I have been in the fastener industry for 26 years now and I am still learning. Recently we had a case of a very experienced contractor reporting that our Squirter DTI® washers were not squirting. We supplied a new batch (all our Squirter DTI® washers are individually marked with a unique batch number) and then started an investigation. Within hours, the contractor was reporting that our AS1252 flat washers were cracking. Again, we immediately resupplied a new batch of AS1252 assemblies and started investigating. The contractor did not report any more problems, yet we found absolutely nothing wrong with any of the product returned.

We carried out compression tests on the Squirter DTI® washers, tensile tests on the bolts, hardness tests on the washers, and even performed cross sectional Vickers hardness tests on all items.

Each of these tests was carried out at HOBLAB, our affectionate name for our NATA endorsed Fastener Testing Facility. The solution should have been obvious to us, but the fact that we had no other reports from other users, and new batches “seemed” to fix the problem, complicated the answer. After researching AS4100 “Steel Structures” and the definition of an oversized hole and the NATA reports on the washers, the answer was revealed....

The contractor was working with 23mm oversized holes, they were in excess of 1mm larger than the standard states for a M20 bolt assembly, and there was also a 1mm chamfer, which in fact effectively made the hole 25mm. At this point, I want to make it clear, oversized holes are acceptable, but AS4100 states “An oversize hole may be used in any or all plies of bearing-type and friction-type connections, provided hardened or plate washers are installed over the oversized hole under both the bolt and the nut”. This explains why the Squirter washers were not squirting; they were getting “pulled” into the oversized hole and the dimples were not getting compressed. Arrgh..... but you ask why did the replacement batches seem to work correctly?
The answer lies in the flat washers. The first batch was right on the top range of the hardness figures allowed by AS1252-1996, the replacement batch were in the middle of the hardness range. Hence the first batch cracked under the increased load resulting from the oversized holes, the second batch probably deformed without cracking.

This issue started me thinking. AS4100 requires extra washers, but it does not detail the exact washer to use. So I went to Professor Saman Fernando and asked him to prepare a report on the subject for me. I have known Saman many years and he holds the same goal as us at Hobson Engineering..... to lift the quality of fasteners and their installation practices in the industry, in order to prevent unnecessary injuries and engineering failures. Relevant extracts from his report are below. I hope you find it as educational as I did.

"Most fabrication standards such as AS4100 / AS3990 etc. prescribe that the hole size must not exceed 2mm (for up to M24 and 3mm for greater than M24) larger than the nominal bolt size. The bolt assemblies; i.e. Bolt, Nut and Washer are designed for this condition. However, in some situations, it is necessary to use either elongated holes or oversized holes due to other fabrication requirements. When this is the case, the engineer and the fabricator should be aware of the additional actions that need to be taken to overcome the potential negative effects resulting from this situation.

The main function of the washer is to evenly distribute the large pressure (stresses) exerted by the bearing surface of the high tensile bolt/nut on to the low tensile joint plate in such a way that the bearing stress on the low tensile joint plate does not exceed the yield stress of the material. The second function of the washer is to avoid damage to the joint plates during the rotation of the hardened tightening member of the assembly (bolt head or nut). The harder surface on the washer will not be scarred by the harder surface on the bolt or nut. That is why a high strength washer is always placed under the rotating member of the assembly. The washer should remain stationary when tightening the Nut/Bolt.

The diameters of washers are designed to distribute the stresses as evenly as possible over a large area, thus reducing the maximum stress on the joint material. The high pressure applied on the washer by the bearing surface of the high tensile bolt/nut is balanced by the reaction pressure generated by the joint surface. The material of the joint is locally deformed proportional to this reaction pressure. More deformation will occur at the edge of the bolt hole where the stresses are largest, with deformation decreasing outwards. As these unbalanced forces closer to the bolt are accounted for in the design of the washer, they do not lead to significant bending or cause significant tensile stresses on the washer.

With increase in diameter, the outer periphery of the washer experiences a lower reaction pressure from the joint plate. The reaction pressure is always associated with a corresponding deformation, based on Young’s modulus.

As the Young’s modulus, most likely, is the same for the washer material and the joint material, the thickness of the hardened washer helps reduce the deformation of the low tensile joint surface by distributing the stresses over a larger area. This will, however, cause a small upward bending moment, giving a cupping tendency to the periphery of the washer. In order to control this tendency, the washer thickness and hardness are selected in the design of a washer.
Hardness will reduce the possibility of yielding of the washer, and thickness will reduce the deformation of both washer and the joint surface. This reduction in deformation helps redistribute stresses over larger areas, thus lowering the maximum stresses on both washer and the joint surface.

This will incur downward bending on the hardened washer and generate tensile stresses on top fibres close to the neck of the bolt. At the same time, the outer boundary of the bearing surface of the nut/bolt will also experience upward bending due to longer fetch, and cause undue tensile stresses in the bottom fibres of the washer. This combination could lead to tensile failure of the washer during the tightening of the bolt, as this condition is not allowed for in the design of the washer.

If the washer failure did not occur during the tightening of the bolt, this condition will cause uneven deformation in the joint due to a part of the joint not being supported as intended in the design. This will reduce the joint stiffness. This in turn will reduce the stiffness ratio between the bolt and the joint and significantly alter the dynamic properties of the joint. If the joint is subject to cyclic loading, this condition could cause premature washer failure followed by bolt failure due to poor dynamic performance of the joint.

In AS1252:1996 version, two hardness ranges are prescribed for structural washers. This is a deviation from AS1252:1983. In the latter version, a lower hardness range 28HRC-45HRC, is allowed for HDG washers. For plain hardened washers, this range is 35HRC – 45HRC, the same as that of the 1983 version. If the washer is of lower hardness, it would be permanently deformed at tightening due to yielding as a result of undue stresses as discussed above. This will further compromise the geometry and stiffness of the joint leading to the same effects as discussed before.

As oversized holes are not uncommon in structural engineering, there should be a proper way of addressing this issue.

By looking at the failure mode, as discussed above, the easiest and simplest solution available for this problem is to use multiple hardened washers between the bolt/nut and the joint surface. This will increase the effective thickness of the washer and the stresses will be redistributed, avoiding excessive stresses and deformation on both washer and the joint material. This will help maintain the joint stiffness.
As sizes and shapes of oversized holes vary, it is not possible to prescribe the number of washers to be used for each oversized hole. If the oversized hole is very large, one may seek larger OD (large series) washers as any number of normal series washers may not help. Some trials at tightening should be carried out to determine the optimum number of washers to be used. No visible deformation or no cupping of the washers should be noticed in the tightening process. The only negative with this approach is the bolt length needing to be increased to accommodate extra washers.

The international standard for normal series through hardened washers is ISO7089:2000 and for hardened and tempered structural washers is ISO7415:1984. For the dimensions of large series washers, ISO7093.1:2000 or ISO7094:2000 should be used with hardness 300HV. However, with AS1252 bolt assemblies, it is recommended that hardened washers made to AS1252 are used.”

**Hobson Newsfeed:**

*Melbourne Cup*
Hobson Engineering have added to their growing CONXTRUCT range. We are now stocking MKT globally approved adhesives. The Hobson MKT adhesives range offers European Technical Approvals (ETA) and other industry approvals. Our adhesives have been tried and tested in a wide variety of applications and in all sorts of conditions, for peace of mind and proven performance where it matters.

Chemical Anchor V
- Glass capsule filled with resin, hardener and filler.
- The three materials combine to create a fast curing resin-mortar when the threaded stud is driven into the drill-hole.
- Designed to anchor steel elements or rebar to concrete; works in both damp or dry concrete.
- Fire rating of 30 to 120 minutes.

VME-EPOXY
- Epoxy based chemical anchors are ideal for heavy duty anchoring applications.
- Designed to anchor steel elements or rebar to concrete.
- Suitable for cracked concrete, and damp or water-filled holes.
- Being a slow-curing epoxy, there is more flexibility in minor adjustments and deep embedment.

VM-K Styrene Free Polyester
- Polyester-resin based injection mortar.
- Designed for bonding threaded rods, and reinforcing steel in concrete, masonry or natural stone.
- By using a special (metal or plastic) perforated sleeve, a secure fastening is also possible in perforated masonry.
- Suitable for interior or exterior applications.
- Opened cartridges can be re-used with a new static mixer.

VM-PY Polyester
- Polyester-resin based injection mortar.
- Designed for bonding threaded rods, and reinforcing steel in concrete, masonry or natural stone.
- The adhesive is injected directly into the drilled hole or perfo sleeve with a dispenser gun.
- Opened cartridges can be re-used with a new static mixer.

... Further information, including pricing, is available from your local Hobson branch representatives.
Despite many modern and very effective systems to prevent fastener assemblies loosening, such as Nord-lock Washers, Schnorr VS washers and thread adhesives, a system that is over 150 years old is still sometimes used. Like most things, there is a right and wrong way of using this method. Although it may seem counter-intuitive, the thin nut should go next to the joint and not be put on last.

This article covers the correct tightening method to achieve effective locking. The correct property class of the thin (locking) nut is also detailed and many will find this information very surprising.

Tightening one nut and then simply tightening another nut on top of it achieves little locking effect. A specific procedure needs to be followed if locking is to be achieved.

The thin nut should be placed on the bolt first. This nut is typically tightened to between 25% to 50% of the overall tightening torque. The second (thick) nut is then placed on the bolt and the thin nut held to prevent rotation by a spanner whilst the thick nut is tightened to the full torque value. The series of diagrams show the effect that the procedure has on forces present between the nuts and in the bolt.

When the thick nut is tightened onto the thin nut, as the load increases, the load is lifted from the pressure flanks of the thin nut.

As tightening continues, a point is reached when the bolt thread touches the top flanks of the thin nut. At this point $F_3 = F_2$. Continuing to tighten the top nut results in the jamming of the threads leading to $F_3 > F_2$. If tightening is continued, the force between the two nuts will continue to increase. If the thick nut is over tightened, there is the risk of thread stripping or the tensile fracture of the bolt between the two nuts.

The reason why the two nut system is effective in resisting self loosening is due to the way the threads are jammed together (hence the term jam nut being frequently used for the thin nut).

Since the bolt thread is in contact with the top flank of the small nut and the bottom flank of the top nut, relative thread movement is not possible. For self-loosening to occur, relative movement between the bolt and nut threads must occur. It is this jamming action that is the secret of the two-nut method.

The lower nut is tightened to a simple torque value.

A Junker vibration test machine was used with M10 nuts and bolts. The results are illustrated in the following graph. With the small nut on top, both nuts can be observed to rotate together and can subsequently come completely loose.

The results are slightly better than is normally observed with a single plain nut. With the small nut next to the joint, some relaxation occurs but not a significant amount of self-loosening.
Many of you will have received inquiries for AS1252 lock nuts. These lock nuts are actually not covered in AS1252. The use of lock nuts is only required in special situations where the bolts are only tightened to snug tight (S) conditions and the joints are subject to vibration that could promote vibration loosening.

The correct lock nut to use with AS1252 bolt assemblies should be in line with AS1112.4 thin nuts and the material property class should be Class 4 of AS4291.2. There is no proof stress/load requirement for thin lock nuts. The lock nut is essentially working as a washer that provides locking, and the total strength is generated through the large Class 8 nut. Hence the softer the lock nut, the better it works. So next time you are asked for AS1252 Class 8 lock nut, it should be conveyed to the client that they do not exist and in fact if it is being requested as an anti-loosening device, a Class 4 is the one that should be used. Hobson lock nuts are Class 4.

Sources:
- Bolt Science Limited
- Professor S. Fernando

The performance of the two-nut method, when properly applied, provides a superior locking capability when compared to many so-called lock nuts. The proper application of the two-nut method is time intensive and requires a degree of skill and is hence unlikely to make a major comeback any time soon, especially when Hobson sell Nord-lock and Schnorr VS washers that are extremely effective.
ENGINEERS THINK OUTSIDE THE BOX...

“The following is an actual question given on a University of Washington Engineering mid-term. The answer was so profound that the Professor shared it with colleagues, and the sharing obviously hasn’t ceased.

Most of the students wrote proofs of their beliefs using Boyle’s Law, (gas cools off when it expands and heats when it is compressed) or some variant. One student, however, wrote the following:

“First, we need to know how the mass of Hell is changing in time. So we need to know the rate that souls are moving into Hell and the rate they are leaving. I think that we can safely assume that once a soul gets to Hell, it will not leave. Therefore, no souls are leaving. As for how many souls are entering Hell, let us look at the different religions that exist in the world today. Some of these religions state that if you are not a member of their religion, you will go to Hell. Since there are more than one of these religions and since people do not belong to more than one religion, we can project that all souls go to Hell. With birth and death rates as they are, we can expect the number of souls in Hell to increase exponentially.

Now, we look at the rate of change of the volume in Hell because Boyle’s Law states that in order for the temperature and pressure in Hell to stay the same, the volume of Hell has to expand as souls are added.

This gives two possibilities:

1. If Hell is expanding at a slower rate than the rate at which souls enter Hell, then the temperature and pressure in Hell will increase until all Hell breaks loose.

2. Of course, if Hell is expanding at a rate faster than the increase of souls in Hell, then the temperature and pressure will drop until Hell freezes over.

So which is it?

If we accept the postulate given to me by Teresa Banyan during my Freshman year, “...that it will be a cold day in Hell before I sleep with you.,” and take into account the fact that I still have not succeeded in having sexual relations with her, then, #2 cannot be true, and thus I am sure that Hell is exothermic and will not freeze.”

This student received the only A.
- Unknown

Bonus Question: Is Hell exothermic (gives off heat) or Endothermic (absorbs heat)?

THE HOBSON QUIZ

Answers to cryptic puzzle found in the last issue of The Hobson Update. How did you go??