Why use washers?
By Bill Eccles – Bolt Science

Washers have traditionally been used to protect the joint surface from damage during the tightening process and to distribute the load under the bolt head and nut. The stress under the face of a standard hexagon headed nut can result in indentation into standard strength steel surfaces. In recent years washers have started to be replaced by flanged headed fasteners for several reasons that will be discussed in this article. Prior to going into the details, let's look at some background.

The way in which this can affect replacement fasteners is that the original equipment manufacturers (OEMs) specify the tightening torque based upon tests or calculations on the fasteners that are installed on the equipment. Many OEMs specify flanged headed fasteners (figure 2) for a number of reasons. Using a replacement fastener not of the same type, strength and finish as that originally specified will lead to potentially serious problems since the torque-tension characteristics will be affected. That is, the preload generated by the tightening torque may be insufficient to prevent the joint or the bolt failing.

Flanged headed nuts and bolts have been developed to eliminate the deficiencies that have been found with the use of washers.

Standard washers are typically softer than the nuts and bolts that they are used with and can often plastically deform under the high compressive stress that they must sustain. For higher strength fasteners, this can lead to the washer disching and indenting resulting in the clamp force being reduced significantly. An example of such a washer is shown in figure 3.

Flange headed nuts and bolts do not suffer from this effect since the washer face is as strong as the bolt/nut itself.

To overcome the indentation problem, special hardened washers can be used, however, such washers are not available usually off the shelf. Research conducted in the 1980’s in the U.K. showed that because of the clearance hole in the washer, an eccentric loading can occur that can lead to very high localised stresses. A reasonably large clearance hole in the washer is needed to ensure that the radius that is present under the bolt head does not contact the hole edge. Such clearance on the nut can lead to the washer being tightened eccentrically to the bolt axis. This leads to a high localised load concentration increasing the risk of indentation and joint damage. This effect is illustrated in figure 4.
One further effect that was noted in the research was movement of the bearing face during tightening. Normally when the nut is tightened, the nut moves on a stationary washer. However, it has been found that sometimes as the nut is being tightened, the washer begins to rotate on the joint surface. That is, the nut and the washer rotate as one. The effect of this is shown in Figure 5. The relationship between the applied torque and bolt tension can change. For a given applied torque this can result in a significant loss of bolt tension. Unless careful observation is made during tightening, you will not be able to tell whether this effect has happened or not.

Figure 5

One final consequence of using washers is an effect referred to as embedding. Surfaces that may feel flat are anything but flat when viewed under a microscope. A photo of the surface of a zinc plated washer is shown in Figure 6. As you may be able to predict, when this surface is placed into contact with another, only the tops of the surfaces touch.

Embedding is a result of local plastic deformations that occur under the nut face, in the joint faces and in the threads as a result of plastic flattening of the surface roughness. To some extent, this always will occur when two surfaces are placed in contact and loaded. It is known that the majority of embedding losses arise when the working load is first applied to a joint changing the contact pressures. The adverse effect that this can have on the joint's structural integrity is obvious.

As has been explained, there are several reasons as to why flanged nuts and bolts are preferred over standard hexagon fasteners used with washers. The sensible approach is to replace like fasteners with like fasteners; unless you are feeling lucky.

Bill Eccles is a Chartered Engineer and formed his company Bolt Science some 12 years ago to specialise in bolting technology. The company writes and markets bolted joint analysis software together with completing consultancy assignments and training courses.

Further information is available from Bill via email (bill@boltscience.com) or from the website at www.boltscience.co.uk

Figure 6