

When Washers

Fail



Fig. 1. Washer fracture

The Helical Spring Lock Washer

Millions of lock washers are sold every year; more likely, every month. Why do we sell this much? Because users ask for them because of prior use or they are automatically included in assortment kits.

This is one product which has caused many debates over the years as to its usefulness in today's environment and this section will undoubtedly spur even more controversy. That is to say, there are many other products on the market whose performance and reliability is far superior to the venerable lock washer.

But first, let us put this into proper context: **there are many applications where the common lock washer will work, what it was designed to do originally, while there are others where it does not. In fact, its use could be dangerous.**

The common lock washer is a helical spring. At one time it was also referred to as a 'split washer' since there are two ends. One end was slightly bent upwards and the other bent down. Both of these 'ends' may have sharp corners from the forming operation which may help its effectiveness by digging into the surface of a softer joint material.

Lock washers are made from medium carbon steel (1055-1065) heat treated to a Rockwell hardness of up to C45. They used to be as high as 51 Rc but were lowered in the mid-1990s. Originally, they were electroplated. However, their high hardness made them very susceptible to hydrogen embrittlement: a delayed brittle failure caused by atomic hydrogen being absorbed into the steel during the plating and/or a chemical cleaning process. The current trend is to have the lock washers mechanically zinc plated to minimize the potential for hydrogen embrittlement.

How Lock Washers Work

When either the nut or bolt head is tightened against the lock washer, the open ends are compressed against the surface of the joint flattening the washer. The idea is, if clamp load is lost, the sharp ends of the lock washer spring into action by producing a counter force against the nut or bolt head and the joint surface to prevent any further loosening.

The fact is **the fastener or joint must first lose clamp load or have moved sufficiently to cause the lock washer to spring open enough to produce a counter force against the nut and the joint surface.**

A relative amount of clamp load is lost from just a slight amount of movement of the joint. Going back to Hooke's Law; a joint losing 0.001", per inch of joint thickness, will produce a clamp load loss of 30,000 pounds per square inch. This is significant enough to cause further loosening or the beginning of metal fatigue on the lock washer.

The basic problem is with the user's perception between what the lock washers can do and what they want it to do. A lock washer does not improve nor increase a fastener's ability to maintain preload nor will it prevent preload from being lost.

How It Really Works

The last statement is very powerful and should be remembered: **a lock washer will not prevent preload from being lost.**

Springs flex. If compressed, it will produce a force in the opposite direction. This is the reaction of a coiled spring. A helical spring is of but one revolution and acts a little different. If the washer compression is graphed on a load cell, the spring rate looks like an 'S' curve.

This means that when it is fully compressed, there is little to no backwards force as the preload applied to the fastener takes precedence. As the preload decreases, the split ends of the lock washer open and the backwards force begins to increase. This is the point where the 'locking effect' takes place. Continuing through the 'S' curve, there is also a point where it decreases again, much like drawing on a compound bow, then increases again.

Essentially, for a lock washer to work, something must go wrong: the joint becomes loose. The fastener wasn't properly tightened during the initial installation and preload was lost, or the preload was lost in service from excessive loads or was lost due to compression from the joint materials.

So let's say the lock washer is doing its job. The ends are only opened a few thousandths of an inch. Visually, this is impossible for anyone performing a visual PM (Preventive Maintenance) to detect, due to dirt or positioning. The joint stays loose for a while, absorbing the daily cyclic impact of the service loads on the connection.



When the joint and lock washer begin to absorb these normal service loads, the joint and lock washer compress. Once the load is switched off and removed, or cycles, the joint and lock washer ends spring back open again. This cyclic compression and relaxation promote metal fatigue in hardened steels. Soon, the lock washer separates from fracture (Fig. 1).

The dangerous condition here is, there is no warning of any imminent failure. Now, with the lock washer gone, the nut is free to vibrate off and disassemble because we used a standard free-spinning nut.

As far back as 1969, the SAE (Society of Automotive Engineers) recommended against the use of helical spring lock washers with any Grade 8 (10.9) fastener and in any critical application. In the early 1980s, the specifications for lock washers were removed from the SAE Handbook. However, dimensions, specifications and testing methods can still be found in the IFI (Industrial Fasteners Institute) Handbook referencing the ANSI/ASME B18.21.1 standard.

There have been instances where a less expensive lock washer, due to inadequate hardening or thickness, would actually spread open during tightening. (Fig. 2)



Fig. 2. A lock washer opens during tightening

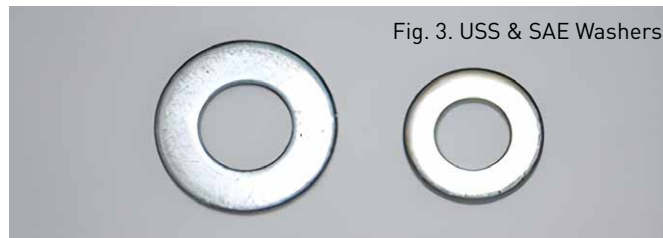


Fig. 3. USS & SAE Washers



Fig. 4. Soft washer



Fig. 5. Deformation

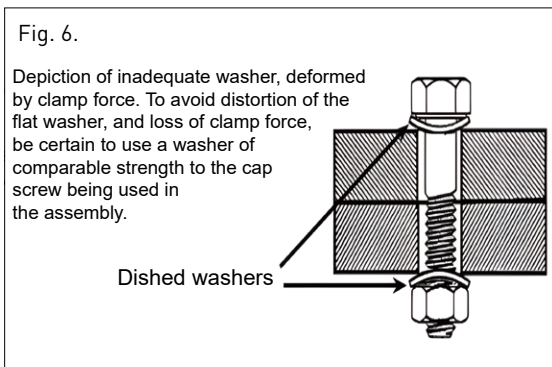
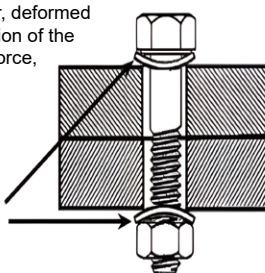


Fig. 6.

Depiction of inadequate washer, deformed by clamp force. To avoid distortion of the flat washer, and loss of clamp force, be certain to use a washer of comparable strength to the cap screw being used in the assembly.

Dished washers



Flat Washers

We have always had a choice between the style of ordinary flat washers to use. However, choosing the incorrect type for some applications can cause failures.

Many years ago, USS stood for United States Standard. The current terminology is 'Unified' when related to threads. Therefore, when we specify UNC threads, it means Unified Coarse. UNF would indicate Unified Fine.

However, the larger diameter series of flat washers are still named USS. This does not reflect on the type of fasteners it needs to be mated with, such as a USS washer and a UNC (USS) bolt. The better choice to offer customers is the SAE (narrow) flat washer to be used with all SAE Grade 5 and Grade 8 inch fasteners and/or 8.8 and 10.9 Property Class metric fasteners, because the inside diameter of the SAE washer is smaller than the USS washer and will support the entire load under the fastener's head whereas the USS inside diameter is too large for most applications.

In Figure 3, the larger USS flat washer is on the left and the SAE flat washer is to the right.

When soft washers from annealed steel are used under the head of the bolt, the bolt head can cause massive distortion to the washer and does not fully provide support under the bolt head, as in Fig. 4.

The same type of deformation and loss of clamp load will occur when tightening a washer under the nut. (Fig. 5)

Figure 6 is another illustration of using an inadequate washer and/or having the hole in the joint too large.

It is also important to realize that a large washer will not increase the load bearing resistance on hard materials. The flat washers work well on softer materials, such as fiberglass, plastics, bumpers, etc. A flanged nut will increase the stress load over the joint and maintain joint integrity. (Fig. 7)

Conclusion

- If the parts did not come from the factory with a lock washer, do not use one for repairing the part.
- If the flat washers look like any in Figure 4 or 5, use hardened flat washers.
- It is always best to use an SAE style flat washer against hardened steel.
- Flanged nuts and bolts (Fig. 7) will increase the load bearing surface area. ■

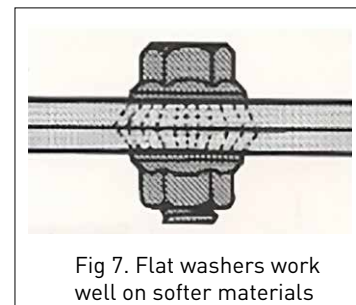


Fig 7. Flat washers work well on softer materials

Copyright owned by Fastener World
Article by Guy Avellon

