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# A "GALLING DEVELOPMENT"- WHAT EVERY DISTRIBUTOR SHOULD KNOW ABOUT THREAD GALLING

A number of year's back I was engaged by a Midwestern distributor to review an application problem that had intermittently plagued one of their more important customers. Upon meeting with their customer, I learned the problem occurred during the assembly of a stainless steel Nylon insert lock nut to a like stainless steel screw. Although this was a sporadic problem, when it occurred the customer would experience assembly difficulties like nuts that were very hard to turn, nuts that reached installation torque levels before seating, and in the worst cases, nuts that became totally frozen (seized) in mid-run down position, often breaking the screw in torsion.

Anyone that has been selling stainless steel hardware for a while may immediately recognize that this case demonstrates all the signs of thread galling. Fortunately for users, galling is usually an infrequent problem and one that can be addressed in multiple ways. However, when it occurs it is, at best, a nuisance and, at worst, a dangerous condition that could leave incompletely fastened joints vulnerable to failure.

Since galling is a problem characteristic to fasteners, it is a failure that all distributors should understand and be prepared to troubleshoot with their customers. This article will provide the reader with a fundamental understanding of what galling is, the telltale signs, and ways that it can be addressed or completely eliminated when it appears.

## *What Is Galling?*

So what exactly is galling? Galling, also commonly referred to as Cold Welding, is a form of adhesive wear that occurs when material transfers from one surface to the other when they are sliding together. When parts become subject to galling, the process begins modestly at a microscopic level but quickly progressives into a worsening macro condition. It all starts when the mating surfaces that are sliding against each other begin to experience an increase in heat and friction that results in the surfaces beginning to adhere to one another. As torque continues to be applied to the turning fastener, the areas of adhesion promote tearing of the weaker metal below its surface and redepositing it on the adjacent surface. The result is a lump or ball-like deposit of material from the original surface adhered to the adjacent surface. The ASTM G40 Standard says, "Galling is a form of surface damage arising between sliding solids, distinguished by macroscopic, usually localized, roughening and creation of protrusions (e.g. Lumps) above the original surface." [1]

These newly adhered lumps then "plow into" the approaching virgin surfaces as the fastener continues to be turned onward often damaging any protective surface layer and exposing, soft, bare metal. The original lumps develop more friction and heat which progressively accelerates tearing and generates additional lumps, grows original lumps in size, or promotes additional adhesion between the surfaces until the point that the threads are completely frozen together and the fastener can no longer turn or is broken.

Although this condition is theoretically possible with any material it is generally limited to softer materials, especially those which produce natural protective oxide layers.

In other words, materials like hardened steel or those with hard, strong protective layers are rarely subject to galling. Stainless Steel, Aluminum, and Titanium fasteners are particularly vulnerable. These materials possess a protective natural oxide layer. If this protective layer is punctured or abraded away the resulting base metal interface is generally soft and vulnerable to galling.

## Galling Mechanism

To better understand this phenomenon one should have a general idea of the mechanism that allows materials to gall. Galling is actually a severe form of Adhesive Wear. "Adhesive wear occurs when two metallic components slide against each other under an applied load where no adhesives are present."[2] All metallic surfaces possess irregularities, projections, and whiskers known as "Asperities". Considering the surface of a part or material sample, the rougher the surface is, the greater the influence of the asperities. However, even very highly polished metallic surfaces possess asperities at the microscopic level. When the contacting surfaces slide over one another the asperities bind together through metallic bonding. More heat and pressure intensifies the metallic bonding and once it reaches a threshold level the weaker of the two sliding materials experiences a shear failure which deposits itself on the opposing surface. As these deposits or lumps grow, they may penetrate the protective oxide layer on materials like Stainless Steel and Aluminum, which is working to counteract the metal bonding attraction, exposing the bare metal, and accelerating the adhesive wear.

Scientists have also determined that the crystalline structure can have a dramatic impact on the tendency of the material to gall. The ease with which the crystal lattice can slip in multiple planes during plastic deformation is another indicator of galling tendency. Although there are fourteen primary crystal structures (how the atoms align themselves to form identical repeating units) possible, metals tend to only take the form of three or four of them. Scientists use terms like Face Centered Cubic (FCC), Body Centered Cubic (BCC), and Close Packed Hexagonal (CPH) to describe these crystal structures. Investigation has shown that the crystal lattice and ease of dislocation slip play a key role in galling so that many, although not all, fasteners which possess FCC structures, like Austenitic Stainless Steels, possess a greater tendency towards galling than those possessing a CPH structure, like fasteners plated with Cadmium or quench and tempered to form hardened Martensitic steel.

## Prevention

Since certain materials, like Austenitic Stainless Steel, provide significant advantages for fasteners, it is unreasonable to suggest that designers simply avoid designing and using fasteners made of materials with strong galling tendencies. Instead, designers and users must develop strategies which minimize or eliminate the risks of deploying these materials. Factors related to design, lubrication, environment, and application can all play a role in whether fasteners will gall or not. In essence, most prevention strategies will take aim at reducing contact stress. Some of the more commonly adopted preventative measures are:

- Assembly Speed
- Lubrication
- Surface Roughness
- Surface Finishes
- Material Choices
- Thread Pitch
- Thread Damage
- Debris in Thread
- Thread Engagement
- Part Alignment
- Tightening Practice
- Insert Lock Nuts

Let's explore each of these preventative measures in greater detail.

## Assembly Speed

One of the triggers for galling is heat. The faster that a screw thread is assembled, the greater the development of localized heat through sliding friction. When a fastener is assembled with a power driver there may not be sufficient time for the heat to dissipate through the fastener leaving high localized temperatures in the thread flank.

Therefore, one of the simpler preventative fixes, especially with stainless steel fasteners is to reduce the assembly speed or adopt a hand assembly procedure. By slowing things down, the heat is given more time to dissipate through the rest of the fastener. Dropping automatic assembly equipment by several hundred rpms (if it is a fast spinning device) can provide noticeable improvement. Although not all assembly lines may be able to accommodate it, hand assembly should provide even more striking results. Many times, experimenting with and optimizing assembly conditions is enough to eliminate the galling.[3]

## *Lubrication*

Lubrication allows the mating surfaces to slide across each other more efficiently and with lower friction. Frequently, adding a lubricant will eliminate galling. Relying on lubricants as the solution, however, can sometimes be tricky. In some instances the application is not favorable to a lubricant solution. In these cases other measures will have to be adopted.

There are many options of lubricants that can be selected, although common ones include lubricants with substantial quantities of molybdenum disulfide, PTFE (Teflon), graphite, mica, talc or metal flakes. Often these lubricants are known as anti-seize compounds. Additionally some waxes, greases, or oils may be effective.

For fasteners, lubricants are often pre-applied as a dry-film lubricant, wax coating, or embedded into the top coat of the fastener plating. Naturally, these lubricants can also be applied at the point of use as well, which is especially well suited for maintenance activities but not always practical in high volume assembly.

Importantly, one must exert a degree of caution when using lubricants. There are certain instances where the presence of lubricants could contaminate or are incompatible with the surrounding environment and either should not be deployed or should be chosen very carefully. One that comes to mind, particularly germane to stainless steel fasteners, are fasteners used in food processing. These applications may only be able to use lubricants which have been approved safe in a food processing environment. Another area of concern is that the tension generated in a bolted joint is a strong function of the frictional characteristics of that joint. If the lubrication is either improved or reduced outside of the purview of the design recommendations, there is a strong likelihood that joint tension will change, which could lead to a variety of disastrous outcomes.

## *Surface Roughness*

Surface Roughness can play an important role in galling. Ironically both "highly polished surfaces or very rough finishes increase the tendency for wear and galling."[4] Although it is intuitive that rough finishes result in greater interaction between asperities, it is likely counterintuitive that very finely polished surfaces may also be more prone to galling. Experts hypothesize that these highly polished surfaces, which still possess microscopic asperities, lack the ability to store wear debris or lubricants in the valleys between asperities. With no place to store this material, it triggers greater interaction between asperities and increases the chances of galling.

On the other side of the coin, rough surfaces promote significant interaction between asperities. For this reason, certain fastener manufacturing processes, such as thread rolling, are preferred over other alternatives because they produce smoother, less rough surfaces. Although most externally threaded fasteners are roll threaded, most internally threaded fasteners are cut. The cut threads are rougher and more prone to galling.

## *Surface Finishes*

Surface finishes (platings and coatings) may be a strategic method of reducing galling. Many of today's coatings are designed with integrated lubricants in their top coat. In the event that a lubricant can't be built right into the coating, many modern plating and coating systems include a wide variety of post plating lubricant applications, including wax, oil, and dry film lubricant options. Additionally, there are several common platings or coatings that naturally resist galling. These include:

¤ ***Cadmium*** – provides natural lubricity tendencies. Cadmium plating is commonly used on an array of fasteners in aerospace and defense applications.

A strong warning, however, must be raised related to Cadmium plated fasteners. Almost thirty years ago Cadmium was identified as being both unfriendly to the environment and human health, and, is, therefore, banned from many industrial applications. Even in those industries where Cadmium is still commonly used, recent trends are all moving in the direction to eliminate it.

¤ ***Hard Chrome*** – creates a very hard, wear resistant surface that can be applied to both carbon and stainless steels.

¤ ***Xylan®*** **-** A Teflon® (PTFE) based coating similar to what is applied to non-stick cookware.

¤ ***Tin***[5] – has natural lubricity and "smears" rather than cracks

## Material Choice

If galling is a problem, one possible fix is to vary the bolt and nut material. Using components of the same material may foster like-to-like interactions and more easily promote adhesion than if the materials were different types. Additionally, pairing different stainless steel materials with one another may reduce galling because the hardness and work hardening rates are different. For example, pairing a 304 stainless component with a 316 stainless component could be beneficial. One must be careful if taking this approach, however, because not all stainless steels provide the same properties or hold up equally in certain environments. It would be unfortunate to solve one problem only to replace it with a more serious one.

## Thread Pitch

Thread Pitch is the distance from the point on one thread to the same point on the adjacent thread. Thread Pitch instructs us about the spacing between threads which usually fall into either coarse or fine categories. Fine threads have closer spacing, which provides some advantages like increased strength, finer adjustability, and less inclination to self-loosen, but they also are more prone to nicking and galling. If galling is a high concern, it is generally recommended that designers and users avoid fine threads.

## Thread Damage

Nicks and dings in threads are a strong trigger for galling. These imperfections, even minor ones, increase the torque required to assemble the fastener, which likewise increases friction and heat generation. Nicks may act like the lumps on a part that is already galled and locally damage the protective oxide layers, thus triggering the beginning of galling in those areas.

Fine threads are more prone to thread nicking than coarse threads, yet neither are immune. Cutting tools used to produce cut threads may become worn or damaged and result in rougher surfaces.

## Debris In Thread

In a similar vein as thread nicks, threads that have entrapped debris such as dirt, metal fines, or slivers, are more likely to trigger galling than clean threads. Dirty threads may also impact other processes like adding variability to the method of tightening control, so that best practice encourages the use of clean threads.

## Thread Engagement

In general, standard bolt and nut joints and blind nut joints limit the number of engaged threads. Likewise, nut and bolt joints are designed, when possible, to limit the threads of the bolt protruding beyond the top of the nut to about two pitches. When following such design parameters, the number of engaged threads and the number of threads which must pass through the joint is limited. This is advantageous because excessive thread engagement causes increased interference and friction. Screw threads, like any other manufactured element, cannot all be manufactured exactly alike. Thus as you compare one thread to the next and the next, on down the line, small variations in size and geometry appear. On their own, these minute variations raise little concern, but they are additive in nature, so that when taken as the whole, the engagement of each subsequent thread results in greater amounts of thread fit error that often translates into increasing interference and friction. Thus, increased thread engagement or the number of threads run through a nut can trigger galling.

## Part Alignment

Although many assemblies are far from perfect, efforts should be taken to get all the holes in the fastened joint as aligned as possible. When components are out of alignment, it often puts pressure on the fastener causing the threaded components to be inclined at an angle. This places very localized and uneven pressure on the threads, potentially resulting in high heat and friction.

Where possible, all holes should be as closely aligned as possible, with little or no stress on the fastener components.

## Tightening Practice

In line with the Part Alignment discussion above, the tightening practice can play an important role in whether a fastener will gall or not. As discussed immediately above, the first part of the tightening process should be to make sure all the components are as closely aligned as possible and that the fasteners are as free as possible from any stresses that would result from misaligned components or bearing the weight of a component pushing down on them. Once alignment is achieved, fasteners should be tightened by hand, if possible, until the joint is snugged up. At no time should tightening be used to pull the joint components together. If the joint components are separated or not well aligned, it might be good practice to use a clamp on the joint until the bolt or screw can be snugged up.

In multiple bolted joints, such as a flange joint, using proper tightening practices can be important. In these types of joints, the individual positions should be tightened in a progressive (meaning a fraction of the torque applied in multiple tightening rounds) fashion using a crisscross tightening pattern. This will result in more even application of loading and reduce friction and the chances of galling as compared to the unevenly loaded final fasteners often produced when multiple bolted joints are sequentially tightened in a clockwise or counterclockwise fashion.

## Insert Lock Nuts

One design combination that is known to occasionally trigger galling is stainless steel Nylon insert lock nuts. On the surface this may appear to be a little puzzling. Although the Nylon is intended to provide prevailing torque, because the Nylon material itself is so much softer than the steel bolt or screw material and in some instances acts sort of like a lubricant, it is not intuitive that the insert may have an impact on galling. Experts understand that an axial load must be applied to effectively engage the virgin Nylon insert. This axial load effectively pulls the mating threads more tightly together generating more friction and heat and raising the potential of galling. For this reason, users of this type of hardware may need to consider incorporating some form of lubrication on the nut, provided that it does not trigger any sort of unfavorable interaction with the plastic insert.

## Summary

Galling can be a significant nuisance to customers that are experiencing the problem, even if only infrequently. Since distributors commonly supply a wide range of hardware to their customers, often including some components that are vulnerable to galling, it is in their best interest to be able to recognize the signs and know how to counsel their customers in ways to avoid the problem. Fortunately, there are more than a couple of approaches to troubleshooting, and, in all but the most vexing of cases; recommendations should be available that will limit, if not outright solve, the customer's problems. Being able to provide such application troubleshooting and assistance will, over time, begin to cement a distributor's reputation as a value-added troubleshooter and trusted partner.

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**CITATIONS**

***[1]*** ASTM Standard G40 (2017). "Standard Terminology Relating to Wear and Erosion", ASTM International, West Conshohocken, PA.

***[2]*** Magee, John. ASM Handbook Volume 18, "Wear of Stainless Steel", ASM International, USA, pg 715.

***[3]*** IFI Technical Bulletin. "How to Stop Thread Galling on Stainless Fasteners", Industrial Fasteners Institute, Independence, OH, pg 1.

***[4]*** Ibid Magee. pg 716.

***[5]*** Penn Engineering, Tech Sheet. "PEM® REF/THREAD GALLING", Penn Engineering, Danburo, PA, pg 8.