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Analysis of Vibration loosening of bolted fasteners

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***Abstract*— A significant advantage of a bolted joint over other joint types, such as welded and riveted joints, is that they are capable of being dismantled. This feature however, can cause problems if it unintentionally occurs as a result of operational conditions. Such unintentional loosening, frequently called vibration loosening in much of the published literature. It is widely believed that vibration causes bolt loosening. By far the most frequent cause of loosening is side sliding of the nut or bolt head relative to the joint, resulting in relative motion occurring in the threads. If this does not occur, then the bolts will not loosen, even if the joint is subjected to severe vibration. By a detailed analysis of the joint it is possible to determine the clamp force required to be provided by the bolts to prevent joint slip. Junker's vibration test rig is the most popular method to measure the vibration loosening of bolts or commonly referred to as bolt decay phenomenon. The Junkers vibration test rig uses a special form spring to connect the eccentric arrangement for providing vibration to the test specimen .Commonly used material for the material of this form spring steel in the tempered form.**

***Index Terms*— Self-loosening, threaded joints, Transverse vibration.**

I. INTRODUCTION

Threaded fasteners are widely used in assemblies because of their ability to develop a clamping force and ease of disassembly for maintenance. The two most common modes of failure of threaded fasteners subjected to dynamic loads are fatigue and vibration induced loosening.

Due to shape of spring and nature of loading the springs made from spring steel do not last for the expected number of work cycles , thus resulting into premature failure of spring thereby leading to unsuccessful test and loss of time and money. Object of project is to develop a mathematical model to develop the shape of the spring to impart 0.5 to 1.5 mm amplitude of vibrations and frequency in the range of 800 to 1400 cycles per minute. The spring models will be developed using Unigraphix and critical modal and strength analysis will be done for EN48(D) and SS304 as materials using ANSYS. The analysis will be carried out as single load step and multi-load step approach and to validate the theoretical stresses . The force transmitted and net displacement of springs thus determined will be further validated experimentally by application of these springs in a Junker's vibration test rig to determine the bolt decay in M6 size bolts. The force transmitted by the springs will be experimentally evaluated using load cell where as the strain gage bridge will be used to determine the amplitude of vibration or displacement offered by the spring.

The other parameter of design will be the experimental determination of change in dimension of the springs and change in form of the mounting holes of the springs after a predetermined number of cycles and the data thus obtained will be used to predict the failure of springs at the specified locations for given values of amplitude and frequency by use of iterative techniques. Data thus generated will be used to recommend specific material of spring for a given application of Junker's vibration for determination of bolt decay.

II. JUNKER'S MACHINE – FASTENERS TRANSVERSE VIBRATION MACHINE

Work completed during the 1960's in Germany indicated that transversely applied alternating forces generate the most severe conditions for self loosening. The result of these studies led to the design of a testing machine which allowed quantitative information to be obtained on the locking performance of self locking fasteners. Such machines, often called Junkers machines. In the literature - after its inventor, have been used over the last twenty years by the major automotive and aerospace manufacturers to assess the performance of proprietary self locking fasteners. As a result, a rationalization of the variety of locking devices used by such major companies has occurred. For example, conventional spring lock washers are no longer specified, because it has been shown that they actually aid self loosening rather than prevent it. There are a multitude of thread locking devices available. Through the efforts of the American National Standards Subcommittee B18:20 on locking fasteners, three basic locking fastener categories have been established. They are: free spinning, friction locking, and chemical locking. [4]

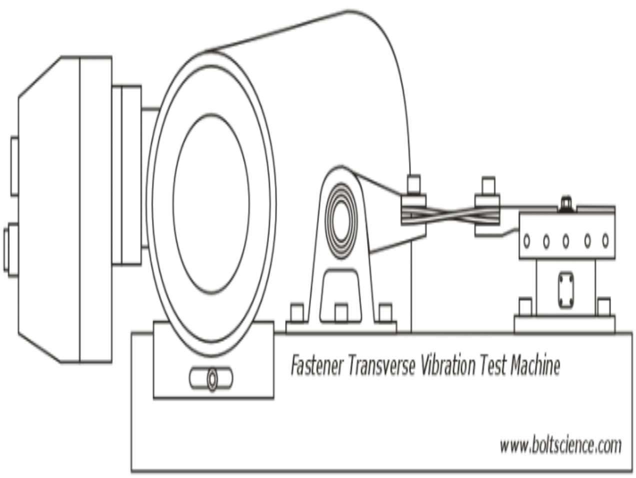

Figure no.1: Fastener transverse vibration test machine

Fasteners coming loose is a common problem across many industries. We can complete an assessment of a fastener's self loosening characteristics using a transverse vibration test machine (often referred to as a Junker machine and the test performed, a Junker Vibration Test). The fastener preload decay graphs produced can allow an assessment to be made of a fastener's resistance to self-loosening. The test can be performed on the locking mechanism forming part of a nut (such as with nylon insert nuts), on a bolt (such as bolts with a nylon coated patch on the bolt) or a washer (such as a helical spring lock washer).

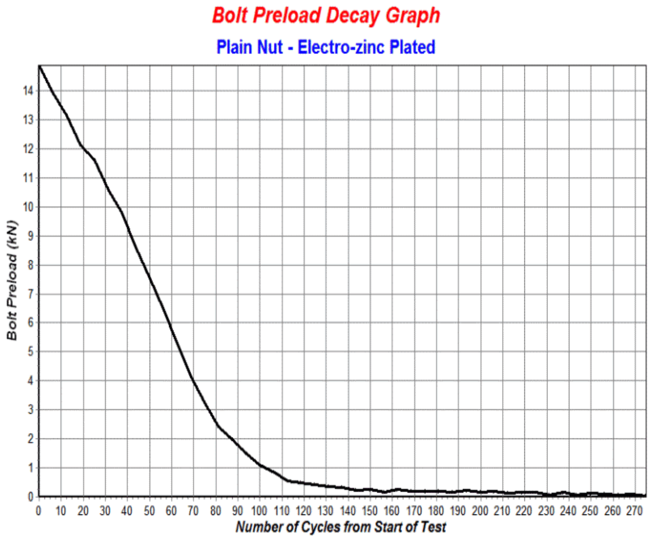

Figure no.2: Bolt preload decay graph

III. EXPERIMENTAL SET UP

A)Problem statement

Junker's vibration test rig is used to find the bolt decay characteristics in which we are to test M6 bolt and nuts for vibration loosening sing different Z Shape leaf spring namely , without hole , with hole at various pretension in bolt i.e., various torques.

In earlier case the leaf spring used for transmission of vibrations from the input eccentric to moving plate via the jokey is of the following profile:

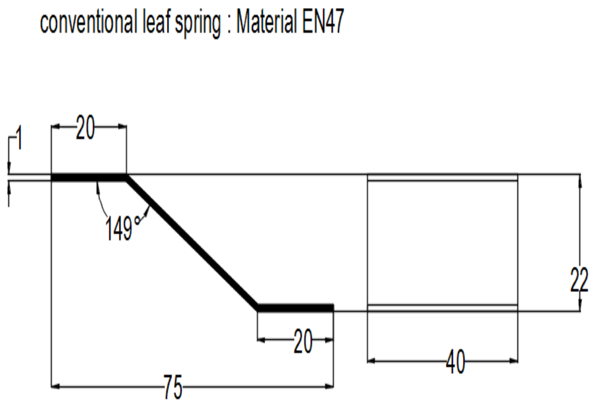

Figure no. 3: Conventional leaf spring

The EN47 spring showed pre mature failure and could not withstand the number of vibrations cycles necessary with pretension above 0.6 N-m in bolts hence it was decided to replace the spring steel material by EN8k, which is recommended material with slight tempering for stress relieving.

B)ACTUAL SET UP

The objective of this study is to apply correct engineering principles to establish the relationship between tightening torque and preload and to verify the loosening characteristics of bolted joints under transverse vibration by experimental setup.

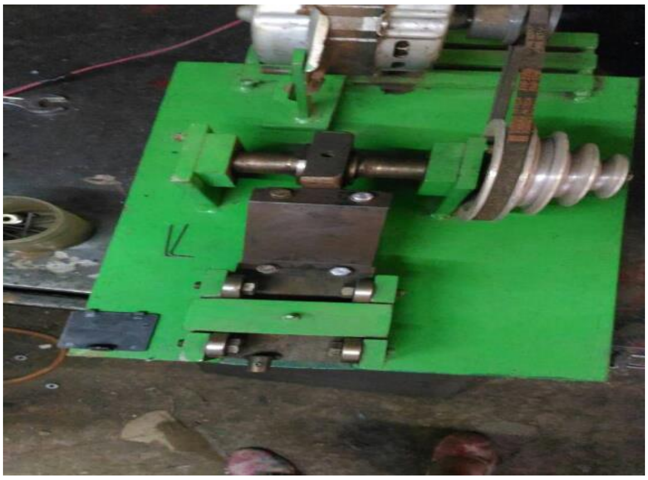

Figure no. 4: Actual set up

IV. EXPERIMENTATION

Vibration testing was conducted on a Junker's transverse vibration machine. As per problem statement we have tested EN8k z shape spring with centered hole by fixing one end and by using love joy coupling keeping one end free to vibrate. By using vibration meter different frequency ,acceleration and displacement is measured which gives us information about displacement at different torque.

Figure no 5: Testing

Figure no. 6 : Vibration meter

V. TEST RESULTS

The test results are summarized in Table 1. The performance difference under vibration condition is shown in figure no..

- *OBSERVATIONS FOR VIBRATION TEST TRIG*

Bolt size : M6 End condition : en8k with hole

Table no 1: Spring with centered hole

SR. NO.	TORQUE N-m	TIME IN MIN	No of cycles	ACCELERATION m2/sec	DISPLACEMENT	Frequency Theoretical Hz	Frequency Experimental Hz
1	0.1 2	10	14490	201	0.24	-1.6	1.8
2	0.24	16.4	23620	246	0.36	2	2.3
3	0.36	21.8	31370	297	0.48	1.5	1.6
4	0.48	29.69	42740	317	0.98	2	2.3

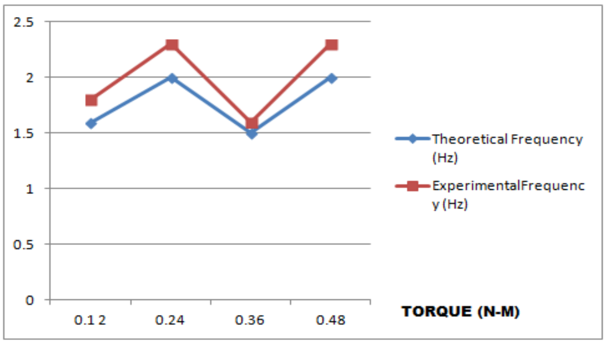

Figure no.7 : Graph torque vs frequency of spring with centered hole

VI. CONCLUTION

Preloaded fasteners self-loosen when relative movement occurs between the matting treads and the fasteners bearing surface. Such relative movement will occur when the transverse force acting on the joint is larger than the frictional resisting force generated by the bolts preload. Under repeated transverse movements this mechanism can completely loosen fasteners.

Junker developed a test machine to investigate the effect of transverse movement on preload treaded fasteners. The test machine allows a cyclic transverse displacement to be imparted into a bolted joint. By using the same principle Bolt test rig can be design and we can take the different results for leaf spring as damping device with different bolt size. We can compare different leaf spring material and find best material for preventing vibration loosening of bolts.

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