Methods That May Be Used To Combat Corrosion Of Sub-surface Pumps

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Few mechanical operations will demand greater durability of equipment than do the sub-surface pumps used in lifting oil to the surface. This requirement has developed through several changes that have occurred within the last few years and includes such factors as deep pumping wells, more corrosive fluid, and greater emphasis to decrease lifting cost.

All these trends place greater responsibility upon the design engineer to build pumps that will afford greater production and durability at less cost. There will be a number of problems to solve, but the one which requires constant vigilance is corrosion damage.

This article deals with methods that may be used to combat corrosion damage to sub-surface pumps.

Corrosion can be classified by the many forms by which it attacks metal; these forms are erosion-corrosion, stress corrosion cracking, intergranular corrosion, galvanic or two-metal corrosion, uniform attack, pitting, concentration-cell corrosion, dezincification, and graphitization.[1]

In sub-surface pumps we deal with all these different forms with exception of dezincification and graphitization.

Each form has individual damaging characteristics for ready identification. The cause for the attack and the necessary corrective measures to employ are not as readily understood or determined; and in some cases further laboratory testing and data searching work will be involved in order to conclude and recommend corrective action.

Erosion-corrosion is the form of metal deterioration by fluids moving at substantial velocities, turbulence at change of sections and impingement. The erosive action created by the fluids can either initiate or acdelerate corrosion attack. When this occurs, rapid metal failures are expected to result.

Erosive action can be lessened by the use of certain types of pumps and improved design of pump parts, that provide such as: (1) fluid flow as slow as possible; (2) streamlined fluid flow; (3) uniform fluid velocity; (4) parts designed to minimize working stress level; (5) kept threads away from main fluid path; and (6) use of top hold-down or traveling type pumps to minimize effect of high pressure dormant fluid.

A second method of combatting corrosion in sub-surface pumps is in the selection of materials used in their construction. This is not an easy task for it involves careful consideration of many problems along the path from the raw material to a finished part. We must start our selection at the initial design recognizing such problems as fabrication, working stress, proposed service environment, availability of material, estimated cost, and economic justification where expensive high alloy materials are involved.

To proceed with our selection, based on corrosion resistance, we must understand the conditions under which the various forms of attack can occur.

VARIOUS FORMS OF CORROSION ATTACK

Intergranular Corrosion

This form of corrosion is defined as a type of electro-chemical corrosion that progresses preferentially along the grain boundaries of an alloy, usually because the grain boundary region contains material anodic to the central regions of the grain. The 18-8 chromium-nickel stainless steels are particularly susceptible to intergranular corrosion when they are not properly heat treated. This would also involve weld area corrosion if 18-8 stainless is not peroperly heat treated subsequent to welding or if stabilized materials are not used.

This is not a problem in sub-surface equipment; however, it deserves consideration where corrosive environment exists.

Galvanic or Two-Metal Corrosion

When two unlike metals are connected in good contact and exposed to a solution capable of carrying an electric current, such as salt water, the more noble metal will corrode less rapidly, whereas the less noble metal will corrode more rapidly as a result of the development of an electric current.[2] The factors influencing galvanic corrosion are conductivity of the current, potential between anode and cathode, polarization, relative cathode and anode area, geometric relationship between dissimilar metal surfaces, and contact between surfaces. Of these, the influence of relative area to anodic and cathodic surfaces has the most pronounced effect on the degree of damage produced by the galvanic action, as a small anode and a large cathode result in an increase in current density at the anode, resulting in an increase in corrosion rate.

Our metals should be compatible whenever possible; and we should also realize that other differences can exist to produce a galvanic attack, and are more appropriately defined under concentration-cell corrosion.

Concentration-Cell Corrosion

This type of attack is associated with surface crevices, scale, and other surface deposits in which differences in solution concentration or distribution of dissolved-oxygen content from point to point on a single metal surface can set up potential difference. Three types are known; namely, metal-ion, oxygen, and active: passive cells.

Uniform Corrosion and Localized Pitting

This form of corrosion attack proceeds uniformly over the complete exposed area, and although this type can be severe it is not as damaging as the localized pitting type which creates sites for fatigue, leakage in seals, and stress corrosion failures. A uniform corrosion attack will be preferred over the pitting type. Unfortunately, because of the many variations existing in mechanical factors, materials and produce fluids, we rarely experience uniform corrosion of sub-surface equipment.

Stress Corrosion Cracking

Tensile stresses plus a corrosive chemical environment are the major factors in the susceptibility of some metals and alloys to stress corrosion cracking. Both conditions must be present for such failures to occur. If we could control either, it would be possible to establish limits for the other and eliminate the problem.

A more severe form of stress corrosion in sub-surface equipment is found in sour wells or those producing brine plus hydrogen sulfide. This type has been appropriately called "sulfide-stress cracking." Possibly cracking of steel in sulfide environments is not a singular mechanism for failure but may be (1) true stress corrosion; (2) the effects of nascent hydrogen absorbed by steel under stress; or (3) a combination of both.[3] Research work and field failure analyses show that most ferritic steels and several stainless steels can be made susceptible to sulfide-stress cracking and will be dependent upon residual and applied stress, micro-structure, plastic deformation from cold working, and resulting hardness or strength level.

MATERIAL SELECTION UNDER HYDROGEN SULFIDE PLUS BRINE ENVIRONMENT

When these fluids are free of oxygen or some other oxidizing agent, the material selection will be made of those metals resistant to acid corrosion under non-oxidizing conditions.

Fittings

The selection will be monel (nickel-copper) and inconel (nickel-chromium-iron) where the fluids are considered very corrosive. Under less acid conditions the 304 and 316 austenitic stainless steels and copper alloys of 70-30 and 85-15 grades have been used successfully.

In mild corrosive conditions low alloy steels of AISI 8600, 4600 and 4100 series have been used with some success.

To my knowledge the monel and inconel have not shown susceptibility to sulfide-stress cracking in the soft or hardened condition. Severely cold worked monel tubing has shown stress corrosion cracking if not adequately stress relieved prior to hard chromium plating. Stainless steels of the 18-8 grade should be used in the annealed condition and not severely cold worked. Cold working has shown to promote stress corrosion cracking of this series.

The low alloy steels which may be heat treated should not be used in a hardness range over 22 Rockwell C or 237 Brinell. With the lower hardness, and if the part is not overloaded, failures will most likely be the result of uniform corrosion attack or corrosion fatigue.

Balls and Seats

Tungsten carbide balls and seats have given satisfactory service in this type of environment. Other types of hard carbide grades with cobalt or nickel-base have been successful in less severe acid conditions.

Barrels and Liners

Pump barrels and liners for severe H S corrosion and abrasion are limited to chromium plated monel or chromium plated nickel tubes. Liners of hard nickel-boron and centrifugally cast hard chromium-nickel-carbon alloy are successful in many applications where sectional liners can be used.

Nitrided tubes of Nitralloy N (3-1/2% nickel) material will give satisfactory runs where abrasion and mild H_2S corrosion exist.

Where abrasion is not encountered, the brass tube, 316 stainless tube and monel tube without chromium plate will suffice.

Plungers

The plunger which seems to be most widely used in H^2S corrosion is the one with nickel-base chromium-boron metal spray surface. This plunger may be made with either a high alloy base metal or plain carbon steel. Both have been extremely successful.

Another plunger that has proven itself in mild H_2S corrosion and severe abrasion is the Ni-Hard nickel-chromium-carbon grade made from centrifugally cast metal sections.

Hardened cast iron composite plungers should not be overlooked for use in mild corrosive environments where soft premium tubes are to be used. This plunger offers non-galling properties by virtue of inherent graphite particles.

MATERIAL SELECTION FOR BRINE AND CO_2 ENVIRONMENT

Corrosion of parts subjected to this environment has been controlled by use of 18-8 series stainless steels. This is possible by the oxidizing condition which passivates the metal surface. Monels, 400 series chromium steels, brass and bronze are also used to some extent.

Fittings

The most preferred material would be 18-8 stainless steels and should be in the annealed condition in order to eliminate the possibility of intergranular disintegration.

Low chromium steels or high chromium stainless steels would be satisfactory for use.

Balls and Seats

The 440 series is considered excellent when hardness is required.

Tungsten carbide units are also giving outstanding service in this type environment and will be preferred under conditions of extreme corrosion and abrasion.

Barrels and Liners

Cooper alloy of 85-15 grade is frequently used when corrosion is the only problem. If abrasion resistance is required, the chromium plated 85-15 brass tube can be used.

When extreme abrasion and mild corrosion exist, a carburized 4-6 chromium steel tube will give good results.

Centrifugally cast high chromium carbon and high chromium-nickel metals with inherent high hardness will effectively resist carbon dioxide sweet corrosion.

Plungers

For extreme carbon dioxide sweet corrosion, a chromium plated 18-8 stainless steel or chromium plated 5% chromium steel may be used.

The hard spun metal plungers which contain chromium and chromium-nickel alloys will be considered satisfactory.

CONTROLLING CORROSION THROUGH INHIBITION, SACRIFICIAL MATERIAL AND COATINGS

Inhibitors are used either to form a protective film upon the part or parts in question or to change the corrosive fluid to one that is non-corrosive. The organic inhibitor, which I believe is the most popular type, forms the protective film.

Inhibition has proven successful and economical in most cases for the protection of tubing, sucker rods and casing. However, because of fluid turbulence, metal to metal wear, sand abrasion, etc., sub-surface pumps have not responded to protection by inhibition.

Sacrificial materials, such as magnesium and zinc alloy cast on fittings or pony rods, have been tried with no known economical success.

Coatings of the Epoxy resin type have been used on the inside of fittings to mitigate corrosion in localized areas and retard formation of paraffin on the inside of pumps. Spray metal coatings may also be helpful for protection in localized or specific areas on the pump.

It is well to remember that each well has different characteristics as related to the problem of corrosion. The material requirements may be similar, but the selection should be made only after giving consideration to all the variables which exist when mechanically lifting oil bearing fluids to the surface.

REFERENCES

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