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Review on the Workings of Threaded Fasteners

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ABSTRACT: The most important structural parts are threaded components, which have a considerable impact on the overall strength and endurance of the structural assembly. Threaded connections are utilized because they can create a clamping force and because they can be disassembled for maintenance. Fasteners have also been reported to loosen when subjected to dynamic loads in the form of vibration. This decreases the bolt's preload force, resulting in joint failure. In safety-critical applications, such a failure can be fatal. Some machine parts benefit from threaded fasteners because they can be easily assembled or disassembled without causing damage to any of the components. This is required for clamping, setup, servicing, inspection, and overhauling, among other things. Threaded fasteners, on the other hand, frequently fail to sustain tightening torque under adverse vibration conditions, resulting in loosening. Screw fasteners have a long history dating back thousands of years. Bolt-based threaded fastener is widely used in the industrial and other areas. Threaded fasteners that use bolts, on the other hand, have a tendency to loosen and cause numerous mishaps. The goal of this research is to create self-loosing thread fasteners by using spring characteristic effects on bolt architectures. Three-dimensional (3D) CAD modeling tools are used to introduce helical-cutting applied bolt structures. The finite element model was used to execute analytical approaches for evaluations on the spring characteristic effects of spiral applied bolt constructions and self-loosing preventable performance of threaded fasteners, and the results are presented.

KEYWORDS: Fasteners, Loosing, Bolts, Structural, Clamping.

1. INTRODUCTION

Bolted threaded fasteners are affordable and simple to apply and release [1]. As a result, they're used not only in the industrial field, but also in fields like precision instruments and medicine [2]. There is a variety of bolt fastening methods [3], like using bolts and nuts together or tapping screws, that a designer can choose from depending on the environment in which different goods are used [4]. However, threaded fastener loosening is unavoidable when using the bolt tightening method, and many incidents have occurred and been reported. For example, one of the most well-known accidents was a railroad crash in the United Kingdom in 2002. The railroad switch screw became loose, causing fatigue failure due to vibration, which resulted in this accident. Bolts or screws with locking functions have been invented and developed to prevent such accidents [5]. One of the most popular methods for joining assemblies in mechanical components is with threaded structural fasteners. When compared to other processes such as welding, they make it easier to detach and reassemble components. However, there are a number of drawbacks to employing threaded structural fasteners (i.e., the ability to determine the preload applied to a bolt and the non-linear behavior of a bolted assembly). Figure 1 depicts an example of a bolted assembly.

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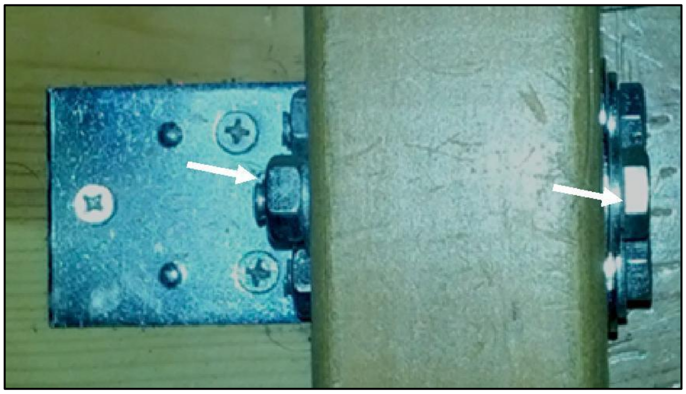


Figure 1: Threaded Fasteners

In engineering practice, a wide range of threaded fasteners are used[6]. These are threaded cylindrical bars that go into nuts or internally threaded holes. Three regularly used fasteners are shown in the diagram below. The head of a bolt is located at one end of the cylindrical body. The form of the head is hexagonal. The bolt's other end is threaded. The bolt is rotated into a hexagonal nut, which may sit on a circular washer, after passing through slightly bigger holes in two segments. A wrench on the bolt head rotates the bolt into the nut. The two components are clamped between the bolt head and the nut, as shown in Figure 2.

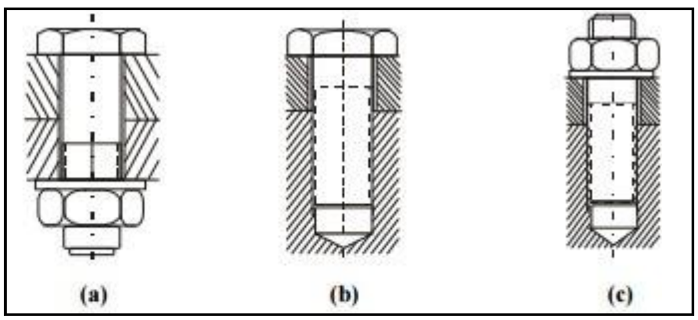


Figure 2: Two components are clamped between the bolt head and the nut.

A threaded fastening is a screw, which has a heads and threads on a portion of its cylindrical body. However, as seen in Figures, a screw's threads are thread into an internally threaded hole. While a bolt tightens a joint between two components by spinning either the bolt or the nut, a screw tightens the pieces by turning the screw with a wrench connected to its head. In the case of screws, friction occurs between the bottom of the bolt head and the surfaces of the part in contact, as well as between the threads of the screw and the hole. Friction occurs at the bolt head or at the nut in the case of a bolt. The wrench must provide torque [7] against friction between the part's surface and the bolt head or nut, as well as in the contact threads. Because the bolt and screw are both pulled, they have tensile force. A stud is another type of threaded fastener that is threaded on both ends but lacks a head. One of its threaded ends screws into a threaded hole, while the other threaded end is threaded with a nut (Figure 3).

Bolts are accessible in the market as ready-to-use components. They are classified as black, semi-finished, or finished, depending on the manufacturing procedure. Hot heading is used to create the head on the black bolt. Threads are either cut or rolled, and bearing surfaces of the head or shank are machine polished. The head of semi-finished bolts is formed by cold or hot heading. Threads are either cut or rolled, and bearing surfaces of the head or shank are machine polished. By machining a bar of the same section as the head, a finished bolt can be made. A turret lathe or an automatic thread cutting machine is used to cut the threads. Aside from hexagonal and square heads, the bolt or screw can have other shapes as shown in Figure below. Machine screws use other shapes than hexagonal and square heads. Those in (a) and (b) are tightened with a wrench, the bolt or screw with internal socket is rotated with a hexagonal key, and the screws with slits in the head are rotated with a screw driver, and those in (c) are rotated with a screw driver.

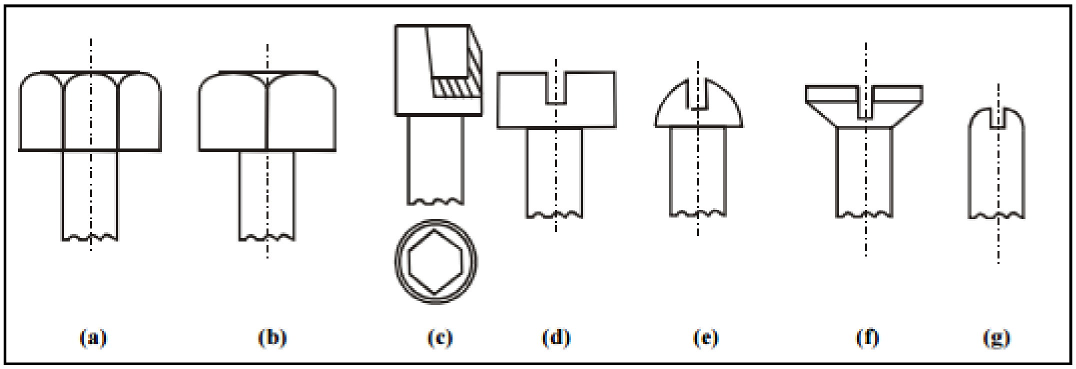
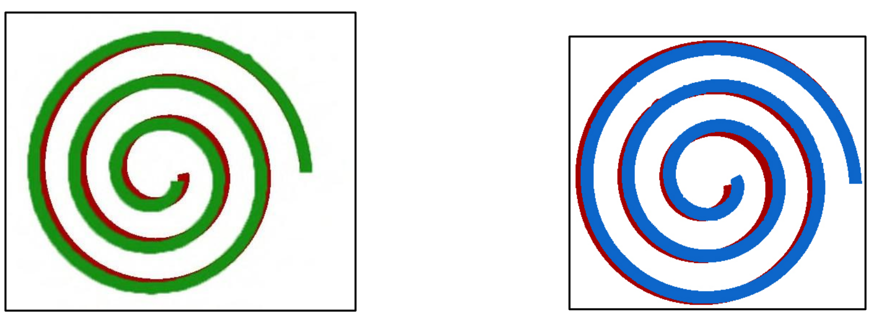


Figure 3: Types o Head bolts

2. Analysis:

The spring characteristics effect, as seen in Figure 4, is of particular importance in our work. The goal is to create self-loosing threaded fasteners that can be prevented by introducing spring properties to bolts. By introducing a helical-cutting procedure to ready-made bolts, spring characteristics can be introduced to bolt structures, resulting in self-loosing avoidable threaded fasteners. Swelling occurs when the spring is rotated counterclockwise (loosing direction), as shown in Figure 4 [a], and shrinking occurs when the spring is rotated clockwise (tightening direction), as shown in figure 4 [b].



[a] [b]

Figure 4. Conceptual diagram of spring characteristic effects. Swelling effect in loosing direction [a], Contraction effect in tightening direction [b].

2.1 Design of bolt structures for self-loosing preventable threaded fasteners

Using the 3D CAD software Solid Works, the structural design of bolts for self-loosing

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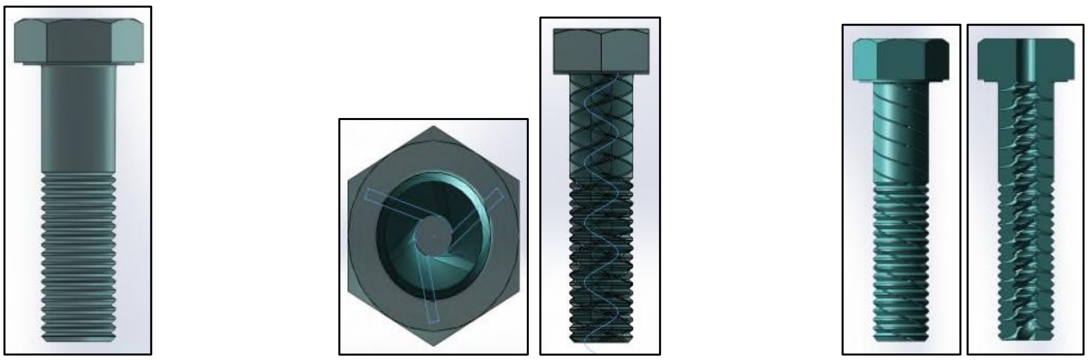
avoidable threaded fasteners was explored. To the general hexagon bolt illustrated in figures 2(a) and 2(b), helical cutting with a cross-sectional shape as the cutting shape and cross thread turning in the opposite direction to the thread rotation direction of the screw is introduced (b). As a result, bolt structures comprised of a multiplicity of springs that cross each other are designed to impart spring characteristic effects.



(a) Conventional bolt (b) Cutting shape & cross thread turning (c) Helical-cutting applied bolt

Figure 5. Image of helical-cutting applied bolt for self-loosing preventable threaded fasteners.

2.2. Analytical evaluation of threaded fastener self-loosing preventive performance

Analytically, the self-loosing preventive performance of threaded fasteners utilizing helical-cutting applied bolts is compared to that of a general hexagon bolt. Figure 6 depicts a Junker vibration test [8]modeled according to ISO 16130 standards, which includes a bolt, nut, fixed plate, and vibration plate. In this model, the material properties of structural steel are also utilized for the bolt structure.

2. DISCUSSION

Fastener failure background:

Fastener failure [9] background Similar to other metallic components, fastener failures include overload, corrosion related cracking, embrittlement, creep, and fatigue. Fastener overload can occur upon installation or in service due to an externally applied load. Fastener overload failure investigation should include assessment of the material properties to determine fastener strength, as well as the loads that contributed to the break. Stress corrosion cracking (SCC)[10], or hydrogen embrittlement in some metals, represents an important failure mode in fasteners due to the static tensile nature of the loading in many applications. Given the expected stresses on fasteners, the material and environment must be carefully considered to appropriately mitigate SCC or hydrogen embrittlement potential. Hydrogen embrittlement can also be caused by improper manufacturing conditions, particularly in plating processes. To reduce hydrogen embrittlement in susceptible materials, fasteners must be subjected to appropriate baking treatments. Creep failures can occur when fasteners are subjected to sufficient stress at elevated temperatures. Again, stresses, materials, and the environment (temperature) must be considered to help mitigate creep damage and potential failure.

Fastener fatigue:

Fatigue[11] is the most common form of fracture of metal structures, accounting for up to 80% of all costs associated with fracture. Fasteners are no exception, as fatigue remains the most common cause of fastener breaks. Fatigue crack initiation and growth occurs when cyclic stresses exceed the fatigue strength of local material for a sufficient number of loading cycles. Fastener material, geometry, stress amplitude, mean stress, and assembly parameters all affect fatigue performance. The fastener assembly process is one of the most important, but often overlooked, contributors to fatigue performance. The cyclic-stress amplitude imposed on a given fastener (and therefore fatigue performance) is highly dependent on preload. Specifically, increased preload results in decreased cyclic stress-amplitude, particularly at loads below the clamping force imposed by the fastener.

IZUMI, [12] 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,[13] constructed a 3D FE model with hexahedral elements, which provides an approach for modeling of the helical thread effect of thread connection.

S. SAHA[14] et al have discussed the anti loosening properties of different fasteners and they havecontributed in brief towards threaded fasteners.

TONYE K. JACK [15]stated A Method for the Stress and Fatigue Analysis of Bolted Joint Connections: together with Programmed Solution Often the weakest link in integral engineeringequipment, 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 variablesunder consideration. A step-by-step guide, together with all required equations for evaluating a typical bolted joint connection is given.

LIAO Ridong [16]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.

3. CONCLUSION

Fasteners are essential components in many structural engineering, and their failure can have serious consequences. Fracture by fatigue is the most prevalent cause of fastening failure, which is frequently caused by insufficient tension and clamping force during installation. Increasing the amount of tensile preload in screws or bolts, contrary to popular belief, might reduce fatigue susceptibility. Some of the essential manufacturing and design factors that affect fastener fatigue are highlighted in a case study of steel screw failures. The steel screws cracked in fatigue for two causes, according to the research. First, fatigue crack initiation was aided by small intergranular cracks, which were likely generated by tempered martensite embrittlement. Second, the assembly torque required to provide suitable preload and clamping force between components was insufficient. Fatigue was fostered by a lack of appropriate preload, which resulted in fatigue crack propagation under service loads.

In this study, self-loosing threaded fasteners with helical-cutting applied bolt structures are designed. Finite element analysis is used to investigate the spring characteristics of helical-cutting applied bolts and the self-loosing preventative performance of threaded fasteners. Based on the findings of the analysis,

- The analytical results of swelling effect under counterclockwise rotating loads indicate the spring characteristic effect of the helical-cutting applied bolt.
- The finite element approach was used to confirm the self-loosing preventable performance of threaded fasteners utilizing helical-cutting applied bolts. In a future study, the findings of the slackness test will be compared to analytical data, and more details on evaluating mechanical properties will be provided.

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