



Galling and Galling Resistance of Stainless Steels

Introduction

Galling, or cold welding as it is sometimes referred to as, is a form of severe adhesive wear. Adhesive wear occurs between two metal surfaces that are in relative motion to each other and under sufficient load to permit the transfers of material between themselves. This is a solid-phase welding process. The load must be sufficient, during relative motion, to disrupt the protective oxide layer covering surface asperities of the metal and permit metal to metal contact. Under high stress and poor lubrication conditions, stronger bonds may form over a larger surface area. Large fragments or surface protrusions may be formed and the result is galling of the surfaces. Severe galling can result in the seizure of metal components.

Materials which are highly ductile or which possess low work-hardening rates tend to be prone to galling. Austenitic stainless steels show a tendency to gall under certain conditions.

Factors Affecting Wear and Galling

The factors affecting wear and galling are related to design, lubrication, environment, and steel properties.

The material properties relevant to the issue of galling of stainless steels include: -

- design tolerances and surface finish of the steel
- surface properties (hardness) and structure of the steel
- applied load
- contact area and degree of movement.

Design tolerances should provide sufficient clearance. The contact load on sliding components should be kept to a minimum, while the contact area should be maximised. In this situation, lubrication plays an important role and the design must ensure that adequate lubrication can be effectively delivered to the components in relative motion.

Surface finish of components is important as highly polished ($< 0.25 \mu\text{m Ra}$) or very rough ($>1.5 \mu\text{m Ra}$) surfaces increase the tendency for wear and galling. Smooth surfaces result in more contact. The small "valleys" and "asperities" on the smooth surface means that lubricant cannot be held in place between the surfaces and dislodged material is retained in close contact with the surfaces resulting in wear. Rough surfaces result in interlocking of asperities, which promote severe tearing and galling.

Surface finishes between these extremes are therefore preferable.

The hardness and microstructure of the material play an important role in adhesive wear and galling. A high hardness (obtained by work hardening) austenitic stainless steel and a stable oxide film can provide resistance to galling. Surface hardening treatments can also have the same effect.

The microstructure can also reduce adhesive wear and cold welding, where there are two or more phases (austenite with ferrite or austenite with martensite).

A similar effect can result if the steel structure has dispersions of "particles" such as carbides, nitrides, sulphides etc embedded in it.

Additions such as sulphur made to improve machinability in grades such as 1.4305(303) and 1.4005(416) can affect the behaviour of the steel.

The inclusions formed (mainly manganese rich sulphides) act as solid lubricants in sliding contact and so these steels exhibit better galling resistance than the non treated 1.4301 (304) and 1.4021(420) grades from which they are derived.

In contrast to the austenitic stainless steels, the hardenable martensitic stainless steels have better resistance to galling as a result of their harnesses that can be in excess of 53 HRc (Rockwell "C").

Resistance to Galling

Austenitic and precipitation hardening stainless steels exhibit low galling resistance. The AISI booklet¹ shows the galling resistance of various combinations of stainless steels in terms of an unlubricated threshold galling stress.

These data show that combinations of the softer austenitic stainless steels with harder martensitic grades or with the manganese / nitrogen "Nitronic" grades 32 & 60 should help reduce the risk of galling and seizure.

It has also been shown in work carried out at the Corus (British Steel) Technology Centre² that combinations of the work hardened austenitic fastener grades A4-80 and A2-80 are less prone to seizure than combinations of the "70" property class materials together or with other class "80" components.

The specification of these property classes is shown in BSENISO 3506³.

This can be considered in selection of materials for fasteners, provided the corrosion resistance of the harder martensitic grades is consistent with proposed service conditions.

The galling characteristics of duplex stainless steels is claimed by one US manufacturer to be similar to austenitic stainless steels⁴

Improving Wear and Galling Resistance of Stainless Steels

Lubrication is often applied to stainless steel fasteners as a method of preventing galling and seizure. This can take several forms, depending on service condition, from the application of oils and greases to solid lubrication systems such as thermosetting or PTFE coatings.

Work carried out at the Corus (British Steel) Technology Centre² shows that PTFE provides the best galling resistant system, when compared with greases. It is also suggested that this system has the additional advantage that the coatings can be applied under "workshop" conditions, rather than "on-site", reducing the risk of contamination pick up, compared with the use of greases.

This in turn should help maintain optimum corrosion resistance of the fastener system.

Wear Coatings

Improvements in both wear and galling resistance may be obtained by altering the surface characteristics of stainless steels by nitriding or chromium plating.

Nitriding

Austenitic stainless steels do not respond well to nitriding treatments and so the scope for nitriding is limited.

Better results can be obtained on martensitic and precipitation-hardening stainless types, particularly as the "substrate" core of the steel can be strengthened. This helps support the hardened surface layer when loads are applied to mating components.

There are limitations even then to the scope for nitriding, as the corrosion resistance can be reduced due to depletion of chromium at the surface as chromium nitrides are formed. Additionally there can be a risk of intergranular corrosion as the nitriding temperature can result in the precipitation of carbides at the steel grain boundaries.

Hard chromium deposits are intended primarily to improve wear/galling resistance and are usually applied directly to the substrate. The thickness of hard chromium electroplated coatings range from 0.003 to 0.5 mm, while decorative coatings seldom exceed 0.003 mm. Electrodeposited chromium is not recommended for high temperature or high-pressure applications, which tend to reduce the hardness of the coating and may lead to cracking/spalling.

References

1. "Review of the Wear and Galling Characteristics of Stainless Steels", American Iron and Steel Institute, Designers Handbook Series, April 1978
2. "Long-term performance of stainless steel fasteners", K Shemwell, DR Johns, EU Commission report EUR 17848 EN, 1997
3. British Standards Institution
BSEN 3506:1999 - Corrosion Resistant Fasteners
4. "Corrosion Resistant Duplex Stainless Steel with Improved Galling Resistance", Magee, Jr et al, US Patent No 5,254,184, October 19, 1993.

Before commencing any task ensure that you have received the appropriate health and safety literature from the supplier and fully understand it. If in doubt seek advice.

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