Background to Self-Loosening of Threaded Fasteners

The program will assist in preventing self-loosening by providing information to allow the joint to be engineered such that the causes of self-loosening will not arise.

Some preload loss will occur as a result of relaxation loss. On metal to metal joints, most of the relaxation is due to embedding. Embedding is collapse of the surface asperities within the joint and on the contact surfaces of the nut and bolt. The program will establish what is the magnitude of such losses.

Modern joint design is based upon stopping transverse joint movement from occurring after allowing for the effects of relaxation. The program can assist in this by establishing the preload and joint conditions necessary for this principle to be achieved.

The example that follows shows how the BOLTCALC program can be used to resolve a self-loosening problem without the need for a locking device.
Example of the BOLTCALC Program used to resolve a bolt self-loosening problem
Details of the Joint

A driveshaft is secured to a gearbox on a commercial vehicle by the use of ten M12 property class 8.8 bolts and nuts. Several customers have reported loosening of the fasteners. This is based on finding that nuts/bolts missing during regular maintenance and in a couple of cases, the drive shaft becoming detached during service operation.

There have also been cases that even after checking the specified tightening torque of 80 Nm immediately after assembly, subsequent checks a few weeks later have found the nuts to be almost loose.
A Friction Grip Joint

The torque transmitted by the shaft is carried through the two flanges of the coupling by friction grip. Essentially, the clamp force provided by the bolts generates friction between the two flanges so that the torque is transmitted. The bolts themselves do not carry any significant shear force. This approach allows clearance holes to be used with the associated reduction in manufacturing costs.

The clearance hole diameter used in the flanges is 13 mm. It is required to establish the likely root cause of the problem and what steps can be taken to resolve the problem.
The driveshaft transmits a torque of 7000 Nm in primarily a clockwise direction but also, on occasion, in an anti-clockwise direction. The joint also sustains a thrust/pull due potentially to the splines locking up as the vehicle suspension moves. Based upon experimental work, this pull/thrust is determined to be up to 25 kN. Based upon the coupling loading, it can be determined that each region around the bolt sustains a shear force of 7000 N and an axial loading of 2500 N.
A certain amount of data gathering is required before the details can be entered into the program. In this case it was previously determined that the coefficient of friction between the two flanges is 0.25.

Based upon the forces previously determined, this data can be entered into the program. From the program's main screen, select the menu item 'Analysis Type' and 'Joint Analysis' and the screen shown below appears.
To enter the shear force information, click on the button marked 'Additional Assistance on Shear Force Determination' and the window shown appears.

Enter 0.25 for the coefficient of friction and 7000 N for the shear force and press the Calculate button. The 28000 N shown is the minimum clamp force required to be provided by the bolt to prevent slip.
After click the OK button, click on the Bolt Details tab on the Joint Analysis Entry Form. The screen shown is revealed.

Examples in the use of the Program

Self-Loosening Problem
Click on the button marked 'Select Thread Size from a Database' and the window shown is revealed. Scroll down so that the thread size 'M12x1.75' Coarse Thread is selected and then press the OK button.
The information regarding the bolt thread size is transferred from the thread database and recorded on the Bolt Details Form. The Bolt Clamp Length for this joint is 40 mm. This is entered as the clamped length as shown in the image:

**BOLTCALC**

**Entering information into BOLTCALC**

The information regarding the bolt thread size is transferred from the thread database and recorded on the Bolt Details Form. The Bolt Clamp Length for this joint is 40 mm. This is entered as the clamped length as shown in the image:
Click on the Property Details Tab and the screen shown is presented.

**Fastener Strength Grade Selection**
- **Bolt Standard** (Optional)
- **Grade or Property Class (Optional)**

The Fastener Material Database contains listings of the most common fastener materials.

A key value used in the calculations is the yield strength of the fastener material. Because for many bolting materials there is not a definite yield point that is easily defined, the 0.2% permanent set stress is usually specified instead.

**Fatigue Properties of Fastener Material**

To determine if the fastener will fail as a result of fatigue, the endurance limit must be determined. The program can calculate the endurance limit based upon equations fitted to test data.

Lower bound values used to allow for the inherent scatter in such data and depends upon the diameter of the bolt and the production process used to produce the thread. The default value is for the threads to be rolled before heat treatment.

If the bearing surface of the bolt head or nut is out of square with the bolt axis, then a reduction in the fatigue endurance strength can be anticipated. Click on the button for a form to be displayed to allow for this effect to be taken into account.

**Modulus of Elasticity for the Fastener**
- **Modulus of Elasticity for the Joint Material**
  - **Steel**, **Aluminium**, **Other**
  - **Modulus of Elasticity**

Note: There is no need to enter a value here if a multi-plate analysis is to be completed.
To enter details of the bolt strength used, click on the button marked 'Consult the Fastener Material Database' and the screen shown is presented. Select 8.8 as the property class and then press the OK button.
The information from the Fastener database is then transferred onto the form, as shown.

The default values presented by the program will be accepted.
Select the Joint Details tab and the screen shown is presented. In this example, all the default values presented by the program will be accepted.
Select the Tightening Details Tab and the screen shown below is presented. The Tightening Factor is a measure of how much scatter there will be in the bolt preload.

The default value used by the program of 1.6 is typical of torque tightening. The default value for the friction in the threads and under the nut face of 0.12 will be used in this example.
Entering information into BOLTCALC

The tightening torque used in this application is 80 Nm. To enter this value into the program - click on the radio button marked 'Tightening Torque' in the Bolt Tightening Condition section and the form shown appears:

Click the OK button on this form. All the essential data has been entered into the program. Press the 'Calculate' button and a joint analysis will be performed by the program.
Results of the BOLTCALC Joint Analysis

The results of the analysis can be summarised by the Preload Requirement Chart. This is presented below for this joint.

To view the chart, select the menu option, View, followed by Preload Requirement Chart.
Essentially, a Preload Requirement Chart looks at the forces acting on the joint interface. The red area is the anticipated variation that will occur in the bolt preload. The green area on the right of the chart is the clamp force loss due to embedding. Embedding is a form of relaxation and is the collapse of the surface asperities of the clamped surfaces.

The yellow area is the axial force reducing the clamp force. In this joint it is the result of the force trying to pull the joint apart. The large blue area is the clamp force needed to prevent the joint slipping. Add these component forces together and you get the grey area which is the total preload requirement.
Since there is an overlap between the grey and red areas, it indicates that potentially the joint will slip. Joint slip is the primary mechanism that threaded fasteners self-loosen. It is likely that the preload being insufficient is the root cause of the loosening problems being experienced.
Essentially, the options available to resolve this problem is to either increase the bolt preload or decrease the forces acting. Increasing the bolt preload can be completed by increasing the size of the bolt or its strength, decreasing the forces acting on an individual bolt region can be achieved by increasing the number of bolts.
Using a locking device that works may prevent the self-loosening problem, in part. Since the joint movement is still likely to occur what will happen is that the bolt will experience some bending. Repeated many times there is a likelihood that the bolts will fail by bending fatigue. This, together with self-loosening, are the common modes of failure when joint slip occurs.
The easiest solution to implement is to increase the strength of the bolt and increase the tightening torque so that the increased strength is utilised. Checking if this is a feasible solution by changing the bolt strength to property class 10.9 and increasing the tightening torque to 110 Nm. The Preload Requirement Chart shown is the result.
Solving the Self-Loosening Problem using BOLTCALC

As can be seen there is a gap now between the total preload requirement and the minimum preload value indicating that the joint will no longer slip. Engineering judgement comes in when deciding whether the gap between the values is sufficient in this application or whether other measures/changes are needed.
A results summary sheet can be created by the program presenting the key results. The excessive surface pressure could be resolved by the use of washers.