EFFECTS OF DYNAMIC LOAD ON INITIAL TIGHTENING TORQUE OF NUTS AND BOLTS

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Abstract This study presents the effects of dynamic load on the initial tightening torque applied during fixing the nuts and bolts. Stresses on nuts and bolts arises due to two different types of loading- one is static loading due to tightening of nut and other dead weights and another is dynamic loading which is developed by applying variable loads. So it becomes essential to design and construct a setup that will exert these two types of loading on nuts and bolts simultaneously. In this study variation of initial tightening load and fluctuating load were considered. The combined load was measured by using a load cell using an ADC (analog to digital converter) and a computer.
At the end of study it was found that the initial tightening load applied on nuts and bolts gradually decreases if dynamic load is applied even though the applied load is far below its endurance strength or below its plastic deformation limit. The rate of decrease depends on alternative component and mean value of dynamic load.

Keywords: initial tightening load, dynamic load.

INTRODUCTION

In the engineering applications nuts and bolts are used frequently for joining different parts of the machines and other elements. Bolt is one of the important threaded joint device. Bolted assemblies form a major part of most engineering structures, i.e. in machine tools and in transport industries, loading in almost every case is static and dynamic. So, it is important to know about the different characteristics of nuts and bolts when load (static and dynamic) is applied on them and to improve so that higher speeds and forces can be accommodated.

In obtaining the properties of materials relating to the stress-strain diagram, the load is applied gradually, giving sufficient time for the strain to develop. These conditions are know as static conditions and are closely approximated in many structural and machine members.

Machine members such as bolts are often found to have failed under the action of repeated or fluctuating stresses, and yet the most careful analysis reveals that the actual maximum stresses were below the endurance strength of the material and quite frequently much below the yield strength. The most distinguishing characteristics of these failures that the stresses have been repeated a very large number of times. Hence the failure is called a fatigue failure.

It is also important to know about the stresses developed on the bolt due to tightening of nuts and bolts. Applying a wrenching torque to the head of the fastener generates the initial tightening torque on the bolt. This wrenching torque must overcome the opposing thread friction torque and the under head torque. The distribution of wrenching torque between thread friction torque and under head torque depends on the frictional conditions on the thread and under head surfaces. As the bolted joint takes an important role in a threaded joint device, so it is necessary to study the inherent behaviors of bolted joints for various application under different load conditions. In this paper, it has been studied the behaviors of the bolts particularly, the applied torque and the developed tensile load on the bolt shank and how this load and torque varies due to the application of dynamic loads. A set-up has also been constructed to study the above effects.

Background

The purpose of a bolt is to clamp two or more parts together. The clamping load stretches or elongates the bolt; the load is obtained by twisting the nut until the bolt has elongated almost to the elastic limit. If the nut does not loosen, this bolt tension remains as the clamping force. This clamping force is called the bolt pre-load or pre-tension, initial static load. When tightening the bolt head is held stationary and nut is twisted so that the bolt shank will not feel the thread friction torque. This pre-load exists in the connection after the nut has been properly tightened no matter whether the external tensile load is exerted or not. Since the members are being clamped together, the clamping force which produces tension in the bolt induces compression in the member. Initially when the pre-load is applied, due to tightening of the nut, the bolts are elongated and compression members are compressed.

Then when the external tensile load is applied a portion of this load is taken by bolt and another portion is taken by the compression members. This external load results in increase in load and deflection for the bolts and decrease in load and deflection for the compression members.

The bolt strength is the key factor in the design or analysis of bolted connections. In the specification standards for bolts, the strength is specified by stating the minimum proof strength, or minimum proof load, and the minimum tensile strength. The proof load is the maximum load (force) that a bolt can withstand without acquiring a permanent set.

The use of the torque wrench for assembly of bolted connection allows better control of tightening. If consistent results are to be achieved when using the torque wrench, nut and bolt threads must be in good condition and the thread should be lubricated. Tension-loaded bolted joints are frequently subjected to fatigue actions. The type of fatigue loading encountered in the analysis is one in which the externally applied load fluctuates between zero and some maximum force.

DESIGN AND CONSTRUCTION OF SET-UP

To observe the effects of dynamic load on nuts and bolts it became necessary to design and construct a set-up that will exert static and dynamic load on them simultaneously. In determining the dimensions of the elements of the experimental set-up the strength of the used material is an important design consideration. The important design parameters that have considered while designing the set-up are strength , reliability, thermal considerations, friction, cost, safety, shape, size, flexibility, stiffness, surface finish, lubrication, maintenance.

Design should be such to protect the bolt from failure. Thickness of the plates should be calculated correctly so that due to applying load the plates do not undergo bending. The fabrication is done in such a way that the load is correctly located and properly maintained the alignment. The strength of the support members and other parts should be calculated properly so that its can withstand the applied load. Mild-steel has been chosen as a design material because its high strength and low cost .For this reason 070M20 HR Steel has been chosen as construction material. After considering all design factors the load capacity of the set-up was found to be 1577 kg or 1.54 ton.

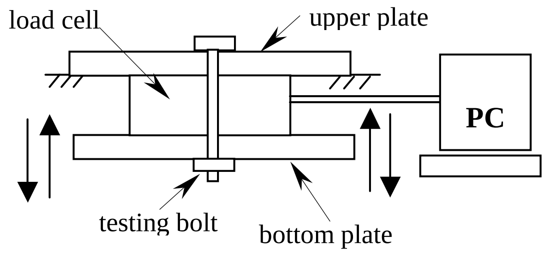

Fig. 1 Schematic diagram of experimental setup

Fabrication

The dynamic load is produced by a revolving mass which is attached at one end of a beam. Due to this rotation of the mass the central beam vibrates up and down. This dynamic load is then transmitted to the bolt by two legs or steel columns which are attached on either side of the beam. The top end of these legs are attached to the lower plate by bolts. The upper plate is supported by vertical angles and horizontal beams. The bolt passes through these two plates and the nut is tightened at the upper plate. A load cell is placed between the two plates. This load cell generates voltage when load is applied on it and this voltage is observed in a computer by using a analog to digital converter. All the supporting members are attached to the base by bolts. The amount of load can be increased by placing another beam at the bottom of the central beam.

This load was measured by a load cell that generates voltage when load is applied on it. So it became necessary to calibrate the load cell to find the change in voltage due to change in load on it. It was done by applying static load on the load cell in a universal testing machine. The calibration curve thus found is shown in Fig. 2 The curve shows the relationship between the load and the voltage is almost linear.

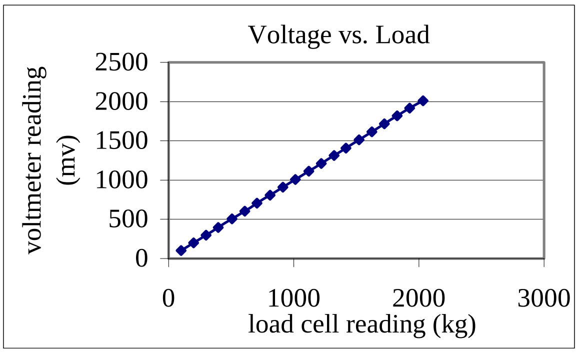

Fig. 2 Calibration curve of load cell

RESULT AND DISCUSSION

These experiments were performed with different alternative component and mean value of dynamic load applied to a bolt for different initial tightening load condition. In these experiments the lubricating condition of bolt and surface finish were kept constant. At first the initial tightening load was measured by load cell and torque was measured by using a torque load cell. Then dynamic load was applied and the change of the initial tightening load and torque with dynamic load were observed. The effects of different amplitude of dynamic load on bolts with same initial tightening load were also observed.

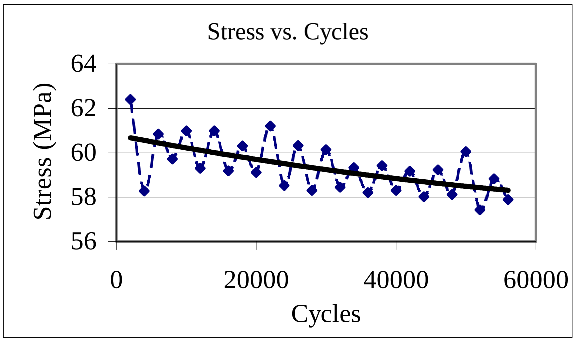

Fig. 3 Variation of stress with cycle (initial tightening load = 33% of proof load)

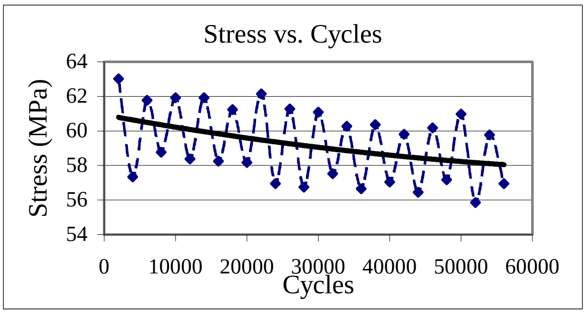

Fig. 4 Variation of stress with cycle (initial tightening load = 33% of proof load)

Fig. 3 and Fig. 4 show the variation of initial tightening load with no. of cycle. In both cases this initial tightening load was 33% of proof load and it decreases with cycle. But in second case the fluctuation of dynamic load was greater than that of first case. It results in rapid decrease of initial tightening load than the first case. The test was done for about 5600 cycles.

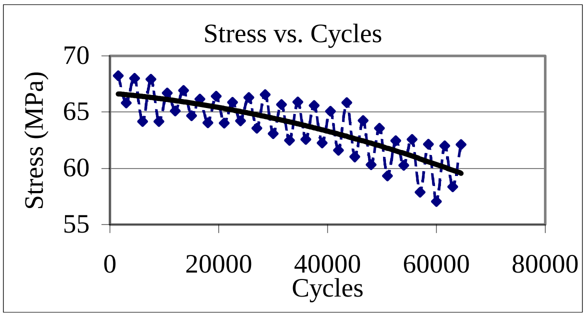

Fig. 5 Variation stress with cycle (initial tightening load = 36% of proof load)

Fig. 5 and Fig. 6 show the variation of initial tightening load due to application of dynamic load. Here in both cases the initial tightening load was 36% of proof load and dynamic load was applied for about 6500 cycles. The same result was obtained in these cases also. Initial tightening load decreases with cycles and this reduction is faster when the fluctuation is higher.

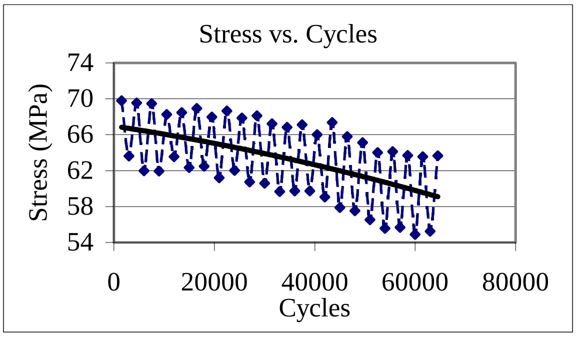

Fig: 6 Variation of stress with cycle (initial tightening load =36% of proof load)

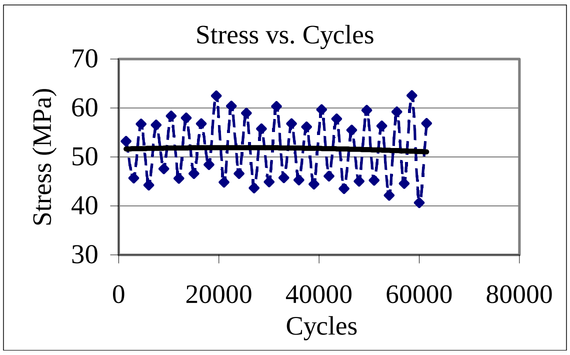

Fig. 7 Variation of stress with cycle (initial tightening load = 28% of proof load)

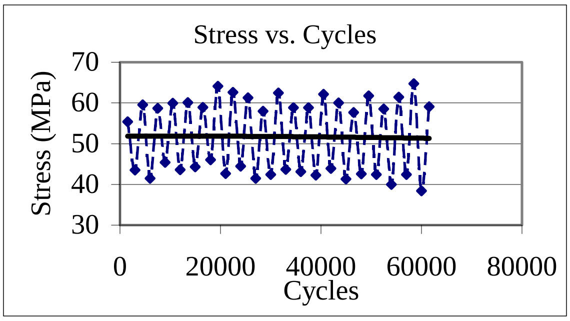

Fig. 8 Variation stress with cycle (initial tightening load = 28% of proof load)

Fig. 7 and Fig. 8 show the variation of initial tightening load when it was 28% of proof load. But in these cases no variation of initial tightening load was observed. This was happened probably due to the fact that is these cases the initial tightening load was less. But if the no. of cycles were more then it might also be decreased with time.

CONCLUSION

The stress varies with dynamic load. The more the no of cycles the more the reduction occurs. The reduction is rapid if the amplitude of the dynamic load is increased though the maximum dynamic load is much below the limit of endurance strength. Pattern of loosing strength depends on the initial tightening load and mean value of dynamic load. To make reasonable conclusion more number of similar experiments are required. For better understanding the effects of lubricating condition, surface finish of mating surfaces can also be considered.

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