Finding out an Efficient Anti-Loosening Bolt

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1. INTRODUCTION

1.1 Historical Background

Some machine parts are essentially constructed in such a way that they may be readily connected or disconnected without making any damage to the machine components or the fasteners. This is needed for the purpose of holding, adjustment, servicing, inspection, replacement, etc. These requirements are most adeptly fulfilled by the use of screw fasteners. The threaded fasteners continue to be the basic assembly method of industry despite the advances of welding, adhesives and other joining techniques.

It is learned [1] that the screw fasteners were used in the Tigris-Euphrates region around three thousand years ago, primarily for the purpose of irrigation. The plate shaped cross-section of the screw thread was used then. The people of Greece were also supposed to use screws to press olives. The next application that followed was its usage as a feeder [1]. Leonardo da Vinci is credited with the mooting and implementation of this important usage of screw threads. Besides his art works, he left many ideas about the application areas for screws. During his time, the shape of screw threads was square.

Within half a century of Leanerdo da Vinci's death, revolutionary changes in screws were made. The most drastic change came in its shape- from square to triangle. The reliability of screw threads gradually increased, and by 1779, these were applied in the construction of the 'The Iron Bridge' in Telford, England [2]. After that, there were wide ranges of screw fasteners developed and used in various applications.

1.2 Application Areas of Screw Fasteners

A screw fastener is composed mostly of two elements - a bolt and a nut. Frequently one of the parts to be connected is so constructed that it becomes one of the elements of the fastenings. In fact, both the parts to be connected may serve as the elements of fastening, as in the case of a handle with a threaded end to engage in a tapped hole in a lever.

The various advantages realized by the use of threaded fasteners, which has so popularized its large scale use in various fields, are as follows [1,2];

i) Components joined by threaded parts are highly reliable in operation

ii) Threaded fasteners are easy to assemble and disassemble

iii) For various operating conditions, a wide range of threaded couples can be adopted

iv) Standardization has helped in the cheap production and availability for replacement of screw fasteners

v) They can be used repeatedly and manipulated by using very simple tools

vi) They can generate very high fastening force by very simple means and they can keep this force for a very long time

Threaded bolts and screws are generally used [1,2] for the following purposes in engineering;

i) These are used for holding components together e.g. the heads of cylinders, machine members that must be readily disassembled and parts of large machines that must be made in small units for ease in manufacturing, assembling or shipping

ii) For transmission of power, e.g. in lead screws of lathes, screws on presses, etc. these fasteners are used

iii) Screws are also used sometimes as a means of adjusting for obtaining accurate movements as in micrometers

iv) Screwed elements have also application in pumping, pulling and sealing

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Screw threads also have some problems as follows [1] :

i) The presence of numerous points of stress concentration on the threaded surfaces which makes them to go under loads causing varying stresses and necessitates the employment of special methods to improve their endurance

ii) The processing inadequacy of certain specific types of threaded parts, which nevertheless have the highest strength

iii) Continuous vibration can result in loosening of screwed fasteners very easily in some cases

The first two inadequacies of screw threads can be easily overcome, but the last one stated is not so. Loosening under vibratory conditions is a major drawback of screw fasteners.

According to the experiments conducted by Fuji and Sase [1,3-5], loosening of the fasteners occur only when repetitive forces are applied to the right angle of the longitudinal axis of the bolt. To prevent loosening, various types of screw fasteners have been developed. These were tested by Fuji and Sase [1]. The conclusions of these tests are :

i) Fine screw threads have a somewhat greater resistance to loosening

ii) Conventional belief that the spring washers provide extra clamping force is unjustified

iii) Nylon inserted nuts showed little resistance to loosening after loosening its half clamping force

iv) Double nuts and eccentric nuts have considerable anti loosening characteristics

v) Some double nuts did not loosen regardless of the initial tightening force, whereas some loosened gradually and some rapidly.

vi) The data on the eccentric nuts showed much less scatter.

2. MECHANISM OF LOOSENING AND REQUIREMENT OF AN ANTI-LOOSENING THREAD

A study of the loosening mechanism of nuts and bolts by Fuji 1 and Sase [1] revealed the following facts :

i) The nut slides on the fastened plate twice in a rocking cycle

ii) During sliding, the nut turns to the positive direction (loosening direction of nut) together with the bolt. This does not occur during other periods

iii) Just before the nut starts sliding on the rocking plate the bolt slides in the negative direction (its loosening direction)

iv) The relative rotation of the nut to the bolt, twice in a cycle, is one reason for loosening

The cause for the sliding and consequent loosening was explained as follows [1] :

i) The lateral displacement of fastened element makes the bolt inclined and hence increases the tensile stress coming on to the bolt.

ii) Increase of this tensile stress over a limit initiates slip at the engaged flank surface of the screw thread.

iii) The slip takes place not only in the direction of the flank but also in the direction of the axis of the screw thread due to the presence of lead angle.

Thus, the loosening of fastened element occurs due to simultaneous occurrence of the following two factors :

i) Relative slip between the bolt thread and nut thread

ii) Relative slip between the bearing surface of the bolt or nut and the surface of the fastened material

From the above discussion, it can be declared that loosening can be minimized if,

i) The lead angle is reduced

ii) The flank angle is made as small as possible

iii) Reducing relative slip between bearing surface and fastened material by introducing a taper between the bearing surface and the surface of the fastened material

Without sacrificing most of the advantageous features of conventional screw fasteners, if an anti-loosening fastener is found out, this would find wide applicability. In order to reach this objective, some works have been

started in the Mechanical Engineering Department of this college. A test-rig has been set up, which measures clamping force against the number of oscillations of vibration. The decrease in clamping force after a specified number of oscillations is chosen as a measure of loosening. Different nut-bolt assemblies would be tested in this test-rig to find out the best performing fastener under vibrating conditions.

3. LATEST DEVELOPMENTS

3.1 Step Lock Bolt (SLB)

Fuji et al [l] and Hongo [6] have developed a new concept aiming at eliminating bolt torsion. They have named the fastening element step lock bolt (SLB). This has steps on the helix, hence the name step lock bolt (SLB). The part with zero lead angle is the step part and the part with lead angle is the inclined part. The clamping force is supported by the step parts which in conventional threads has a tendency to push out the nut along the flank angle when friction is overcome (Figure-1).

It is expected that SLB threads hardly slip in the direction of the thread. Also due to the presence of the ability to prevent torsion by itself a SLB will not loosen even though the bottom surface of the bolt or nut slips.

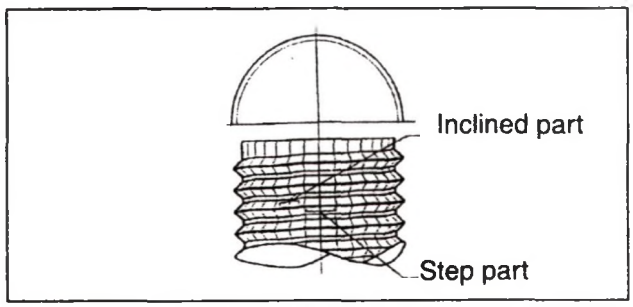

Fig.1 : Outline of a Step Locked Bolt

3.2 Spiralock Bolt

The anti-loosening property of spiralock internal thread form system is simple and the sketch of a spiralock bolt [7] is illustrated in Figure-2. Spiralock fasteners feature a unique 30° wedge ramp. This ramp portion clamps and locks any standard bolt in place by drawing crests of the bolt thread tightly against the wedge ramp thereby preventing transverse movement of the bolt thread with respect to the nut, thus "wedge locking" the threaded joint.

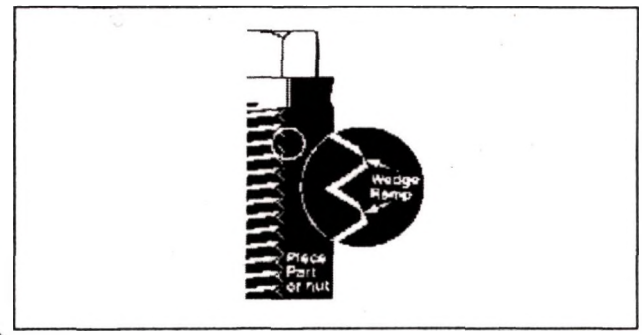

Fig. 2 : Spiralock Bolt

The increase in surface area, thereby increasing the contact friction between the materials and total elimination of the transverse motion as stated earlier, may be the reason behind the development of anti-loosening properties under vibration of these bolts.

3.3 Proposition of Anti-Loosening Thread Profile

3.3.1 BUTTRESS THREAD

This thread profile is in use where axial thrust exists like in the screw of a bench vice. It is proposed that this thread profile should have superior anti-loosening properties. This thread is a combination of triangular and square thread. One flank of the thread is perpendicular to the axis of the thread. The angle between the two flanks is 45°. The clamping force is supported by the straight portion of the flank, and hence the relative slip between the bolt and the nut, which gives rise to loosening torque, is somewhat reduced.

Though this thread is in use where high axial thrust is to be withstood, it is not yet used as a profile with anti-loosening properties. It is proposed to find out (by experimenting in the testing rig) the exact extent of anti-loosening obtained by using this profile.

3.3.2 DOUBLE HAND BOLT

Anti-loosening property can also be observed in the double hand bolt (DHB). A right hand thread profile is initially produced. Next, a left hand thread is superimposed on this thread, thereby producing a DHB. As has been discussed in Section-2, during a rocking cycle two relative slips occur which cause loosening. During the development of this concept, it

has been considered that the loosening direction of a right hand nut-bolt combination is the tightening direction of the left hand nut-bolt combination and vice-versa.

During one rocking cycle, there are four loosening (two for left hand thread and two for right hand thread) and consequently four tightening (two for right hand thread and two for left hand thread respectively) in case of a double hand bolt. Hence, in effect, there is presumably no loosening of the nut-bolt combination of left hand- right hand thread assembly.

4. SCOPE OF WORK

As has been discussed in the Section-2 of this paper, loosening in screw fasteners is caused by the two factors. If either one or both of the two causes can be limited or eliminated, anti-loosening property can be developed. In order to eliminate the relative slip along the flank, the flank angle should be very small (smaller than friction angle), i.e. almost zero. Torsion will not be produced as frictional forces will negate the effect of torsion.

The disadvantage of making flank angle zero or of very small value will result in an increase in the fastening torque requirement as there is no slip expected along the flank. The fastening torque of a screw with zero flank is 1.5-2 times the torque requirement of a conventional screw thread [5,8,9]. Another idea to prevent the bolt from being twisted is to make the lead angle nil. This will reduce relative slip along the lead, even if slip occurs along the flank surface. If this is done, it cannot be called fastener any more.

An idea towards decreasing loosening by preventing relative slip between the bearing surface and the surface of the fastened material is to introduce a taper on the bearing surface and the surface of the fastened material [5]. The drawback of this method is the requirement of very high accuracy in the location of the holes in the fastened material. This increases cost of production and decreases interchangeability with conventional screw elements.

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To invent, you need a good imagination and a pile of junk.

— Thomas Alva Edison