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REVIEW OF THREADED FASTENERS LOOSENING AND ITS EFFECTS

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ABSTRACT

Threaded components are the most important structural elements influencing significantly the strength and endurance of the whole structural assembly. Threaded connections are used for their ability to develop a clamping force and for the disassembly possibility that is important for maintenance. It has also been widely observed that fasteners turn loose when subjected to dynamic loads in the form of vibration. This reduces the preload force of bolt and leads to joint failure. Such failure can be catastrophic in safety critical applications. 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. History of evolution of screw fasteners dates back to few thousand years ago.

In this paper stresses developed in screw fastenings due to initial tightening load and external load have been reviewed along with relevant examples. Following this combined effect of initial tightening and external load on bolts is discussed

INTRODUCTION

Threaded structural fasteners are one of the most common methods used to join assemblies in mechanical components. They allow components to be disassembled and reassembled with greater ease, as compared to other methods like welding. However, there are several difficulties associated with using threaded structural fasteners (i.e., the ability to determine the preload applied to a bolt and the non-linear behavior of a bolted assembly). An example of a bolted assembly is shown in Figure 1.

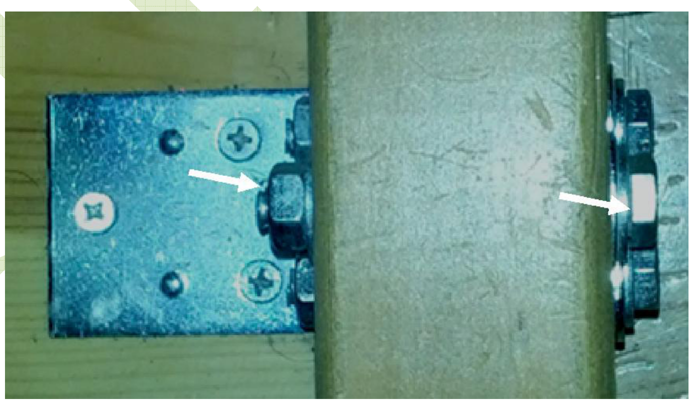

Figure 1: Example of a Bolted Joint

The bolt preload is the clamping force that holds bolted assemblies together. Therefore, the bolt preload is an important factor used to determine the acceptability of a given joint. The amount of bolt preload at installation can be estimated by Equation 1 from [5]:

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However, there can be significant scatter when determining the torque coefficient

(K) and the applied torque (T). These values can be affected by the friction of the threads or bearing surfaces, thread geometry, and how the torque is applied to the bolt or nut.

As the bolt is tensioned, the applied load is divided between compressing the flange and tensioning the bolt; see Figure 2. The ratio of flange stiffness to bolt stiffness

Determines how much of the applied load is divided between compressing the flange and tensioning the bolt.

The same load sharing behavior exists after the desired preload is reached in the bolt. As an external load is applied to the joint, part of the load is reacted by the bolt and part is reacted by the flange. The joint resiliency ratio can determine the percentage of the applied external load that the bolt will resist; see Figure 3. Figure 3 shows a plot of how the joint resiliency ratio changes depending on the clamping ratio. Figure 3 also shows that there is a maximum joint resiliency ratio that is dependent on the clamping material properties.

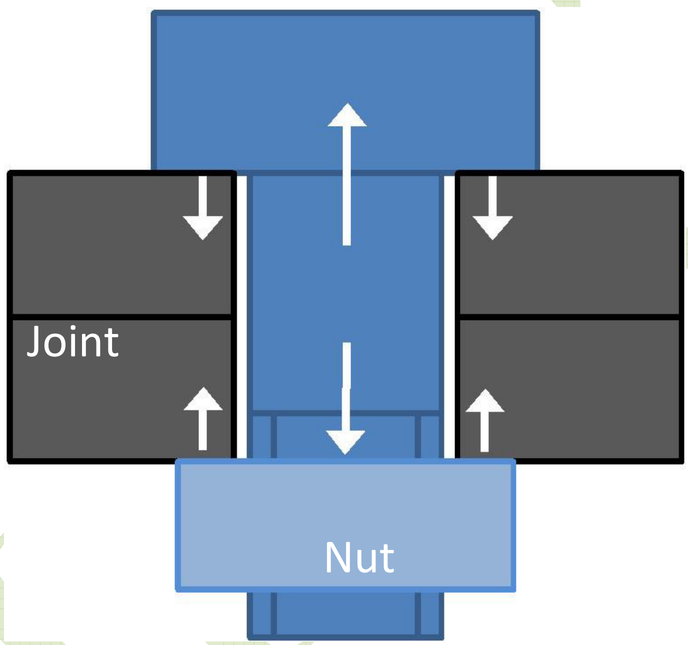
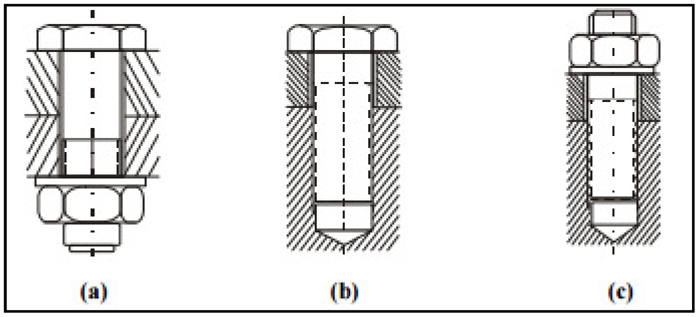


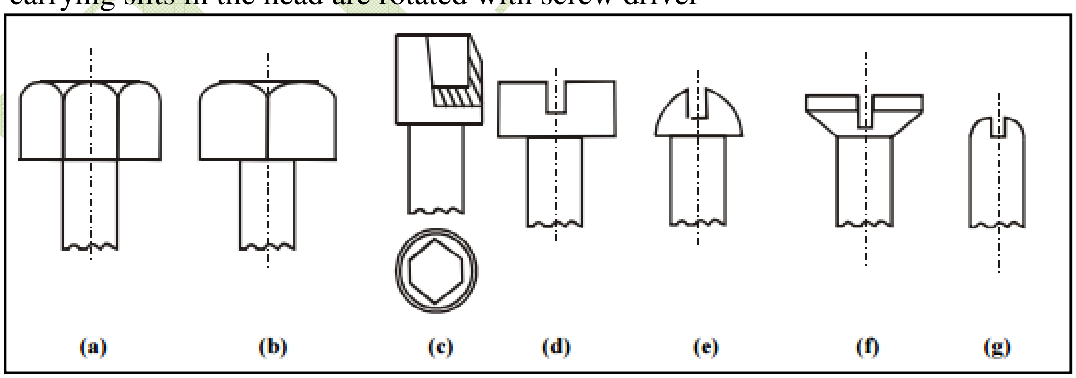
Figure 2: Bolted Joint Clamping Forces

Apart from transmitting motion and power the threaded members are also used for fastening or jointing two elements. The threads used in power screw are square or Acme while threads used in fastening screws have a vee profile). Because of large transverse inclination the effective friction coefficient between the screw and nut increases by equation cos $\mu' = \mu / \mathrm{COS}\ \theta$ is the basic coefficient of$\mu$where is the effective$'\mu$ is the half of thread angle and θfriction of the pair of screw and nut, coefficient of friction. The wedging effect of transverse inclination of the thread surface was explained.

Wide variety of threaded fasteners is used in engineering practice. These are cylindrical bars, which are threaded to screw into nuts or internally threaded holes. Figure below depicts three commonly used fasteners. A bolt has a head at one end of cylindrical body. The head is hexagonal in shape. The other end of the bolt is threaded. The bolt passes through slightly larger holes in two parts and is rotated into hexagonal nut, which may sit on a circular washer. The bolt is rotated into the nut by wrench on bolt head. As shown in Figure the two parts are clamped between bolt head and nut



A screw is another threaded fastener with a head and threads on part of its cylindrical body. However, the threads of the screw are threaded into an internally threaded hole as shown in Figure (b). While tightening of joint between two parts by bolt occurs by rotating either bolt or nut, the screw tightens the parts, through rotation of screw by a wrench applied at its head. In case of screw the friction occurs between bolt head bottom and surface of the part in contact, and between threads of screw and hole. In case of bolt the friction occurs either at bolt head or at the nut. The wrench has to apply torque against friction between the surface of part and bolt head or nut and in the threads of contact. Both the bolt and screw are pulled and hence carry tensile force. A stud is another threaded fastener which is threaded at both ends and does not have a head. One of its end screws into threaded hole while the other threaded end receives nut. It is shown in Figure (c). The bolts are available as ready to use elements in the market. Depending upon manufacturing method they are identified as black, semi finished or finished. The head in black bolt is made by hot heading. The bearing surfaces of head or shank are machine finished and threads are either cut or rolled. In semi finished bolts the head is made by cold or hot heading. The bearing surfaces of head or shank are machine finished and threads are either cut or rolled. A finished bolt is obtained by machining a bar of same section as the head. The threads are cut on a turret lathe or automatic thread cutting machine. Besides hexagonal head the bolt or screw may have shapes as shown in Figure below except the hexagonal and square head which are common in bolts, other forms are used in machine screws. Those at (a) and (b) are tightened with wrench, the bolt or screw with internal socket is rotated with a hexagonal key, at (c) and the screws carrying slits in the head are rotated with screw driver



LITERATURE REVIEW

Threaded fasteners are the most widely used machine elements because they can repeatedly be assembled and disassembled by an easy operation. Mechanical behaviors of the threaded fasteners, such as the strength and the stiffness of bolted joints, have been analyzed by experiment, theoretical analysis based on elastic theory, and numerical method. Finite element method (FEM) is found to be the most powerful numerical method because of development of numerical techniques for solving the problems of bolted joints.

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KIM J et al studied and highlighted non threaded FE models.

LIAO Ridong et al discussed the 2D axisymmetric thread models. Which has been employed to simulate the mechanical behavior of threaded fasteners (bolt and nut) the non threaded models ignore the influence of screw threads on the load transfer in thread connections. The 2D axisymmetric thread models can consider the load transfer and stress concentration in screw threads, but they ignore the helical effect of threads. So it is necessary to build a more effective and accurate model in the case of detailed design.

IZUMI, et al [4] investigated the tightening and loosening mechanism of threaded fastener using a 3D FE model with tetrahedral elements, but their model is too rough to accurately obtain the stress distribution in threads.

FUKUOKA, et al [5] constructed a 3D FE model with hexahedral elements, which provides an approach for modeling of the helical thread effect of thread connection.

S. SAHA et al have discussed the anti loosening properties of different fasteners and they have contributed in brief towards threaded fasteners.

GÖNCZ, P. & GLODEŽ, S. Shown that because of the specific clamping and loading conditions of the slewing bearing rings it is difficult to accurately verify the stress conditions in the connecting bolts with the help of the usual pre-stressed bolted joints calculation methods. The presented calculation model uses a finite element analysis to obtain the axial stress distribution along the bolt axis during loading. From these results the axial working stress σS and the alternating stress σa can be determined. Both stresses serve as a basis for strength verification of the used pre-stressed bolted joints. In the further researches more attention should be paid to the to the working load (FA) determination as the main goal is to determine the dependence between working load (FA) and the belonging bolt load (FS). As many authors already pointed out, in some cases it is a oversimplification to consider the supporting structure as ideally rigid. Beside that an influence of more realistic material, contact and geometrical properties of the bolt should be investigated. This would probably significantly improve the applicability of results.

TONYE K. JACK stated A Method for the Stress and Fatigue Analysis of Bolted Joint Connections: together with Programmed Solution Often the weakest link in integral engineering equipment, bolted joint connections require proper attention and detailed analysis at the design stage for a fail safe operation in service. The analysis is often lengthy with several variables under consideration. A step-by-step guide, together with all required equations for evaluating a typical bolted joint connection is given. A computer programmed solution in Microsoft Excel TM for such analysis is shown through a worked example.

He showed that changing the preload value through altering the preload-to-yield factor, significantly influences the degree of reliability of the joint. The question of an adequate preload is thus best answered by conducting a what-if type analysis with the program. This is also in line with Aaronson's [1] design check for static load condition: Preload ≤ 70% of load at yield point Design check for Fatigue loading condition: Bolt working load or equivalent stress ≤ load at yield point

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