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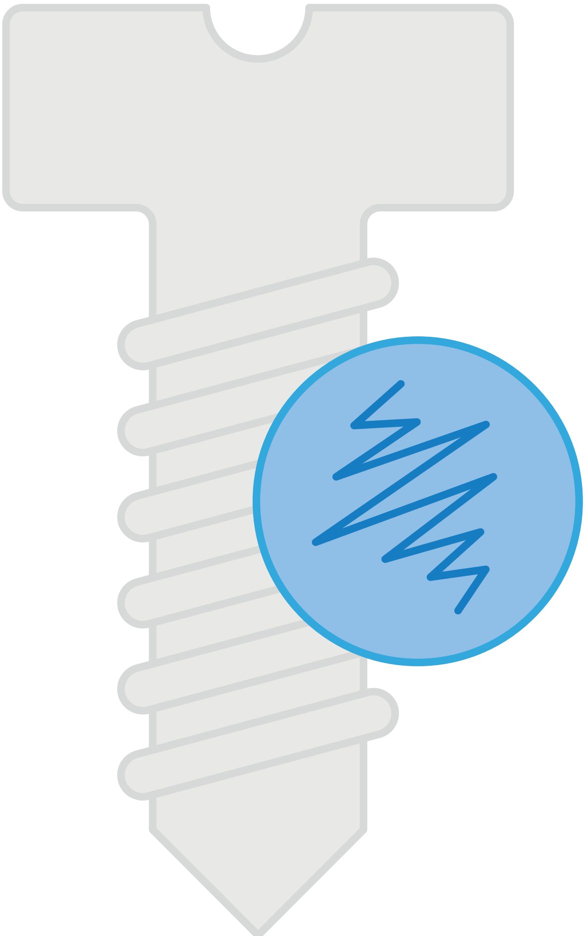

Galling of stainless steel fasteners

White Paper

Galling of stainless steel fasteners

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Bossard Group

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GALLING OF STAINLESS STEEL FASTENERS

Introduction

Fasteners made of stainless steel, aluminum and titanium are most commonly prone to galling when tightened. Stainless steel fasteners are available in austenitic, ferritic and martensitic grades. Austenitic grade of stainless steel fasteners is most commonly used in the industry. Stainless steel material has chrome oxide layer which protects it from corrosion.

When two fasteners are tightened together, surface pressure builds between the thread surfaces of the bolt and nut, and the protective oxide layer might break off. The high friction between the interfaces of the joining fasteners, where the base metal has been exposed (due to the shaved oxide layer), can cause interlocking of the surfaces; this phenomenon is known as galling. The higher coefficient of friction increases the risk of galling.

Galling is seizing or abrading of the threads, in which either the joint elements jam during the assembly or threads get damaged. It is also known as local cold welding (frictional bonding) of the thread flanks. It is generally formed when the thread flanks rub against each other for an extended period of time.

Different types of stainless steel materials with different heat treatment conditions behave differently in terms of galling. The following chart compares galling characteristics of seven types of stainless steel. It indicates that the galling time can be from 7 seconds to 58 seconds at a specific load.

Figure 1: Galled fastener

Type	Condition	Initial Hardness	Surface Treatment	Load (lbs)	Time for Galling to Occur (Seconds)
416	Heat Treated	43 Rc	None	400	12
416	Heat Treated	43 Rc	Tufftrided*	1000	37
440C	Heat Treated	59 Rc	None	800	17
440C	Heat Treated	59 Rc	Tufftrided*	1100	41
440A	Annealed	96 Rb	None	650	15
440A	Annealed	96 Rb	Tufftrided*	1000	47
303	Annealed	85 Rb	None	(preload)	3
303	Annealed	85 Rb	Tufftrided*	750	25
303MA	Annealed	88 Rb	None	300	2
303MA	Annealed	88 Rb	Tufftrided*	1350	58
317	Annealed	85 Rb	None	500	7
317	Annealed	85 Rb	Tufftrided*	750	27
347	Annealed	89 Rb	None	600	8
347	Annealed	89 Rb	Tufftrided*	500	22

Table 1: Comparative galling characteristics

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Galling and its causes

This section talks about various causes of galling and prevention methods in those conditions.

Torque and galling

VDI 2230 (Technical guidelines for fasteners) indicates that bolts may only be tightened up to 90% of their yield strength. If the tightening torque is too high, the bolt will be over-stretched or even break. The screws can also be broken by torsional shear forces due to thread galling.

The friction coefficient of stainless steel against another stainless steel is relatively high in comparison with the friction coefficient of many other materials in combination. To achieve the same preload, screws made with austenitic stainless steel material A1-A4 must be tightened with higher torque than the regular steel screws with the same strength.

In the case of thread galling the tightening torque goes up and preload is not achieved. Sometimes the operators tend to apply additional torque to visibly seat the fasteners properly without being aware of occurrence of galling. Such failures may hardly be detected during the tightening operation and can be invisible from outside. It appears during repairs or service that the fasteners can no longer be loosened.

After galling a bolt/nut will certainly not rotate loose or get lost, but joints that are not properly tensioned may fail from fatigue when put under service loads.

Lubricating stainless steel fasteners prior to assembly as well as solid lubricant coated fasteners have demonstrated to be advantageous against galling. (Read more under "Prevention of Galling" section below).

Manufacturing process and galling

The thread surface of different thread profiles may appear smooth when looked at by naked eyes. But under a microscope the thread profile may show folds in the thread crests. This failure occurred due to an improper rolling die setting. Blunt thread crests decrease the thread forming capability of thread forming screws.

Figure 2: Burr on thread

The internal thread of a prevailing torque nut could have the similar issues which lead to seizing of the threads. These types of failures are considered "invisible" failures. Manufac-tures take extra care when producing thread cutting and thread tapping fasteners due to the same reasons. Generation of the burrs (as shown in the fig 1.3) during thread rolling is one of the common issues that can cause galling.

High temperature fasteners and galling

Gas turbines and diesel engines are typical representatives of machines where fasteners are exposed to high temperatures. High temperature can change the physical properties of a material. Due to the high temperature aggressive gases may create scale on the surface of bolts and nuts. Thermal expansion can lead to permanent distortion. Regardless of such external impacts, the required preload must be maintained in fastened joints. In addition, the fasteners must remain detachable for service and repair works.

Galling can also occur when fasteners and structural elements are made from different materials. The design engineer should take high temperature consequences in considera¬tion when designing a joint.

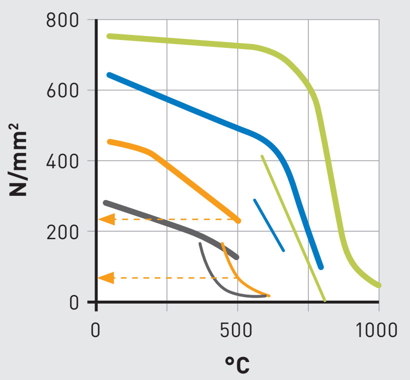

Figure 3: Yield strength/temperature

Examples (fig. 1.4) for yield strength at elevated temperature for some heat resistant bolt materials:

- Ck 35: Steel
- 24CrMo 5: Low Alloy Steel
- X5 NiCrTi 2615: Austenitic Stainless Steel
- NiCr 20 Co 18 Ti: nickel-chromium-cobalt alloy with titanium.

High temperature and relaxation are many times a source for thread galling in service and repair works. To prevent threads from galling, threads of heat resistant bolts have an increased thread play.

Figure 4: High temperature fasteners

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Prevention of galling

Manufacturing process

During the manufacturing process the wire may be coated with copper for lubricity to pre-vent galling in the dies. The copper coat acts as a solid lubricant on the wire. It is removed after thread rolling by pickling the finished fasteners.

Top coat

Galling can be minimized or prevented if metal-to-metal contact of the engaging threads is prevented.

- Lubrication with "Molylub". The solid molybdenum disulphide particles prevent metallic contact and thus minimize abrading. Sometimes application of normal oil or lubricants may not be sufficient to prevent galling.
- Similar solid film lubricants containing silver, aluminum or copper particles can also be beneficial. These lubricants help decreasing the coefficient of friction. Most of the antiseize compounds, those that are applied at the assembly line, contains these metal particles. Lubricants containing graphite are not advisable since there could be dangerous reactions between the carbon and the chromium at high temperatures.
- A thin TEFLON sealing tape can offer protection from galling. For large threaded components such as pipes and valves, the threads of these parts could be wrapped with a thin TEFLON-sealing tape.

Coatings such as Polyseal, Xylan, Delta®-Seal or wax applied to stainless steel fasteners may also prevent galling.

Figure 5: Wire coated with copper

Tribological coating

Fluoropolymer coatings are a blend of resins and fluoropolymer lubricants. PTFE, PVDF, PFA, and FEP provide low friction, chemical and corrosion resistance, non-wetting, and release or non-stick properties at temperatures up to 550° F.

Anti-friction coatings are tribological dry coatings for mechanically loaded fasteners and components (such as screws, nuts, washers). The coating is a thin-layer coating, applied non-electrolytically, with built-in lubricating properties and additional corrosion protection.

The coating comprises a composition containing fluoropolymers and organic solid lubricant particles which are dispersed in specifically selected synthetic resins and solvents. It is referred as an AFC coating (anti-friction coating) which forms a smooth film to even out all irregularities in the surface and thus optimize friction even under extreme loads and working conditions. The synthetic resin also ensures improved corrosion protection.

A thin, dry film of lubricant, which adheres firmly to the substrate, forms after the lubricating varnish has hardened. This film acts as a separating and lubricating layer reducing the friction and wear between friction bodies which are in contact with each other.

Tribological coatings offer an excellent solution for the applications which require controlled coefficient of friction and protection against wear. The tribological characteristics of anti-friction coating solutions minimize galling with fastening elements and help to maintain pre-defined torque to achieve the correct clamp load.

The use of comprehensive solutions with a coating concept for specific performance characteristics is increasing. In particular, there are various base coats with top coats on offer (e.g. zinc flake coating systems). Anti-friction coatings with friction coefficient specifications are preferably applied by the same coater. For friction coefficient windows with tribological coatings, it is essential to ascertain the requirements in advance.

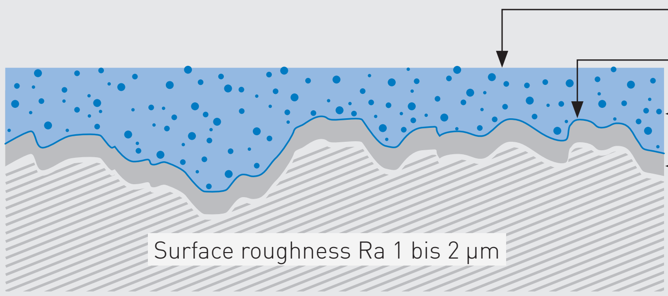

Figure 6: Anti-friction coating structure

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Summary

Coating technology is changing and should adapt to the regulated framework conditions of each market region. Here, Bossard draws on the expertise of chemical manufacturers, their licensees and local coaters. When it comes to coating technology, there is an increasing preference for system solutions with matching base and top coats for specific performance characteristics.

Stainless steel fasteners are frequently prone to galling when assembled. The excessive friction and generated heat during tightening create plastic deformation of the surface(s) that leads to seizing of the mating members. Use of lubricants and intelligent coating, extra care during thread forming, appropriate rpm of the installation tool, cleanliness, and proper design practices can help reduce or eliminate the galling.

With careful attention on prevention of galling, stainless steel can be a very useful fastener material due to its inherent resistance to corrosion and generally higher tensile strength than commercial low carbon steel.

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