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REPORT

The Erosion Corrosion Resistance Of Zeron 100

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THE EROSION CORROSION RESISTANCE OF ZERON 100

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SUMMARY

This report summarises the erosion corrosion data available for Zeron 100 super duplex stainless steel in a range of environments, and shows that even in very corrosive fluids containing solids, Zeron 100 has excellent resistance to erosion corrosion.

1.0 INTRODUCTION

Stainless steels are well known to have good resistance to erosion corrosion in the presence of fast flowing or turbulent fluids. The causes of erosion corrosion are twofold i.e. corrosion and suspended solids. In addition to velocity, the rate of metal loss is influenced by chlorides, pH and H_2S, which affect corrosion, and by the quantity, hardness and size of the solids which affect erosion. Although metal loss can occur in the absence of solids, it requires a very corrosive fluid and very high velocities to produce erosion corrosion of stainless steels. Normally solids are present in one form or another and they cause erosion by damaging the protective film leading to metal loss by corrosion. The rate of attack is controlled by the rate of film damage, which is a function of the quantity of solids, their hardness and their size. The metal loss rate is also controlled by the corrosivity of the fluid, which is a function of the concentration of aggressive species such as chloride and sulphide as well as the pH.

Zeron 100 is a super duplex stainless steel with the nominal composition Fe/ 25Cr/ 7Ni/ 3.5Mo/ 0.7W/ 0.7Cu/ 0.25N. It has a 50/50 austenite/ferrite microstructure, which combines high strength with good ductility. The high concentrations of chromium, molybdenum and nitrogen mean that the alloy has a high resistance to localised corrosion in solutions containing chlorides and other halides. The alloy is available in both cast and wrought forms and has seen wide industrial use since 1986.

The following sections review the resistance of Zeron 100 to erosion and corrosion in some common industrial fluids.

2.0 EROSION CORROSION DATA

2.1 Sea Water

Zeron 100 has excellent resistance to corrosion in natural seawater. Kain (1) conducted high velocity tests in natural seawater at 30m/sec and at 30°C on Zeron 100 and 316L stainless steel. After 30 days the metal loss was as follows:

316L	-	0.06mm
Zeron 100	-	0.00 mm

316L is frequently used as a reference material in erosion corrosion tests. However, due to its susceptibility to pitting and crevice corrosion, it would not normally be used in seawater service. These results show the high resistance of Zeron 100 to erosion corrosion.

The erosiveness of suspended solids is a function of the size of the solids and their angularity. In seawater, solids up to 50µm diameter are usually referred to as silt, while larger diameter particles are sand. Most materials can tolerate much larger quantities of silt than sand, without suffering excessive attack.

In shallow or tidal areas, sand or silt can be present in the water that leads to a risk of erosion corrosion. Parker and Roscow (2) showed that copper nickel alloys can suffer severe erosion corrosion in the presence of silt at flow velocities of ~ 2m/sec, conditions in which stainless steels have very good resistance to erosion corrosion. In practical seawater systems velocities rarely exceed 10 m/sec because of problems with noise and vibration. At this velocity Zeron 100 can tolerate moderate quantities of suspended solids in the seawater with no serious erosion corrosion.

A pin erosion test rig was constructed to compare materials under high velocity erosive conditions (3). Tests were conducted in 3% salt solution (pH = 8.0) with 1000 mg/l CAST sand at 50℃. Two impingent velocities were used, 25 and 30 m/sec. Table 1 shows the volume loss at both velocities for Zeron 100 compared with 316L stainless steel and carbon steel to BS3601. The results show the superior performance of Zeron 100 in neutral brines carrying sand.

The high resistance of Zeron 100 to erosion by silt and sand was used to advantage by the BOC Cantarell plant in Mexico. The seawater for cooling is taken from a shallow bay and the bottom gets stirred up during tropical storms. This means that for several days after a storm there is a high solids burden in the water. The solids are mostly sand and gravel with a peak content of ~50,000 mg/l. The original heat exchangers and seawater pumps were copper alloys and they were suffering severe erosion corrosion. RA Materials won the order to replace the 28 heat exchangers with ones in Zeron 100. At the same time, the aluminium bronze pumps were replaced with eight Zeron 100 pumps feeding the four trains. The cases for these were fabricated from wrought Zeron 100, while the impellers were castings. The Zeron 100 has been in service since 2003 with excellent performance. Figure 1 shows one of the Zeron 100 heat exchangers supplied to Cantarell.

2.2 Production Environments

Zeron 100 has been extensively used for manifolds, pipework, flanges, fittings etc. in production systems for the oil and gas industry. These systems can contain sand, which increases the aggressivity of the production fluid.

2.2.1 Gas Systems

In piping carrying gas there are two potential sources of erosion. One is where the gas stream is wet and carries entrained water droplets, which impinge on the walls and can give rise to erosion. The second source is when sand is also present in the gas stream.

Erosion in gas streams has not been well researched, but Castle et al (4) have reported wellhead tests in wet gas streams on a number of alloys. The tests were conducted under sand-free conditions at 18 m/sec. The results are shown in Table 2. Erosion corrosion resistance increases as the strength and corrosion resistance of the material increases.

Because Zeron 100 is stronger and more corrosion resistant than 22%Cr duplex, it would be expected to have an even lower erosion rate than 22%Cr duplex (UNS S31803). Castle is currently extending his testing to even higher velocities.

In a sand-containing gas stream erosion will be more severe than for a wet gas stream containing only water droplets. There is some data for carbon steel under these conditions, but there is no rigorous examination of the performance of CRA's such as duplex stainless steels.

2.2.2 Three Phase Systems

In oil-carrying pipelines the presence of sand can also lead to severe erosion. The presence of CO_2 results in low pH values, sometimes below 4. A number of materials were evaluated in the pin erosion test rig described above (3) under the following conditions.

Chloride	- 25,000 mg/l
Sand	- 640 mg/l
Temperature	- 55°C
pH	- 3.5
Velocity	- 40 m/sec

The results for the average weight loss of duplicate test pieces are shown in Figure 2. The results clearly show the superior resistance to erosion corrosion of Zeron 100 compared to other alloys used in oil and gas process lines.

Table 3 shows a production environment that was being handled by Zeron 100 at velocities of approximately 30 m/sec. The sand content of 3 lbs/1000 bbls is approximately equal to 10mg/l. This system produced sand for two years and was inspected after 4 years, when it was found to be in excellent condition, with no signs of erosion.

Several authors (3, 5) have shown that in aqueous solutions the rate of erosion is proportional to the sand content and the cube of the velocity.

$$\text{i.e., erosion} \propto s.V^3$$

where, s = sand content
V = velocity

Using the above equation and the single data point for Zeron 100 i.e., 3 lbs/1000 bbls at 30 m/sec, it is possible to construct a conservative velocity limit curve for Zeron 100 in sand-containing fluids. This is shown in Figure 3. All points below the curve should be free from erosion corrosion. It is possible that higher velocities could be tolerated but it will require further data to confirm this. The requirement for this data to be valid is that the alloy is in the passive condition. In very aggressive fluids where general corrosion is occurring, it is not known what effect sand will have on erosion corrosion. The curve in Figure 3 correctly predicts that Zeron 100 will be satisfactory under the conditions in the Cantarell heat exchangers.

2.3 Flue Gas Desulphurisation

The treatment of power station flue gases to remove sulphur-containing gases is often done by passing the flue gases through a slurry of limestone, producing calcium sulphate. The presence of undissolved limestone and fly ash make the slurry erosive. In addition, the chloride content can be very high (up to 50,000 mg/l) and the acid gases can lower the pH to 3 or 4. Hence the FGD slurry is a very corrosive and erosive mixture.

Pin erosion tests were conducted on some candidate alloys for the slurry handling system (3). Figure 4 shows the volumetric metal loss over a range of pH values. The erosion loss for both 25% Cr duplex and Zeron 100 was independent of pH over the range studied. The superior performance of Zeron 100 over not only 316L and austenitic cast iron, but also 25% Cr duplex stainless steel (PREN 35) can clearly be seen.

Following the erosion tests, a loop was constructed utilizing a Zeron 100 pump and pipework, and the slurry shown in Table 4 was pumped around the loop (3). After 5,000 hours, examination of the pump components showed slight corrosion at the vane tips and at the discharge; i.e. the areas of greatest turbulence. On the basis of these successful tests, Zeron 100 was selected for the diffuser plates and main slurry pumps in the FGD plant at Drax power station, U.K. These came on stream early in 1994 and the pumps have run successfully for up to 40,000 hours. No erosion has been seen on the diffuser plates. Zeron 100 has also been used for the slurry centrifuges in the FGD system at the Ratcliffe power station in the UK and to replace GRP piping, which was eroding in the FGD slurry. Zeron 100 has suffered no significant attack at Ratcliffe. Zeron 100 has also been used for the agitators in the main absorber tower at a number of FGD plants, with excellent results.

2.4 Cavitation

Cavitation occurs where there is a sudden pressure drop in a system. This results in the formation of vapour cavities that migrate along the pressure gradient and eventually implode on the metal walls. The energy release can then lead to loss of metal. Cavitation often occurs in high velocity systems and can be linked with erosion corrosion. Typical sites for cavitation are in pumps or after partly throttled valves. Figure 5 shows some cavitation data generated by the Royal Navy in a flow loop in natural seawater (6). The results clearly show the superior performance of superduplex stainless steel compared with nickel aluminium bronze (NAB) and other alloys commonly used for pumps, such as austenitic stainless steels.

3. CONCLUSIONS

The test data and service experience show that Zeron 100 has a high resistance to erosion corrosion in the presence of entrained solids in a wide range of corrosive fluids. These include seawater, flue gas desulphurisation slurries, and oil and gas production fluids.

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TABLE 1 Volume loss from pin erosion tests in 3% sodium chloride solution plus 1000 mg/l sand at 55°C.

ALLOY	Vol. Loss (ml x 0.001)	
	25m/s	30m/s
Carbon Steel	2.33	6.56
316L	1.50	4.85
Zeron 100	1.30	4.18

TABLE 2 Metal loss at 18m/s in a wet gas stream (Ref 4)

ALLOY	METAL LOSS (%)	EROSION RATE (mm/y)
AISI 1018 Carbon Steel	59	6.3
9% Cr/1% Mo Alloy Steel	1.1	0.08
22% Cr Duplex	0.01	0.001

TABLE 3 Production environment experienced by Zeron 100.

CO_2	2.1 bar
H_2S	0.01 bar
Temperature	110°C
Sand	3lbs/1000 bbls
Velocity	30m/s

TABLE 4 Composition of the slurry used in the FGD pump test loop.

Calcium Sulphate	-	10.64 wt %
Calcium Carbonate	-	0.26 wt %
Fly Ash	-	0.47 wt %
Chloride	-	40,000 mg/l
pH	-	5.0
Temperature	-	50°C

FIGURE 1 Zeron 100 heat exchanger supplied to BOC Cantarell to handle seawater with a high suspended solids content.

FIGURE 2 Weight loss of some stainless steels in an acid brine (pH3.5) plus 1,000mg/l sand at 40m/s

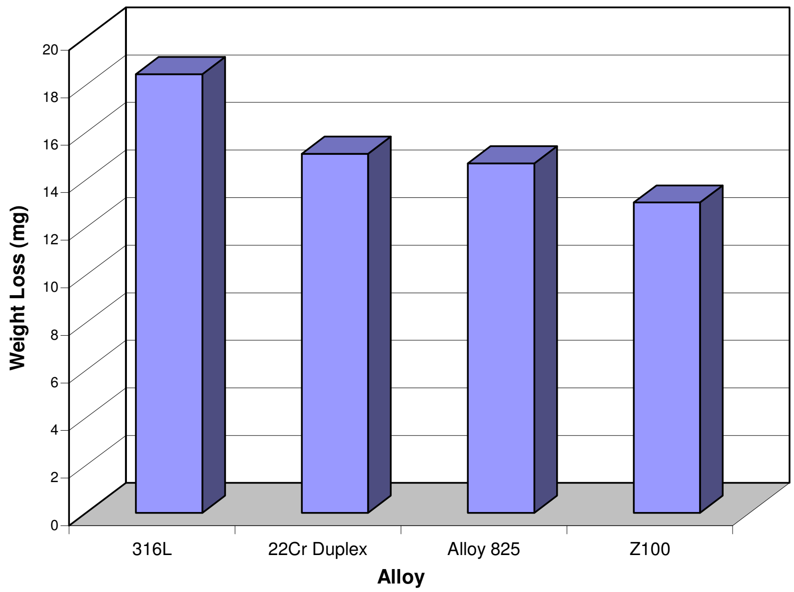

FIGURE 3 Conservative velocities for Zeron 100 in process fluids with sand

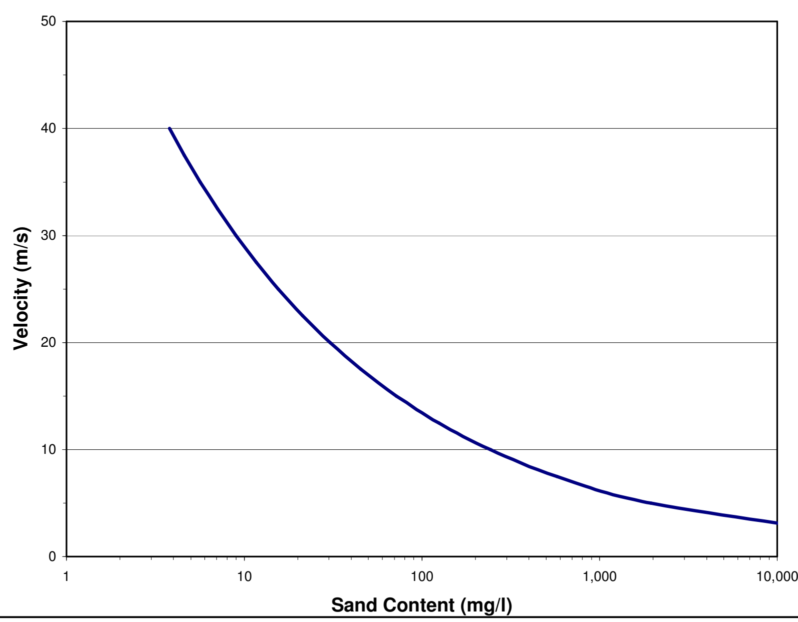

FIGURE 4 Pin erosion rig test results in a simulated FGD slurry

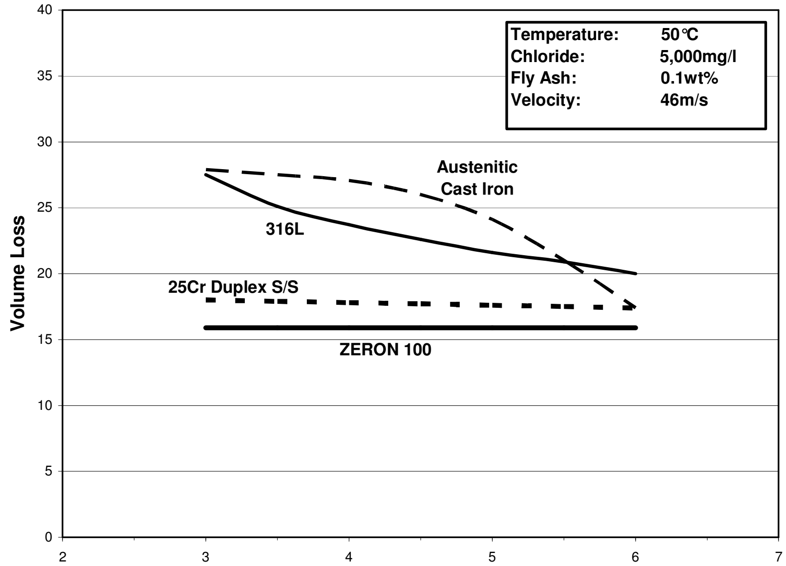

FIGURE 5 Cavitation volume loss rate at 40m/s in natural seawater (Ref 6)