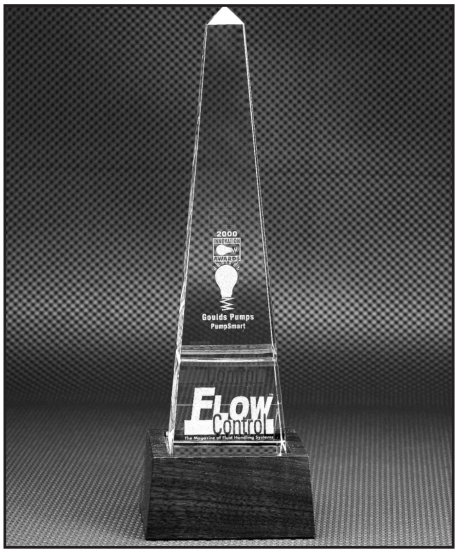
New Products



PumpSmart™ Voted Most Innovative Product

PumpSmart™ process control system has been voted one of the Top 5 Innovative Products of 1999 by the readers of Flow Control Magazine. Out of the over 300 product submissions, Flow Control editors chose 38 finalists to appear in the April balloting issue. PumpSmart, manufactured by ITT Industries' Goulds Pumps unit, was one of the top five products chosen by voting subscribers.

The PumpSmart process system significantly reduces all of the major portions of life cycle costs including: initial capital costs, installation costs, operating costs and maintenance costs.

The PumpSmart system utilizes a standard centrifugal pump in conjunction with a smart microprocessor controller and proprietary pump control software. The microprocessor based controller continually monitors and reacts to both the system and pump conditions.

The PumpSmart system provides continual quantitative measurement of results which include reduced life cycle costs, higher efficiencies and increased productivity. Recent installations have recorded energy savings alone in excess of 40% that translates into more than $15,000 annually on one 75HP pump! PumpSmart can be retrofitted to any centrifugal pump. Since its introduction at the Chemical Exposition in November, PumpSmart has been installed by major process, HPI, and power companies globally.

The Flow Control ISA Innovation Awards was presented during the ISA Show at the New Orleans Convention Center.

Material Matters

When High-Strength Means No-Strength

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Introduction

Failures in highly engineered equipment such as pumps often result in extensive losses due to unscheduled outages, replacement costs, or both. In pumps, wear ring or shaft fractures are often the most damaging, representing a common failure type in rotating equipment. Metallurgical factors are important to understand, however, environmental influences which can promote failures, are of equal importance.

High-strength materials, which are generally selected for strength capabilities, can fail by environmentally induced cracking, particularly in the presence of hydrogen sulfide (H_2S) or other hydrogen sources. Two major types of environmental cracking are hydrogen embrittlement (HE) and stress corrosion cracking (SCC). Both of these phenomena often result in catastrophic, brittle fracture at stress levels significantly below the materials yield stress. An understanding of the synergistic effects between mechanical, metallurgical, electrochemical, and environmental factors on alloy performance is necessary for the safe and reliable application of alloys exposed to environments favorable to either type of cracking.

High-strength steels often utilized for pump shaft applications can be susceptible to hydrogen embrittlement (HE), by a special form of hydrogen stress-cracking (HSC) referred to as sulfide stress-cracking (SSC).

Hydrogen Embrittlement

Hydrogen has no known beneficial effect in ferrous alloys. While the damaging influence of hydrogen on high-strength steels is well documented, even the softest of ferrous alloys are not immune. Hydrogen embrittlement (HE) is the general term given for a loss of toughness resulting from hydrogen absorption. Embrittlement results from the interaction of hydrogen and tensile stresses in susceptible materials.

When high-strength steel containing hydrogen is stressed in tension, it may fail prematurely in a brittle manner. This type of hydrogen damage occurs most often in alloys such as quenched-and-tempered martensitic steels, and the martensitic precipitation-hardened steels. Susceptibility to fracture generally increases with increased strength and hardness. High-strength steel can be embrittled by a very small amount of hydrogen, often as little as a few parts-per-million, which may come from a variety of sources. The source of hydrogen and form in which it exists in an alloy distinguishes the various forms of HE.

Sources of Hydrogen

Hydrogen may enter susceptible alloys from various sources. Some include: solutions containing hydrogen sulfide (H_2S); strong acids; galvanic coupling to more active (anodic) alloys in a corrosive environment such as seawater; cathodic protection; and even microbiological (e.g. SRB - sulfate reducing bacteria) corrosion. Other sources may include residual hydrogen pick up from electroplating or pickling operations, exposure to high-pressure hydrogen gas, or sodium sulfite decomposition in high-pressure boiler feed-water, etc.

Hydrogen can be produced on metal surfaces by sulfide corrosion of an active metal (e.g. $Fe + H_2S \rightarrow FeS + 2H^\circ$); or produced on a passive surface by cathodic reduction. When metal corrodes in a low-pH acidic solution, the cathodic partial reaction is the reduction of hydrogen ions ($2e^- + 2H^+ \rightarrow 2H^\circ$). Although most of the hydrogen generated combines to form molecular hydrogen (H_2), which leaves the metal surface, some of the reduced hydrogen may diffuse into the metal as atomic hydrogen (H°).

The presence of particular chemical substances can hinder the recombination of hydrogen into its molecular form enhancing the absorption of atomic hydrogen into the metal. These substances are called cathodic poisons, and include elements such as phosphorous and sulfur, among others. In high-strength steels, these elements can appear in the form of phosphide or sulfide inclusions, making them more prone to embrittlement. As a result, these elements are generally held to levels that are kept "as-low-as-possible." Among the cathodic poisons that are most damaging, sulfides are common.

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High-Strength...

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Marine structures and pumping equipment are often cathodic protected to reduce the effects of corrosion. Although the protection of such structures usually does not cause hydrogen embrittlement, high-strength steel can be embrittled by the cathodic reduction of hydrogen ions and absorption as previously mentioned.
Hydrogen Stress Cracking & Hydrogen Sulfide
Hydrogen stress-cracking (HSC) involves the absorption of hydrogen, followed by the diffusion into highly stressed regions; particularly those associated with "stress-raisers" or notches. Cracking is caused when it precipitates as molecular hydrogen (H_2) at grain boundaries or discontinuities. This generates substantial internal pressure, which produces blistering or cracking.

HSC (also called “static-fatigue”) is a classic form of embrittlement involving delayed fracture at a stress significantly below the yield strength. It is characterized by the brittle fracture of an alloy that is normally ductile while being tensile stressed below its yield point. High-strength steels exposed to environments containing hydrogen sulfide may exhibit delayed cracking; generally referred to as sulfide-stress-cracking (SSC). This is a special form of HSC, which is essentially a hydrogen-embrittlement phenomenon

Cracking of high strength martensitic steels in aqueous sulfide environments is sometimes erroneously referred to as stress-corrosion cracking (SCC); while sulfide-stress-cracking (SSC) or HSC is the preferred terminology. Hydrogen absorbs into the steel by a cathodic mechanism, rather than an anodic dissolution mechanism (e.g. $M \rightarrow M^{+2} + 2e-$), like chloride stress-corrosion cracking in austenitic stainless steels.

Some materials such as martensitic or precipitation hardened stainless alloys can actually exhibit either type of behavior depending upon the particular conditions. Mixed mechanisms (SSC/SCC) can be operating at the same time under certain service conditions, making it possible to cause failures by both anodic (SCC) and cathodic (SSC) mechanisms. In some services it is difficult to determine which is operating.

Fractograph illustrates Hydrogen-Induced fracture in a UNS S41600 martensitic stainless steel component. Magnification 200X.

Concerns Regarding Precipitation-Hardened Steels in Sulfide Services

NACE MR-0175 is the standard used primarily for “Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment.” This standard presents material requirements for resistance to sulfide stress cracking (SSC) in hydrogen sulfide (H_2S) hydrocarbon services. This standard does not apply to other services such as boiler feed or seawater, which may also contain sulfides. UNS S17400 (17-4 PH) precipitation hardened shaft fractures have occurred in pump services that have not been in what would be typically called a sulfide services. Although hydrogen embrittlement resulted in cracking, the source of hydrogen often has not been clearly identified. Sulfur/sulfide environments not considered sour by NACE MR-0175 definitions can result in failures by hydrogen embrittlement (HE) and sulfide stress cracking (SSC) of susceptible materials such as 17-4 PH precipitation-hardened stainless.

Even though materials may be selected because of compliance to NACE MR-0175, it doesn't guarantee freedom from environmental cracking. It should be noted that materials included in this standard are resistant to, but not necessarily immune to SSC under many service environments. While the susceptibility to SSC can be strongly affected by heat treatment, 17-4 PH precipitation hardened steels that have been properly heat treated to the NACE MR0175 requirements still failed by cracking. Even with NACE requirements specified there is no guarantee that failures will be prevented in 17-4 PH stainless steel.

The NACE MR-0175 heat treatment requirements for UNS S17400 precipitation-hardened stainless steels requires either a Double Aging treatment at 1150°F; or a three step process which is also a Double Aging treatment at 1400°F then at 1150°F for a maximum hardness of 33 HRC. The later three step process can be furnished by specifying steel to meet ASTM A564 UNS S17400 Type 630 in the H1150M condition, rather than the single aged H1150 condition, and adding the requirement for 33 HRC maximum hardness. The resistance of high-strength steels to environmental cracking improves with reduced strength (hardness), and alloying to improve toughness. Specifying ASTM A564, Grade UNS S17400 in the H1150M condition results in significant reductions in strength; lowering the ultimate tensile strength from 135 Ksi to 115 Ksi min.; and the yield strength from 105 Ksi to 75 Ksi min.

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It should be noted that with the strength of 17-4 PH significantly reduced to these lower levels, other more corrosion resistant materials become available as an option. Furthermore, alternative steels such as UNS S20910 (Armco Nitronic 50), UNS S45000 (Carpenter Custom 450), and many Duplex Stainless steels have demonstrated superior resistance to environmental cracking beyond that of UNS S17400 stainless. These steels can offer similar strength/mechanical properties with superior resistance to fracture.

Failure Prevention & Recommendations

The factors controlling hydrogen damage are material selection, stress, and environment. Hydrogen damage can often be prevented by selecting a more corrosion resistant material, reducing the stress, or by modifying the environment. Selection of materials more resistant to hydrogen damage is often possible. In many applications, a lower-strength material will function just as well or better than a higher strength one.

Reducing the stress below the cracking threshold is often possible through design modifications. This can be achieved by eliminating stress raisers in design, reducing residual processing stress, or by reducing stress loads. It should be remembered that the total stress, which includes both applied and residual stress, should be considered. Exposure of components to temperature gradients, or thermal shock, can be a major source of service stress. Cyclic stress from mechanical origins typical of rotating machinery, either from normal operation or abnormal upset conditions, such as vibration and resonance, as well as sudden impact or shock load effects are other sources of stress that may be controlled.

Environment modifications through the use of corrosion inhibitors, or proper controls on the environment chemistry can be made to reduce the effects of corrosion, and the amount of hydrogen absorbed into the metal, often eliminating cracking problems. Removal of aggressive ions and impurities such as sulfides or chlorides, from the environment, and service chemistry control can also prevent embrittlement failures.

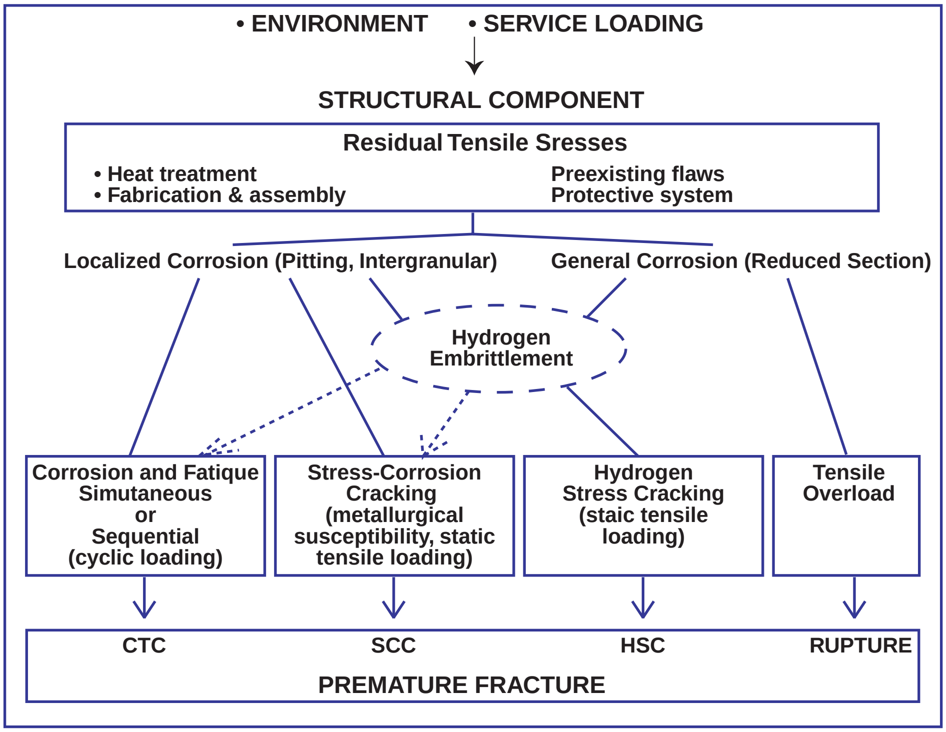

Figure 1: Causes of Premature Fracture Influenced by Corrosion of a Structural Component.

For example, if the reduced strength of double aged UNS S17400 (17-4 PH) precipitation hardened material is suitable for strength requirements perhaps an alternative material with superior corrosion and environmental cracking resistance should be selected for services where sulfide stress-cracking is possible.

I suggest that for services where environmental cracking or sulfide related failure is a concern, product engineers should review optional materials, which may offer similar strength and improved fracture resistance. Alternative steels such martensitic precipitation-hardened stainless UNS S45000 (Carpenter Custom 450 listed as Type XM-25 in ASTM A564), nitrogen strengthened austenitic stainless UNS S20910 (Nitronic 50), or any number of various duplex stainless steels be selected, rather than UNS S17400 precipitation-hardened stainless. Since these alternative alloys can offer similar mechanical properties with superior resistance against environmental cracking, they should be specified for services where environmental cracking resistance is desired.

Reference

*NACE standard MR0175, "**Sulfide Stress Cracking Resistant Metallic Materials For Oilfield Equipment,"** 1999, NACE International, Houston, TX*

*NACE Publication 1F192,"**Use off Corrosion-Resistant Alloys in Oilfield Environments,"** 1993, NACE International, Houston, TX*

*"**Stress-Corrosion Crackin,"** ASM Handbook, 9th Edition, Volume 11, Failure Analysis and Prevention. ASM International, Metals Park, OH, 1986, p 203-224*

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*"**Failure in Sour Gas Environments,"** ASM Handbook, 9th Edition, Volume 11, Failure Analysis and Prevention. ASM International, Metals Park, OH, 1986, p 298-303*