Corrosion of Stainless Steel in Sour High Chloride Produced Water Service

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Abstract

Operators have used equipment and parts made of stainless steels in Permian Basin oilfield operations for years. The material is an improvement over carbon steels in corrosive water environments, but stainless steels are a poor choice when used in sour high chloride produced water service. Parts made from stainless steel in this service are subject to chlorides-induced corrosion. The problem can be even worse when the part is also subjected to fatigue loading.

Failure analysis of failed stainless steel parts reveal chlorides-induced corrosion as the root cause of the failures. The types of corrosion include pitting, stress corrosion cracking, corrosion-fatigue and crevice corrosion. Some of the equipment that is made from stainless steel or have parts made from stainless steel are centrifugal water injection pumps, centrifugal transfer pumps, positive displacement plunger pumps, check valves, gate valves, ball valves, dump valves, pressure relief valves, and sucker rod subsurface pumps.

The alternatives to stainless steel are usually more costly to purchase but may have a longer life. Materials that have shown excellent resistance to chlorides-induced corrosion include nickel-based alloys similar to ASTM A 494 Alloy CW-6MC and ASTM A 494 Alloy CW-12MW, and surface metal coating alloys like Cobalt based overlays (UNS R30001 & UNS R30006).

The Problem

We discovered severe internal corrosion on multistage centrifugal water injection pumps at two different units. We overhauled and upgraded three pumps that were in 100% produced water service after running for only 1 to 3 years. At another unit, we experienced failures within one year of eliminating fresh water that supplemented produced water for injection. An impeller from this pump is shown in Figure 1. A spare pump failed five months after being placed in service. It had very bad corrosion on the case and impellers. One of the impellers is shown in Figure 2.

We were also having failures in stainless steel traveling valves on rod pumps. Figure 3 shows the traveling valves. We have experienced failures in stainless steel trim on dump valves, transfer pumps, PD pumps, and high-pressure relief valves.

The Analysis

We sent samples to our materials and corrosion group to be analyzed by corrosion and metallurgical experts. The material reports that followed sited the cause of failure as chlorides-induced pitting and crevice corrosion. An analysis of a failed impeller from another injection pump, shown in Figure 4, indicated chlorides-induced stress corrosion cracking. All the analysis's indicated that the stainless steel was the improper material for the service.

The analysis of the stainless steel traveling valves revealed the root cause to be chlorides-induced corrosion fatigue.

The Solution

The reports recommended flushing the pumps with oxygen-rich fresh water every time they were shut down for any reason. Even for short periods of time like power blinks, maintenance, or whatever. This would provide oxygen to reestablish the protective oxide film on the surface of the stainless steel parts.

We took an additional step to prevent future failures by replacing the stainless steel impellers on all five of the pumps we overhauled with impellers made of ASTM A 494 Alloy CW-6MC. We did this after researching metallurgy's to find the best metal to resist chloride-induced corrosion. The cases on two pumps were coated with an epoxy coating. We inspected one pump after five months of continuous running. The coating was in good shape and there was no corrosion on the impellers.

We worked with sucker rod pump vendor on the traveling valve problem. The materials report recommended using a nickel alloy like UNS N10276 or UNS N06625. Since our pump vendor already offered the component made from a nickel-copper alloy (UNS N05500), we decided to switch to this material and monitor the results.

Future Tests

The last materials report on an impeller from a spare injection pump that ran five months recommended picking alternate materials using the following pitting index.

$$\textbf{Pitting Index} = \mathbf{Cr + 3.3\ Mo + 11\ N + 1.5\ (W + Cb)}$$

The following table lists some casting materials with their pitting indexes.

Computation of Pitting Indexes for Various Casting Alloys †						
Material	Chrome	Molybdenum	Nitrogen	Tungsten, W	Niobium, Cb	Pitting Index
Type 316 SS	19	2	0	0	0	26
UNS R30001	35	0	0	16	0	59
CW-6MC*	21.5	9	0	0	4	57
N-12MV**	1	28	0	0	0	93
CW-12MW***	16.5	17	0	4.5	0	79
CN3-MN****	21	6.5	0.21	0	0	45

*Nickel Base casting alloy, ASTM A 494 Alloy CW-6MC

**Nickel Base casting alloy, ASTM A 494 Alloy N-12MV

***Nickel Base casting alloy, ASTM A 494 Alloy CW-12MW

****Iron base casting alloy for severe corrosion service, ASTM A 744 Alloy CN3-MN

† There are additional possible replacement materials in the ASTM Specifications A 494 and A 744. A material with a minimum pitting index of 45 would be recommended for this service.

At this point in our study, we have installed some coupons of various metals and coatings in various water stations in West Texas and New Mexico. We hope to learn which material will resist corrosion in our sour high chloride environment and be the most cost effective.

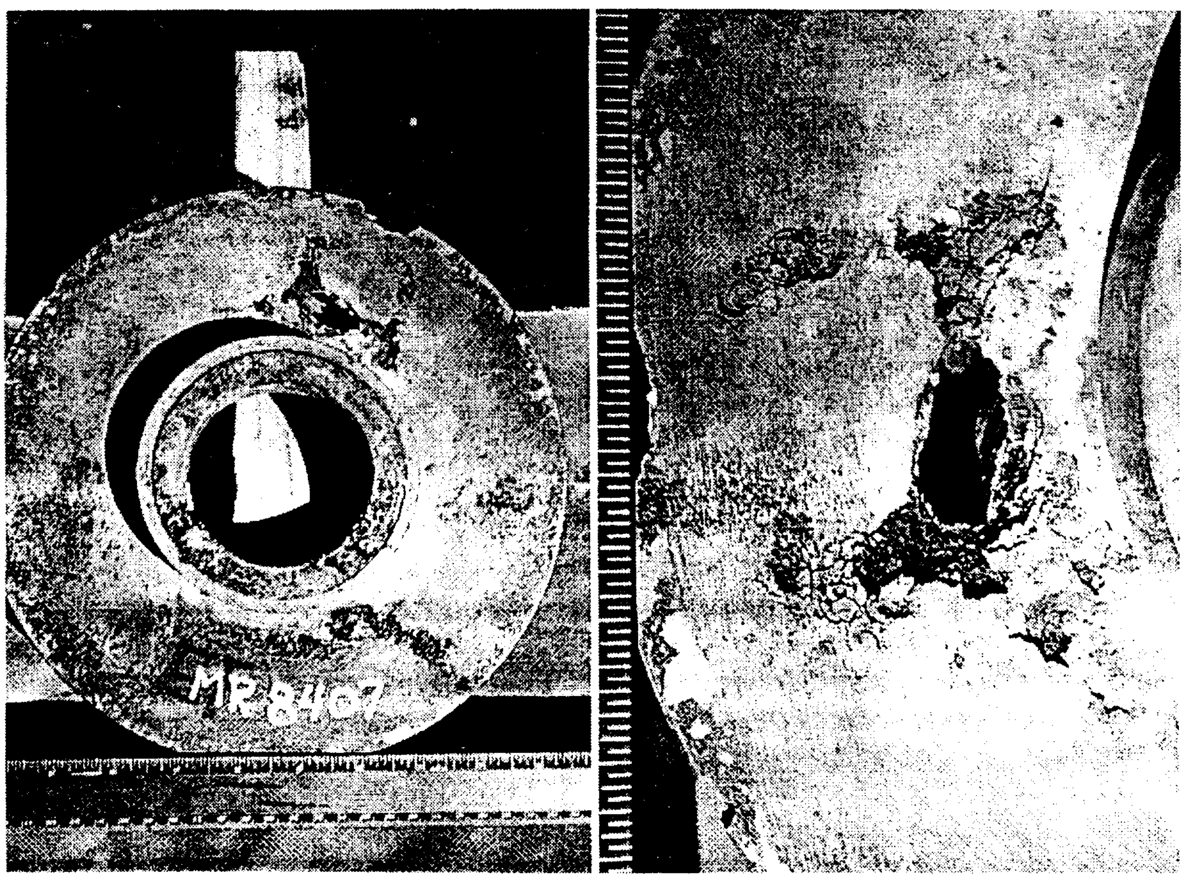

Figure 1

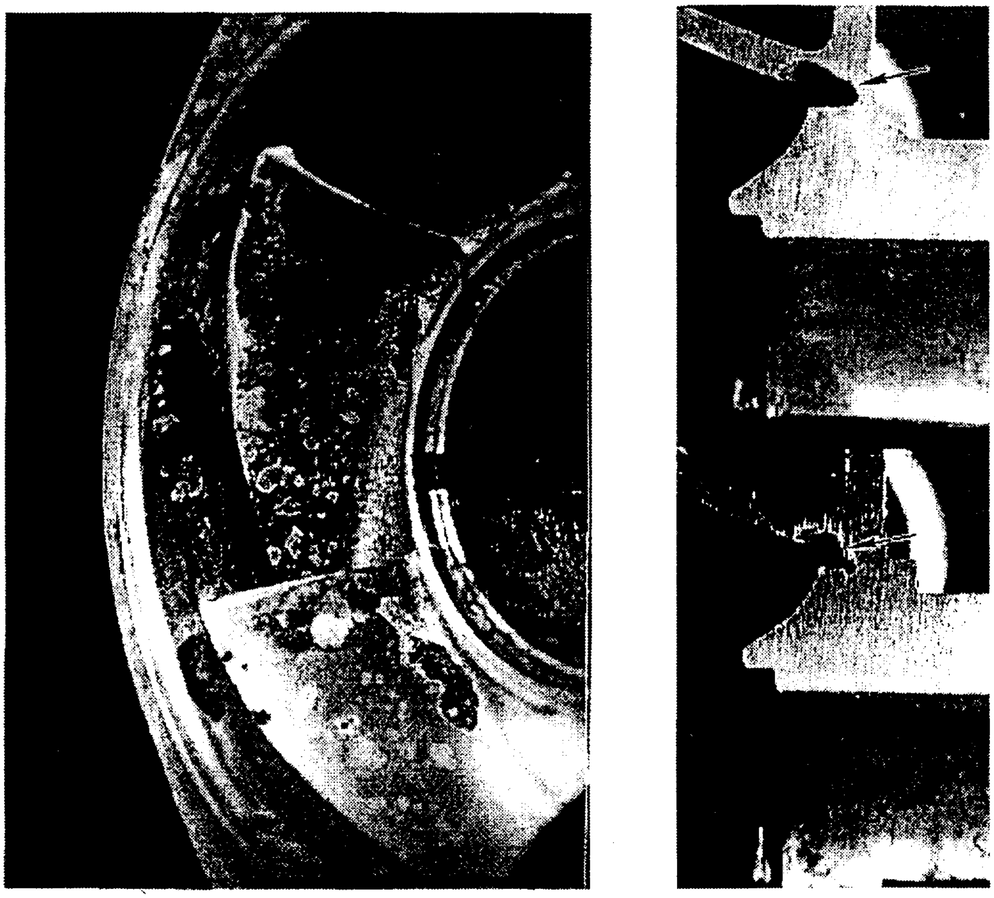
Figure 2

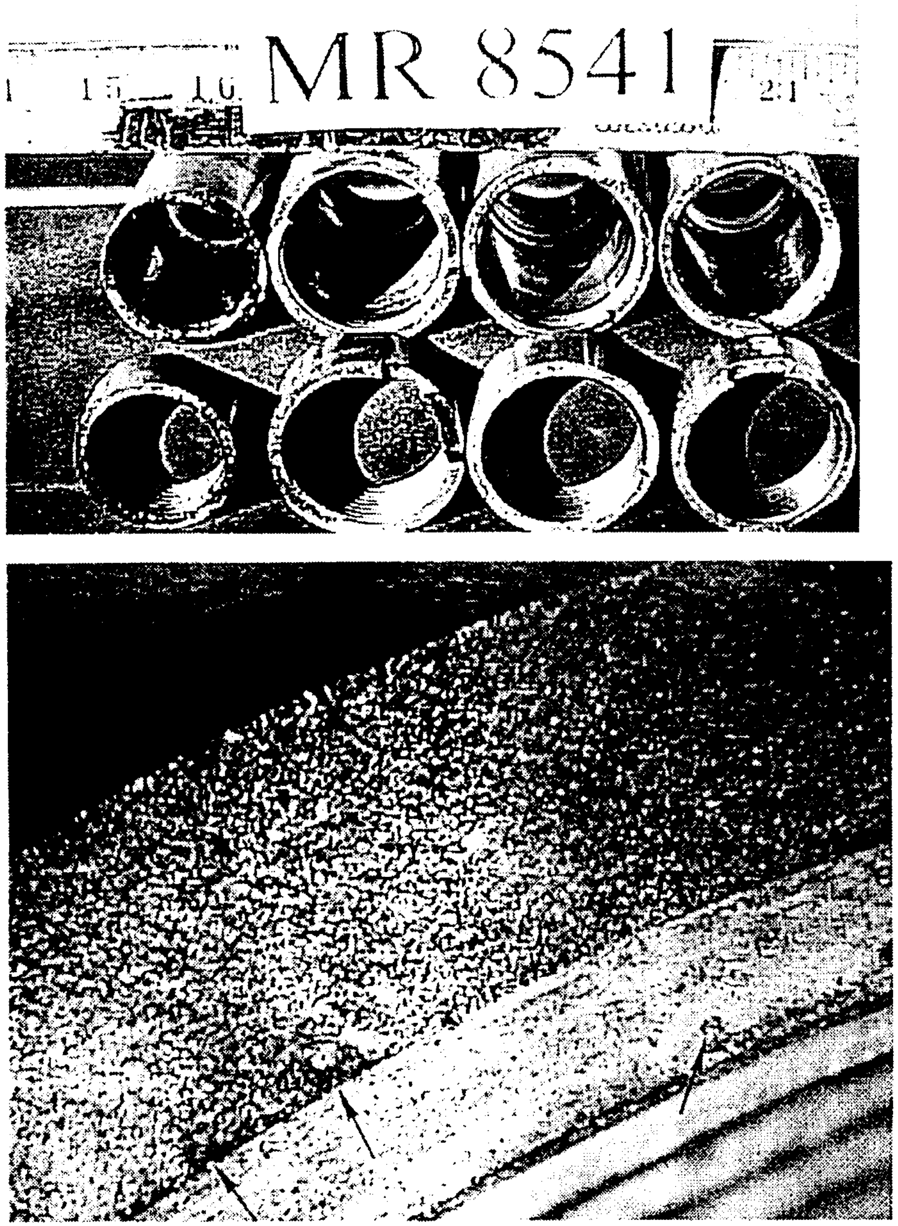

Figure 3

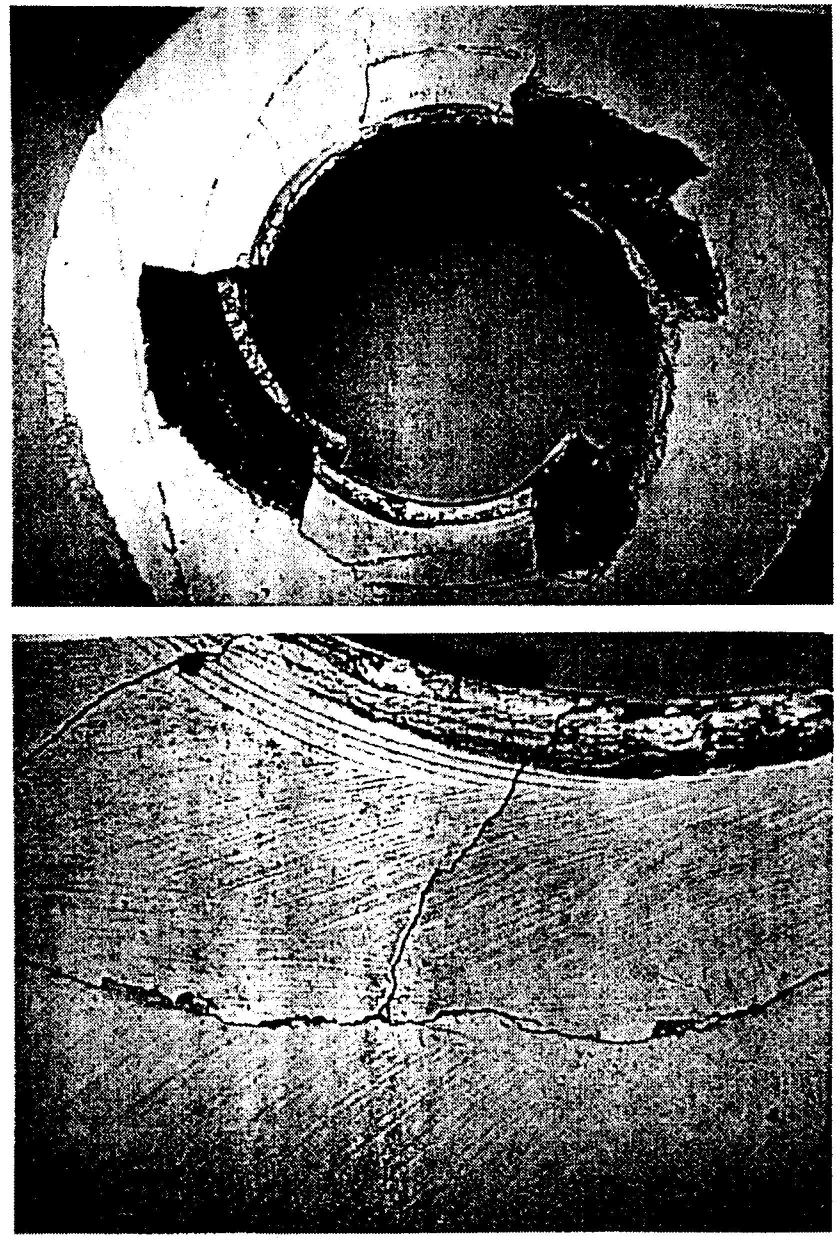

Figure 4