

up to 2200 °F, according to the manufacturer. The oil boils off, but the compound leaves nongalling oxides of nickel, copper, and zinc between the threads. This allows the fastener to be removed, but a new application is required each time the fastener is installed. NASA Lewis personnel tested this compound and found it to be satisfactory.

Silver Goop

Silver Goop is a proprietary compound⁶ containing 20 to 30 percent silver. Silver Goop can be used to 1500 °F, but it is not to be used on aluminum or magnesium. It is extremely expensive because of its silver content.

Thread-Locking Compounds

Some of the removable thread-locking compounds (such as Loctite) also serve as antigalling and lubricating substances. However, they are epoxies, which have a maximum operating temperature of approximately 275 °F.

Corrosion

Galvanic Corrosion

Galvanic corrosion is set up when two dissimilar metals are in the presence of an electrolyte, such as moisture. A galvanic cell is created and the most active (anode) of the two materials is eroded and deposited on the least active (cathode). Note that the farther apart two materials are in the following list, the greater the galvanic action between them.

According to reference 2 the galvanic ranking of some common engineering materials is as follows:

- (1) Magnesium (most active)
- (2) Magnesium alloys
- (3) Zinc
- (4) Aluminum 5056
- (5) Aluminum 5052
- (6) Aluminum 1100
- (7) Cadmium
- (8) Aluminum 2024
- (9) Aluminum 7075
- (10) Mild steel
- (11) Cast iron
- (12) Ni-Resist
- (13) Type 410 stainless (active)
- (14) Type 304 stainless (active)
- (15) Type 316 stainless (active)
- (16) Lead
- (17) Tin
- (18) Muntz Metal
- (19) Nickel (active)
- (20) Inconel (active)
- (21) Yellow brass
- (22) Admiralty brass
- (23) Aluminum brass
- (24) Red brass
- (25) Copper
- (26) Silicon bronze
- (27) 70-30 Copper-nickel
- (28) Nickel (passive)
- (29) Inconel (passive)
- (30) Titanium
- (31) Monel
- (32) Type 304 stainless (passive)
- (33) Type 316 stainless (passive)
- (34) Silver
- (35) Graphite
- (36) Gold (least active)

Note the difference between active and passive 304 and 316 stainless steels. The difference here is that passivation of stainless steels is done either by oxidizing in an air furnace or treating the surface with an acid to cause an oxide to form. This oxide surface is quite inert in both cases and deters galvanic activity.

Because the anode is eroded in a galvanic cell, it should be the larger mass in the cell. Therefore, it is poor design practice to use carbon steel fasteners in a stainless steel or copper assembly. Stainless steel fasteners can be used in carbon steel assemblies, since the carbon steel mass is the anode.

Magnesium is frequently used in lightweight designs because of its high strength to weight ratio. However, it must be totally insulated from fasteners by an inert coating such as zinc chromate primer to prevent extreme galvanic corrosion. Cadmium- or zinc-plated fasteners are closest to magnesium in the galvanic series and would be the most compatible if the insulation coating were damaged.

Stress Corrosion

Stress corrosion occurs when a tensile-stressed part is placed in a corrosive environment. An otherwise ductile part will fail at a stress much lower than its yield strength because of surface imperfections (usually pits or cracks) created by the corrosive environment. In general, the higher the heat-treating temperature of the material (and the lower the ductility), the more susceptible it is to stress corrosion cracking.

The fastener material manufacturers have been forced to develop alloys that are less sensitive to stress corrosion. Of the stainless steels, A286 is the best fastener material for aerospace usage. It is not susceptible to stress corrosion but usually is produced only up to 160-ksi strength (220-ksi A286 fasteners are available on special order). The higher strength stainless steel fasteners (180 to 220 ksi) are usually made of 17-7PH or 17-4PH, which are stress corrosion susceptible. Fasteners made of superalloys such as Inconel 718 or MP35N are available if cost and schedule are not restricted.

⁶Swagelok Company, Solon, Ohio.