Studies on Loss of Preload in the Fastener Joint during Vibration

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Abstract: Fasteners are widely used for temporary joining of different components that required for occasional for assembling and disassembling. Fasteners have problem in self loosening due to vibration, which may leads to decreases in the clamping force and their by causes joint failure. Vibration is undesirable. Vibration introduces stress into mechanical system and creates fatigue which decreases the service life. It can loosen the fastener in the joints. Junker testing machine is used for the testing the fasteners. Based on ISO16130 standard the following test requirements are carried out. Initial torque is given and Preload is given within 30 to 80% of yield strength of the bolt material and coefficient of friction in given to the bolted joint. In the present investigation loosening characteristics of a fasteners and loss of preload in fastener joint during the vibration are presented and discussed below.

Key words: 35NCD16 M12 bolt, bolted joint, Hex nut, NY lock nut, plain washer preload, torque, vibrating system, transverse force, transverse displacement, ISO 16130 / DIN25201 / DIN 65151.

1. Introduction

Fasteners are commonly used for provisional joining of different components that required for assembling and disassembling. Fasteners have difficult in self-loosening due to vibration, which may hints to decreases in the clamping force and their by causes joint failure. Vibration is detrimental. Vibration hosts stress into mechanical system and builds fatigue which decreases the machine life. It can loosen the fastener in the joints. In the present investigation we discuss about the study of loss of preload during vibration in fastener joints. M12 bolt is made out of 35NCD16 with cadmium plated and 35NCD16 cadmium plated washer and Hex nut and NY lock nut with 35NCD16 cadmium plated material are used in the present investigation. These types of fasteners are used in the lunch vehicles. Junker testing machine is used for the testing the fasteners in the present investigation. Based on ISO16130 standard the following test requirements are carried out.

2. The theory of reason why fastener get self-loosen when transverse movement (vibration)

Bolted joints are easily assembled and disassembled. We have to know why self-loosen of fastener is occurred in the joint when it is subjected to vibration. Hence it is transverse moment or axial moment the action of force occurred. Due to vibration, bolted joint is subjected to the transverse moment so that grip or the fractional resistances under head loses and pitch torque increases so that self-loosen of a fastener occurred. Increase in the helical angle also effects to the self-loosening of the bolted joint. The clamp force which is acting the fastener is sufficient to resist the transverse force then the bolt does not get self-loosened. If it overcomes the clamp force then the self-loosen of the fastener occurs.

3. Tightening torque.

Where the tightening torque does goes when we tighten the bolt. When torque is applied to the bolt, the 50% of torque energy is required to overcome the friction under the head of the bolt. And 40% of torque energy is required to overcome the friction in the threads and only 10% of torque energy is used for the tightening of the bolt. It says that only 10% torque energy is used as the preload or pretension as shown in the figure below.

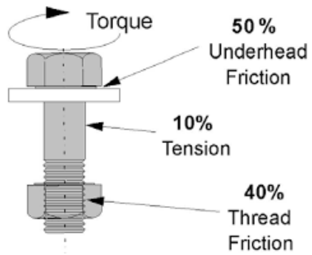
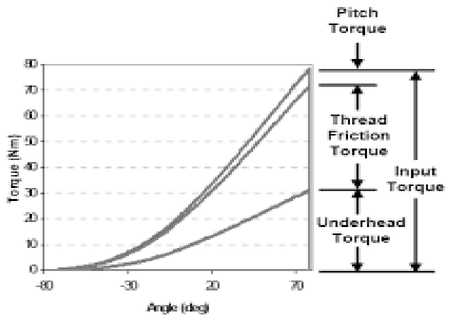


Figure shows the percentage of tightening torque.

To fasten a bolt a tightening torque T_A is needed. Let's T_K be the torque related to the friction under head and T_G be the torque related to the friction in the thread pitch and torque related to the friction in the thread pitch $T_{T.P}$[1].

$$T_A = T_K + T_G + T_{T.P} \qquad (1)$$

In most of the cases the preload is always related to the pitch torque. If the 5% of friction related to the pitch torque increases then decrease of preload up to 50% takes place as shown in the figure [2].



The figure shows the torque related to the friction in the bolt joint.

Formulas which are related to frictional torque under head, in the threads and in the pitch torque in the bolt joint are shown below [1].

$T_K = F_P \times \frac{Dkm}{2} \times \mu k$ (2)

$T_G = F_P \times \frac{d2}{2} \times \frac{\mu}{\cos\alpha}$ (3)

$T_{T.P} = \frac{Fp \times P}{2 \times \pi}$ (4)

F_P = preload

μ = friction coefficient

D_{KM} = nominal diameter

In the bolted joint the pitch torque should be always less than the combine of frictional torque and torque related in the threads.[3]

$T_{T.P} < T_K + T_G$ (5)

Increasing in the friction related to the thread pitch then the loosening of the bolt takes place.

4. Theoretical displacement

The transverse force required to overcome the friction under head that is frictional resisting force is known as "theoretical displacement or marginal slip" it is calculated as [1].

$a_{th} = \frac{Fp \cdot \mu \cdot Lk^3}{12 \cdot E\, I}$ (6)

Where F_P = preload

μ = coefficient of friction

L_K^3 = clamp length

E.I = stiffness of bolt

Practical applications for testing the fastener by the dynamic vibration-

Testing the fastener determines the resistance of force to get self-loosening during the vibration when it is in service condition. This type of resisting force is known as self-locking. It uses the properties of coatings which are coated on the fastener to increase the anti-loosening properties

The Junker testing machine which is used for the testing of the fastener – Gerhard Junker who published the article named as "New Criteria for self-loosening of fastener under vibration in 1969" [4].

For testing the fastener we need to follow few rules of fastener and standards. In our investigation wed follow ISO16130 [5].

5. Coatings

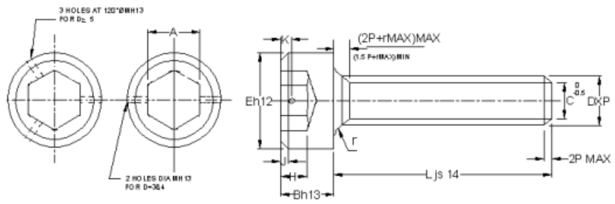
Coatings plays key role in the fasteners. They improve the anti-loosening properties of the fastener and corrosion resistances of the fastener. Not only coating fastening solutions are also used to increase the anti-loosening properties in the fastener [6-9].

In our investigation we used cadmium coating to the bolt, nuts and washers.

Cadmium coatings are high temperature resistance. They are corrosion resistances. They are harm to human life but they are used for the launch vehicles

Modelling of the component

The bolted joint is designed in the catiav5 version according to the dimensions.



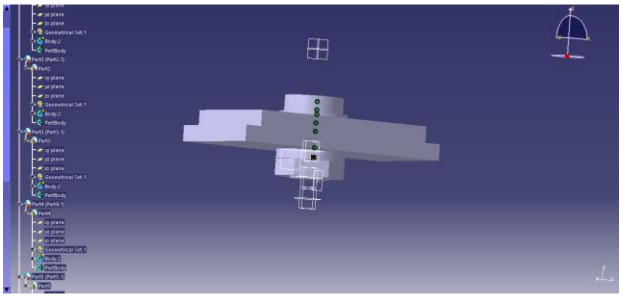
1. Dimensions:

Table No.1

D Nominal	P Pitch	A		B	C	E	H		J Max.	K +0.1	M	r
3	0.5	2.5	+0.060 +0.020	3	2.2	5.5	1.3	+0.4 +0.0	0.5	0.9	0.8	0.2 to 0.4
4	0.7	3.0		4	2.9	7.0	2.0			1.4	1.0	
5	0.8	4.0	+0.105 +0.030	5	3.8	8.5	2.7		0.8	1.6		
6	1.0	5.0		6	4.5	10.0	3.3	+0.5 +0.0		2.0	1.2	0.5 to 0.7
8	1.0	6.0		8	6.2	13.0	4.3		1.2	2.4	1.5	
10	1.25	8.0	+0.130 +0.040	10	7.9	16.0	5.5	+0.7 +0.0				0.6 to 0.8
12	1.25	10.0		12	9.9	18.0	6.6	+0.9 +0.0				
16	1.5	14.0	+0.230 +0.050	16	13.9	24.0	8.8		1.6	3.2	1.8	0.8 1.0
20	1.5	17.0		20	17.9	30.0	10.7	+1.1 +0.0				1.0 1.2
24	2.0	19.0	+0.280 +0.060	24	20.0	36.0	12.9	+1.1 +0.0	2.0			1.0 1.2

The figure shows the dimensions of the fastener with different shank length.

The above diagram represents the dimensions of the fastener which are used in the various applications. These dimensions of the fastener are used in the launch vehicle not launch vehicle all types of the automotive vehicles especially in the air craft applications.



The figure represents the modelling of the fastener.

The above diagram represents the bolted joint which is designed and modelled by using catiav5 according to the above dimensions.

This type of bolted joint is used for testing in our investigation.

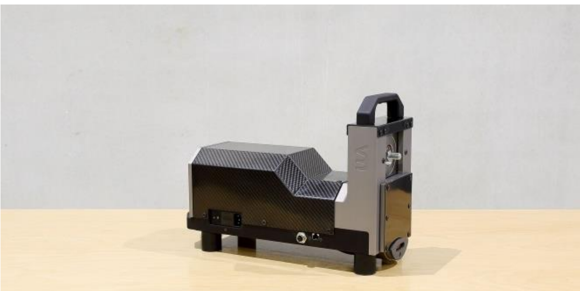
6. Experimental analysis

In our investigation we use material of 35NCD16 M12 Bolt, hex nut, NY lock nut and same composition of plain washers.

Table 1

c	Si	Mn	Cr	Ni	Mo	V	W	S	P
0.30	0.15	0.30	1.60	3.50	0.25	-	-	-	-
0.40	0.40	0.60	2.0	4.20	0.60	-	-	0.020	0.020

The table shows Chemical composition of the 35NCD16 material.



The above figure shows Junker testing machine.

Test parameters

Preload 30% to 80% of yield strength of bolt

Torque

Coefficient of friction 0.2

Clamp length 25mm / clamp length ratio 1:2 or 1:2.5

Frequency 12.5Hz to 15 Hz

Rpm of the machine runs at 800

7. Test procedure

The bolt is arranged in the chamber plate and washer is placed under head and nut bearing surface. Clamp length is kept as 25mm and Hex nut is placed first and NY lock nut is placed second and 13.5Hz is maintained. Initial torque and initial preload is 30% of yield strength is conducted and increased up to 80% of yield strength. Transverse moment of amplitude 10% of nominal diameter of bolt is given. Note the number of load cycles and maintain the test till the bolt maintains continue residual forces. We can observe the decreasing curve if the clamp force decreases at certain cycles. If there is no decrease of cycles and continue residual forces are maintained we can observe straight line. From the ISO16130 standard the fastener should not get self-loosened till the completion of 300 cycles. Note down the values from the data of the testing machine.

8. Results

After testing the samples we have noted the values according to the table as shown below.

Table

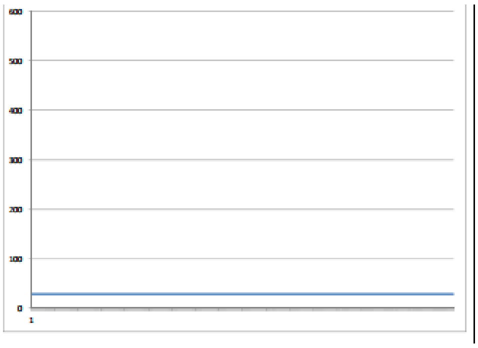
SL.NC	Preloa (KN)	Torque (Nm)	Coefficien of Friction	Clamp length (mm)	Theoretical Displacemer (a mm)	No o Load cycles	Frequency Hz
1	30	108	0.2	25	0.8	309	13.5
2	47	169	0.2	25	1.09	310	13.5
3	55	198	0.2	25	1.64	308	13.5
4	66	234	0.2	25	1.92	312	13.5
5	76	270	0.2	25	2.19	315	13.5

The table shows the results of testing

Above tables shows the results of testing. From the test results we have observe the initial torque and intimal preload which is given in the test machine. For every different type preload and we got different theoretical limiting displacement values.

From the ISO16130 Standard it represents that the fastener which holds its preload without decreasing its clamp force to up to 300 cycles are valid to use in the practical applications.

From the tables we observe that increase of preload and torque increase in the cycles which resists the self-loosen of the fastener.



The graph represents the continuous residual forces of the fastener.

From the graph we observe that a straight line passes between number of loaded cycles and sample. From the graph we observe that the fastener do not get self-loosened a continuous residuals forces is maintained in the graph. We conducted the 10 specimen's with five different variants and we take as average number of loaded cycles. The specimen didn't get loosen till the standard cycle of the bolt.

From the graph it represents that even one bolt also not loosen and continue residual forces are continued from 30% of yield strength to 80% of yield strength. The machine runs with 800rpm and 13.5 Hz frequency.

. It represents that the fasteners do not get self-loosened and satisfies ISO16130 standards and yet it is used for practical applications.

9. Conclusions

From the above investigation we finally conclude that increase in the frictional resistances forces (grip) under head and bearing surface fastener do not get self-loosened.

In the present investigation we used different types of coatings and lock nuts such as NY lock nut and hex nut. The coatings increase the anti-loosening properties of the bolt in the vibration conditions. It increases the properties of the specimen and helps to increase the anti-loosening characteristics.

By using different types of coatings which improve the anti-loosening properties of bolt and nut can reduce the loosening of bolt and nut. Examples - cadmium, aluminium and molybdenum etc.

By using Loctite225 and Loctite 242 lotion or solution which increases the anti-loosening properties and it help to be fitted or sealed in the joints.

10. References

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