 27 | 38880 |
| 4. | 0.4 | 34 | 48960 |

Table No 11 Observations for Bolt M6; End condition: Spring washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 20 | 28800 |
| 2. | 0.2 | 24 | 34560 |
| 3. | 0.3 | 29 | 41760 |
| 4. | 0.4 | 38 | 54720 |

Table No 12 Observations for Bolt M6; End condition: Nyloc washer + Nut

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 22 | 31680 |
| 2. | 0.2 | 27 | 38880 |
| 3. | 0.3 | 32 | 46080 |
| 4. | 0.4 | 41 | 59040 |

Table No 13 Observations for Bolt M8; End condition: No washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 19 | 27360 |
| 2. | 0.2 | 24 | 34560 |
| 3. | 0.3 | 29 | 41760 |
| 4. | 0.4 | 33 | 47520 |

Table No 14 Observations for Bolt M8; End condition: Plain washer

| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 23 | 33120 |
| 2. | 0.2 | 27 | 38880 |
| 3. | 0.3 | 32 | 46080 |
| 4. | 0.4 | 38 | 54720 |

Table No 15 Observations for Bolt M8; End condition: Spring washer

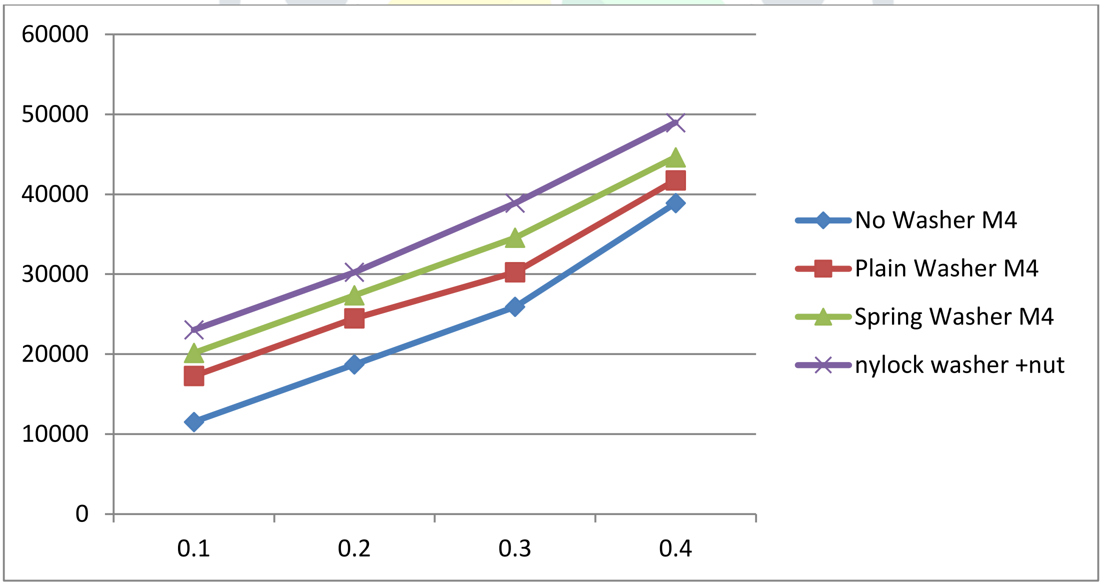
| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 26 | 37440 |
| 2. | 0.2 | 31 | 44640 |
| 3. | 0.3 | 39 | 56160 |
| 4. | 0.4 | 47 | 67680 |

Table No 16 Observations for Bolt M8; End condition: Nyloc washer + Nut

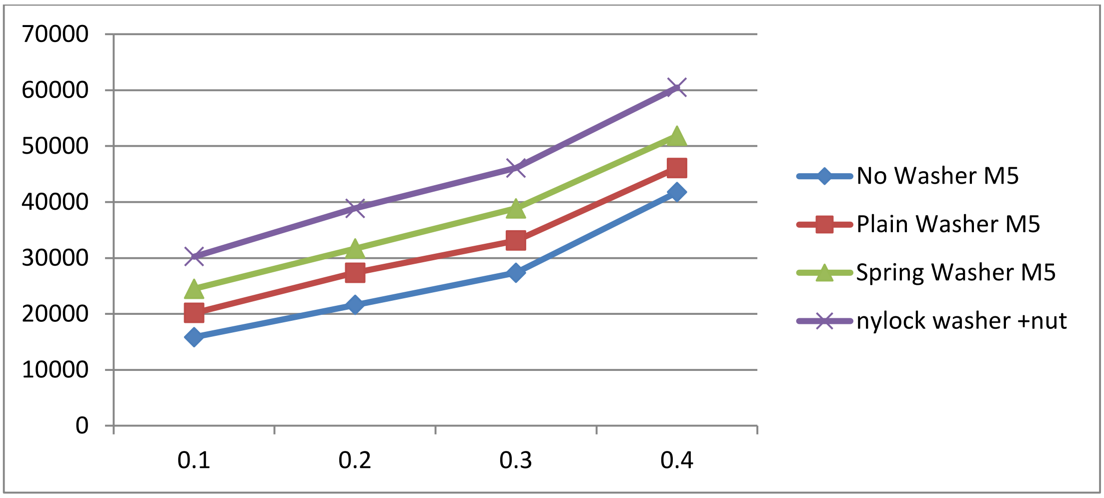
| SR. NO. | TORQUE N-m | TIME IN MIN | No of cycles |
|---|---|---|---|
| 1. | 0.1 | 29 | 41760 |
| 2. | 0.2 | 34 | 48960 |
| 3. | 0.3 | 43 | 61920 |
| 4. | 0.4 | 51 | 73440 |

**4. Result and Discussion**

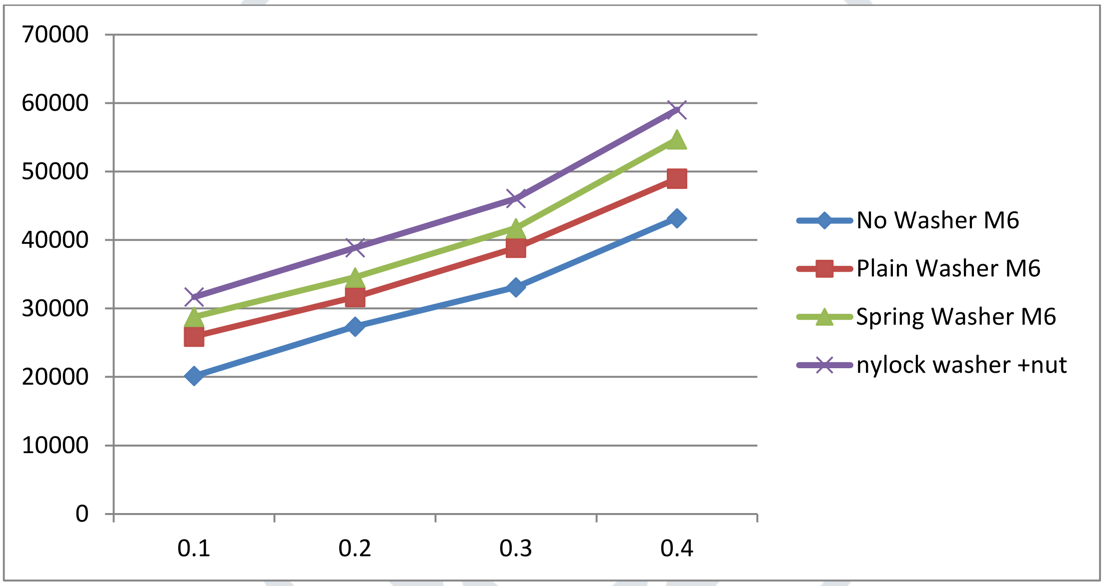
Graph 1 No of Cycles Vs Torque for M4




Graph 2 No of Cycles Vs Torque for M5




Graph 3 No of Cycles Vs Torque for M6




Graph 4 No of Cycles Vs Torque for M8

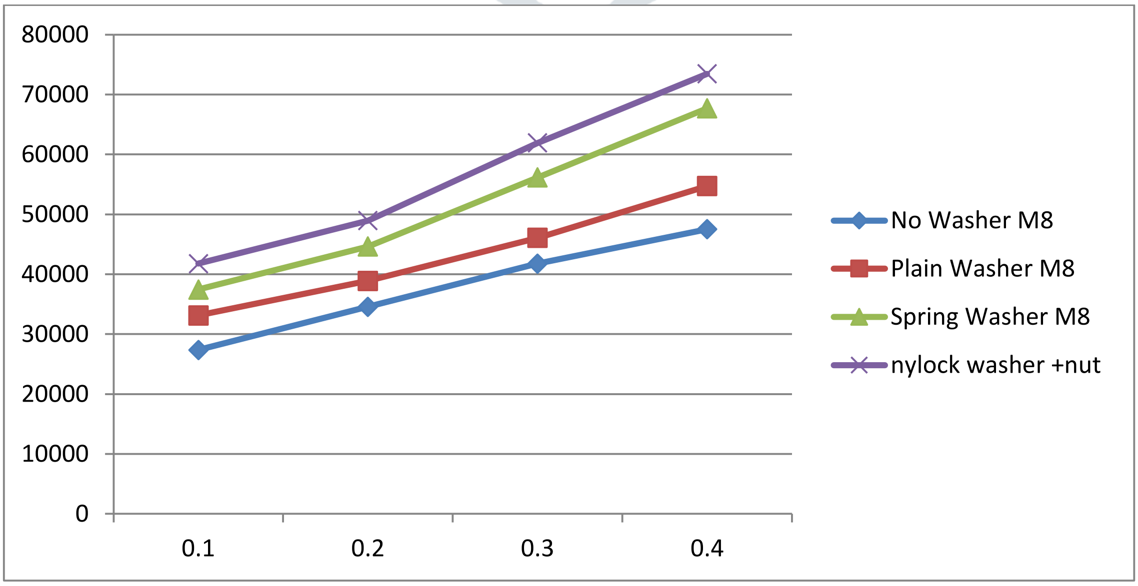


Table No 17 Comparative Analysis of Result for bolt M4

| Torque | No Washer (NW)M4 | Plain Washer (PW) M4 | Spring Washer (SW)M4 | Nyloc washer +nut (NWN)M4 | Eff= PW/NW | Eff= SW/NW | Eff= SW/PW | Eff= NWN/SW |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 11520 | 17280 | 20160 | 23040 | 1.50 | 1.75 | 1.17 | 1.14 |
| 0.2 | 18720 | 24480 | 27360 | 30240 | 1.31 | 1.46 | 1.12 | 1.11 |
| 0.3 | 25920 | 30240 | 34560 | 38880 | 1.17 | 1.33 | 1.14 | 1.13 |
| 0.4 | 38880 | 41760 | 44640 | 48960 | 1.07 | 1.15 | 1.07 | 1.10 |

Table No 18 Comparative Analysis of Result for bolt M5

| Torque | No Washer (NW)M5 | Plain Washer (PW) M5 | Spring Washer (SW)M5 | Nyloc washer +nut (NWN)M5 | Eff= PW/NW | Eff= SW/NW | Eff= SW/PW | Eff= NWN/SW |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 15840 | 20160 | 24480 | 30240 | 1.27 | 1.55 | 1.21 | 1.24 |
| 0.2 | 21600 | 27360 | 31680 | 38880 | 1.27 | 1.47 | 1.16 | 1.23 |
| 0.3 | 27360 | 33120 | 38880 | 46080 | 1.21 | 1.42 | 1.17 | 1.19 |
| 0.4 | 41760 | 46080 | 51840 | 60480 | 1.10 | 1.24 | 1.13 | 1.17 |

Table No 19 Comparative Analysis of Result for bolt M6

| Torque | No Washer (NW)M6 | Plain Washer (PW) M6 | Spring Washer (SW)M6 | Nyloc washer +nut (NWN)M6 | Eff= PW/NW | Eff= SW/NW | Eff= SW/PW | Eff= NWN/SW |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 20160 | 25920 | 28800 | 31680 | 1.29 | 1.43 | 1.11 | 1.10 |
| 0.2 | 27360 | 31680 | 34560 | 38880 | 1.16 | 1.26 | 1.09 | 1.13 |
| 0.3 | 33120 | 38880 | 41760 | 46080 | 1.17 | 1.26 | 1.07 | 1.10 |
| 0.4 | 43200 | 48960 | 54720 | 59040 | 1.13 | 1.27 | 1.12 | 1.08 |

Table No 20 Comparative Analysis of Result for bolt M8

| Torque | No Washer (NW)M8 | Plain Washer (PW) M8 | Spring Washer (SW)M8 | Nyloc washer +nut (NWN)M8 | Eff= PW/NW | Eff= SW/NW | Eff= SW/PW | Eff= NWN/SW |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 27360 | 33120 | 37440 | 41760 | 1.21 | 1.37 | 1.13 | 1.12 |
| 0.2 | 34560 | 38880 | 44640 | 48960 | 1.13 | 1.29 | 1.15 | 1.10 |
| 0.3 | 41760 | 46080 | 56160 | 61920 | 1.10 | 1.34 | 1.22 | 1.10 |
| 0.4 | 47520 | 54720 | 67680 | 73440 | 1.15 | 1.42 | 1.24 | 1.09 |

It is found from comparative study of graphs and tables that the Nyloc washer + nut are more effective than spring washer, Plain washer & No washer. Spring washer is effective than plain & No washer condition. Also plain washer is effective than No washer condition in all types of bolts.

## 5. Conclusion

All the components of the test rig model in Unigraphics are efficiently imported into ANSYS workbench. All the components are safe. Therefore from observations it is found that Nyloc washer + nut is more effective than spring washer, Plain washer & No washer. Spring washer is more effective than Plain washer & No washer. Plain washer is more effective than no washer.

## 6. Acknowledgment

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