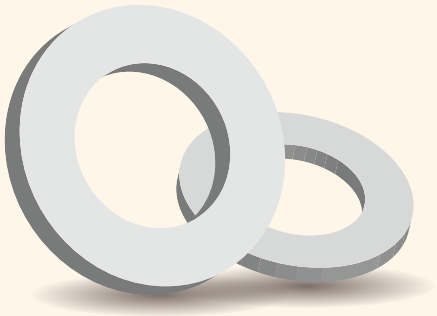

Do We Still Need Flat Washers?

by Guy Avellon

Many times, the question is asked; do we still need washers? The short answer is: yes.

Besides adding a line item to an order, flat washers will offer the customer several advantages; if the surface is rough, the washer covers it and provides a smooth and even load bearing surface; against softer materials, the washer will prevent embedment of the nut or bolt head into the joint material; the washer will protect the surface of the joint material; the washer will assure joint integrity by bridging slightly oversized holes to provide support to the fastener; promote electrical conductivity and contribute to the vibration resistance of the connection.

The maintenance supervisor may have ordered Grade 8 bolts and nuts but the P.O. just says 'washers', it is best to match all of the products with the same performance characteristics, as there are several choices to make; plain wrought washers or hardened, USS or SAE, plain finish, zinc electroplated or galvanized?

USS or SAE?

Among the first known commercial flat washers were the wide style USS flat washers. The USS designation was derived from the name "Unified Standard Series". At the time, coarse threaded fasteners were also called USS bolts. Even today, many will still refer to coarse threaded bolts as being USS and will also believe that the USS flat washer is meant to be used with the 'USS' coarse threaded bolt. As we shall later see, this is not the case and is incorrect for many applications. The 'USS' term has since been replaced with the UNC designation, which represents Unified National Coarse, to properly identify this thread style.

The USS flat washer was first developed in the early 19th century for applications involving compressible materials, such as wood, thin sheet metal, etc. The outside diameter was wide enough to provide a large surface area to prevent embedment of the bolt head into the material and minimize joint compression while the inside diameter was large enough to accommodate bolts with very loose tolerances for handmade bolts of that era.

Since the Great Industrial Revolution, more equipment and machines were made of steel, which did not compress as did the wood. Therefore, the smaller, more compact SAE flat washer was developed and named after the Society of Automotive Engineers.

The inside diameter of the SAE flat washer is much closer to the diameter of the size of bolt it is to mate with since the bolts of today are all manufactured to close tolerances by machine from cold forming to hot heading. The outside diameter of the SAE flat washer is also smaller as it does not need to provide for a large load bearing surface area to prevent compression as did the USS washer against compressible materials.

Figure 1 illustrates the dimensional differences between the same internally sized flat washers: the USS flat washer being on the left and the SAE washer on the right.

Fig 1

The inside diameter of the USS flat washer is between 5-7% larger on average, than the SAE washer.

The common thought was to pair the USS flat washer with the coarse (USS) threaded bolt and the SAE flat washer with the fine thread (SAE) bolt. This is not always the best scenario to follow, especially when using higher strength fasteners such as Grade 8 (10.9) and even Grade 5 (8.8), as this practice could ultimately lead to failures in high strength joints if the inside diameter is too large to handle the service loads and the washer material is not correct for the application.

Material Strength

For steel flat washers, there are two choices; plain or hardened. Flat washers are not designated by grades, per se, with the exception of structural washers under the ASTM (American Society for Testing and Materials) Standard F436.

Many commercially available flat washers are 'plain', which means they are made from cold rolled low carbon steel and are fully annealed and dead soft. The hardened flat washers are made from high carbon steels ranging from 1038 to 1060 and are heat treated to 38-45 HRC. These hardened flat washers may be identified by retailers and distributors as 'Grade 8' or 'hardened' flat washers.

With the demand of today's heavy loads and critical applications, the correct choice of flat washer is extremely critical. For example, **Figure 2** represents two incorrect choices: the style of flat washer and the material.

Fig 2

In order for the flat washers to display such indentations, the washer material must be soft enough to allow the embedment of the hex head. Both flat washers (**Fig. 2**) were made from plain carbon steel, such as 1010 low carbon steel. These plain carbon steel flat washers are soft when compared to the hardness and loads expected of a Grade 5 or 8 fastener. These washers are so soft, that when just tightening the bolts, the hexagon heads of the bolt embedded themselves into the washers.

The inside diameter of the USS flat washer on the left is so much larger that it does not display the full hexagon shape of the bolt head. Therefore, the bolt did not receive full support for the applied loads. The smaller inside diameter of the SAE flat washer does exhibit the full hexagon shape of the bolt head, indicating this will provide full support of the bolt.

Fig 3

Figure 3 illustrates another 'plain' soft washer with indentations made from the nut while tightening during assembly. It doesn't matter if the washers are under the bolt head or the nut, the fastener will compress into these flat washers and clamp load will be lost.

Does this make a difference? Definitely!

Applying Hooke's Law to a fastener, which is Stress = E (elongation) x Strain, there is a direct relationship between the amount of stress (clamping force) and how much strain (bolt stretch) the fastener experiences. Conversely, if elongation is lost from embedment into a clamped material, clamping force will be lost.

Simply stated; for each one-thousandth of an inch of bolt relaxation, per inch of loaded length (grip), the amount of 30,000 pounds per-square inch of clamping force will be lost. This alone will account for the loss of at least one grade of bolt strength.

Hardened Washers

The preferable alternative is to use through-hardened heat-treated washers. Since most flat washers are not marked, it is only natural to purchase the least expensive flat washer and end up with a 'plain' washer in a high strength joint. Even after the initial embedment into the plain washer, subsequent service loads from vibration or impact loads, will cause the bolt head and / or nut to further compress into the washer and lose more clamping force in application service.

Some washer manufacturers will have an 'MC' stamped on them to identify hardened washers as 'mill carb'. Most are not plated and are furnished with a black heat treat oil finish. Some private label distributors will have these flat washers identified with their own unique markings.

For the MRO industry, it is common to offer some type of shelf life to the customer in the form of a protective coating. Many of the 'plain' washers are silver in color from the zinc plating. Many of the premium hardened washers are also plated with zinc but have a yellow chromate color. Another option, to assure prevention of hydrogen embrittlement, is to apply a mechanical zinc coat.

Mechanically applied coatings are formed with impinging metal or glass beads on to the parts in a metal slurry. The effect

Fig 4

produces a thick, corrosion resistant coating that has a matte finish. **Figure 4** will illustrate the dimpling effect in an extreme condition. Normally, the products will be smoother and not as pock-marked.

In the automotive industry, all Grade 8 or 10.9 fasteners have SAE hardened flat washers under the head or nut. Since these fasteners are virtually stronger and harder than the materials they clamp, it is extremely important these fasteners are fully supported under the head with a washer that is harder than the bolt.

Fig 5

Sometimes, being harder isn't going to correct inappropriate installation technique and application. **Figure 5** are two hardened machinery washers that were still destroyed by means of an impact gun.

Many ASTM F436 flat washers are still marked and identified with the 'F436' standard designation, although it was recently voted by the ASTM Fastener Committee that they do not need to mark them as their size would identify them. The F436 flat washers have a slightly larger ID than the SAE washer, but not as large an OD as the USS washer dimensions. This is to accommodate the larger head and nut dimensions of the A325 and A490 structural bolts and 2H nuts.

Many times, when structural bolts are used on harder steel joints, a flat washer is not used under the bolt head due to the wider heads of structural bolts, However, the washers are used against the nut to provide a smoother surface to turn the nut.

Final Thoughts

- Do not try to fit two different diameters of bolts into one size USS flat washer. It will work for some sizes but will be extremely tight against the larger bolt. This may interfere with the fillet area under the bolt head and cause possible increased head stresses and failure.
- Use hardened flat washers with all Grade 8 (10.9) fasteners. It is also recommended for use with Grade 5 (8.8) fasteners as well.
- Use SAE flat washers to provide full contact and support with all high strength fastener applications.
- Always use an SAE flat washer under the bolt head and nut on standard fasteners.
- Even an impact wrench can damage a hardened flat washer when being assembled at full impacting speed. Slow down. ◻