BRUSHWELLMAN
ENGINEERED MATERIALS

Galling of Nonmagnetic Drill String Components

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by
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Galling and Seizing

Galling and seizing are specific aspects of adhesive wear. Other types of wear include: abrasive wear, corrosion wear, fatigue wear, erosive wear, thermal wear and fretting wear. In some cases one type of wear can promote another type of wear. More than one type of wear can occur at the same time. Wear is influenced by environmental factors including: temperature atmosphere, mechanical load applied, relative velocity, contact geometry, contact area, lubrication, surface finish, type of motion, vibration, and material properties.

Galling is a form of adhesive wear with seizing as the most severe form of galling. The terms galling and seizing are often used interchangeably. Threaded connections are subjected to sliding friction and to shear and normal forces. The type of thread, thread profile, lubricant, make-up force and torque, surface finish of the thread and the types of metal in each half of the connection jointly act to determine if galling occurs.

All sliding contact between metals involves frictional contact. When loads are increased, the surface area in contact increases and the frictional forces, frictional heating and frictional wear also increase. Most metals and all stainless steels have a surface oxide which forms in contact with the atmosphere. This oxide imparts the stainless quality to stainless steels. When surface films and surface oxides are removed through sliding contact (abrasive wear) the unprotected metal and smooth surfaces promote metallic bonding. The two surfaces cold weld — and galling begins. When the strength of the welded surface exceeds the sliding force, the parts seize.

The tendency to galling and seizing is greater between two pieces of the same metal than between dissimilar metals. The best approach to eliminating galling and seizing is to change either the box or the pin connection to another metal. The use of coatings and lubricants can also minimize metal contact and friction.

Beryllium Copper

Beryllium copper is the most resistant to galling and seizing of all the metals used in the drill string. In normal use, beryllium copper components inherently provide all the galling and seizing resistance required for life of the component. Components made from beryllium copper do not require coatings and should not be hardfaced.

Beryllium copper is the strongest and hardest of the copper alloys. In the aged condition, beryllium copper has the same strength as tempered alloy steels and can be directly substituted for steel and nonmagnetic steel components in the drill string. Beryllium copper drill string components are usually manufactured from Alloy 25 which contains approximately 1.9% beryllium, 0.2% cobalt and the balance copper. Beryllium copper components are specifically manufactured to obtain a unique combination of mechanical properties best suited for each component of the drill string.

Beryllium copper has a combination of high tensile, bearing and compressive strength, high hardness and high thermal conductivity. These properties make beryllium copper an excellent choice for bearing and bushing applications. The threads in drill string connections are similar to bearings in many respects including high load and sliding contact. The high hardness and strength provide beryllium copper drill string components with the ability to withstand the high loads in drill string connections. The thermal conductivity reduces the temperature increase in sliding contact, such that cold welding does not occur.

Beryllium copper does not gall or seize in contact with steel, stainless steel or other nonmagnetic metals used in the drill string. Beryllium copper also shows no galling or seizing in contact with other beryllium copper components. Beryllium copper components can be and are mated with other beryllium copper parts.

Stainless Steels

Stainless steels, austenitic, are used in drill string applications because they resist corrosion and are nonmagnetic. Stainless steels usually contain 12% or more chromium and sufficient nickel, manganese and/or nitrogen to provide a nonmagnetic structure. These alloys are strengthened by the addition of nitrogen and by thermo-mechanical processing. Stainless steels have an unusually high work hardening rate which produces high surface hardness and excellent resistance to wear in many circumstances.

All stainless steels also have a tendency to gall and seize, particularly without lubrication. The different metallurgical structures of stainless steels do not effect the galling tendency. Galling can occur as easily between austenitic stainless steels as between austenitic and martensitic stainless steels. The high work hardening rate may contribute somewhat to the galling tendency.

Changes in the composition of the austenitic stainless steels have an effect on galling. As the nickel content is increased, less force is required to cause galling and seizing. The low carbon austenitic stainless steels are more prone to galling. The martensitic and ferritic stainless steels have the lowest resistance to galling. Some proprietary stainless steels show improved galling resistance, but require compromising other properties for galling resistance.

Most drill string components are made from one of the chromium-manganese stainless steels. These steels can develop high strength from thermo-mechanical processing and are nonmagnetic. Machining produces a smooth finish which promotes high frictional forces in connections. Nonmagnetic chromium-manganese stainless steel connections frequently gall and seize. Coatings and lubricants should be used whenever possible.

Coatings

Coatings are not required for beryllium copper connections.

Coatings separate the two metal parts and eliminate the contact and cold welding that causes galling and seizing. A number of thread compounds, manufactured for use as a lubricant or sealant, are also used to minimize galling and seizing. Coatings are a temporary solution and must be reapplied prior to each time a connection is made. Coatings often rely on friction reducing additives such as compounds of sulfur or lead. These additives have a low shear strength and fracture under high loads providing lubrication. Additives such as MoS_2 and lead do not adversely effect beryllium copper or stainless steels. Additives that contain ammonia compounds should not be used with copper alloys. Additives containing high concentrations of chlorides or containing zinc should not be used with stainless steels.

Many coatings do not survive the drilling conditions and are washed from the connection. When the coating has washed out, galling and seizing can occur when disassembling the connection. Coatings are formulated with heavy nonsoluble binders to minimize wash out by the corrosive high temperature drilling muds. At the high temperatures encountered during drilling, many of the binders soften and can flow out of the connection.

There are a variety of coatings available. Coating selection is usually based on experience.

Carburizing and Nitriding

Beryllium copper is highly resistant to both carburizing and nitriding. These processes are not recommended for beryllium copper components.

Carburizing and nitriding are methods used to increase the surface hardness of steels and stainless steels (also called case hardening). Nitriding treatments are performed in a furnace or liquid salt bath at temperatures between 925 and 1050 F. Carburizing treatments can be performed in a furnace, salt bath or with a hand held torch. Increasing the hardness of one of the connections can increase the resistance of steels to wear, galling and seizing.

Carburizing or nitriding stainless steels produces chromium, iron and manganese nitrides within the treated area. The reduction in the chromium concentration dramatically reduces the corrosion resistance of the stainless steel. Most drill string components are fabricated from chrome-nickel or chrome-manganese stainless steels. Carburizing and nitriding result in a sensitized surface layer which is highly susceptible to chloride stress corrosion cracking and to pitting.

Hardfacing

Hardfacing beryllium copper is not recommended. The thermal conductivity of beryllium copper components creates a chill to most hardfacing materials resulting in cracking of the hardface weld bead. Nickel-base and tungsten carbide hardfacing materials have been tested. Most hardfacing materials recommend pre-heating before welding. The required temperature is in the aging range for beryllium copper. The properties of the beryllium copper must be compromised to obtain the hardface.

Hardfacing stainless steels is performed with welding, metalizing and plasma spraying equipment. Hardfacing materials are available which provide both corrosion and wear resistance. The coatings develop a mechanically or metallurgical bond to the underlying component. The heat from the hardfacing process can be sufficient to cause local annealing or sensitizing in some stainless steels.

There are a number of hardfacing materials available including nickel-base, cobalt-base, iron-base alloys, chromium carbide and chromium boride. The hardfacing material should be galvanically and mechanically compatible with the stainless steel being coated. The mechanical strength of the coating and underlying metal should be similar. Iron-base hardfacing alloys have less corrosion resistance than most nonmagnetic stainless steel. A galvanic couple between the hardfacing and the stainless steel could result in premature corrosion failures. Nickel-base and cobalt-base hardfacing alloys are used most frequently. Consult the stainless steel supplier and welding consumable supplier before hardfacing stainless steels.

Plating

Plating is not required for beryllium copper drill string components.

A number of platings have been used to provide lubricity and reduce galling and seizing of steels and stainless steels. Copper plating has been used on a number of connections. Copper is a good lubricant and is easy to apply. Copper plating on drill string connections have a limited life because the plating lacks adhesion to the stainless and has low resistance to wear. Copper plating provides lubrication sufficient to make up the joint but often flakes off the connection when connections are disassembled.

Rolled Thread Connections

Thread rolling does not increase the resistance to galling and seizing. Thread rolling, particularly in thread grooves, reduces the amount of surface area in contact. This can partially reduce the heat generated by frictional forces, but the tendency to galling and seizing between metals is not changed. Stainless steels have a high work hardening rate. Thread rolling produces a surface compressive residual stress that can improve fatigue life, chloride stress corrosion cracking resistance and wear resistance in stainless steels. Thread rolling tends to provide a smoother surface which increases the galling and seizing tendency of stainless steels by increasing the frictional surface forces and frictional heating.

Thread rolling beryllium copper components can also improve fatigue life and wear resistance. Galling and seizing resistance of beryllium copper is not changed by cold working operations such as thread rolling.

If you require additional information or technical assistance, please contact Brush Wellman's Customer Technical Service Department at 216-486-4200.■

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For beryllium alloys, come to the source.

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