REPORT

THE USE OF ZERON 100 SUPERDUPLEX STAINLESS STEEL IN SWIMMING POOLS

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SUMMARY

This report describes the properties of Zeron 100 and its high resistance to crevice corrosion in swimming pools filled with high chloride brines, compared with other, lower alloy stainless steels. The report also describes the problems with stress corrosion cracking of 300 series stainless steel components used to support swimming pool roofs. The high resistance of Zeron 100 to SCC in these high chloride/low pH environments is demonstrated. Some applications of Zeron 100 for swimming pool fittings and furniture are shown, as well as the use of Zeron 100 to replace 316 stainless steel for roof supports

1.0 INTRODUCTION

In recent years there has been an increasing use of brines in swimming pools. This is partly for the mildly disinfectant quality of brine and also because chlorine/hypochlorite is readily generated from brine electrolytically to provide disinfection. The use of brine means that the chloride content is much higher than older style pools and consequently the water is more corrosive towards most materials. Some pools, on the coast, use seawater and this can be extremely corrosive.

Stainless steels are being increasingly used for fittings in pools because they are corrosion resistant and easy to clean. However, the increased chloride content of the water means that the traditionally used grades of stainless steel, such as 316L, suffer corrosion.

300 series austenitic stainless steels have also been frequently used as wire, bolts or bars to support swimming pool roofs. Following several catastrophic failures, these alloys are no longer recommended and higher alloy stainless steels are required.

This report describes the laboratory testing of Zeron 100 superduplex stainless steel in both seawater and the swimming pool roof environment, the results from which demonstrate the alloy's suitability for both applications. Some service experiences to support these assertions is included.

2.0 THE ALLOY

Zeron 100 is a superduplex stainless steel i.e. it is 50% austenite and 50% ferrite. This gives the alloy the benefits of the austenitic microstructure, such as ductility, and also those of the ferritic microstructure, such as strength.

Table 1 shows the composition of Zeron 100 compared with some other stainless steels. The high levels of chromium, molybdenum and nitrogen give excellent resistance to localised attack in the presence of chlorides. This is often assessed in an empirical manner by the pitting resistance equivalent number, or PREN, where PREN = % Cr + 3.3 x % Mo + 16 x % N. The guaranteed minimum PREN of 40 for Zeron 100 ensures a high resistance to localised attack in chloride-containing solutions.

Zeron 100 is produced with a 50/50 austenite/ferrite phase balance ensuring high strength and good ductility. Zeron 100 offers high strength and corrosion resistance compared with austenitic stainless steels and other duplex stainless steels such as the 22% Cr duplex (UNS S31803), as shown in Table 2.

Zeron 100 is readily manufactured by a variety of processes and is available as castings (principally for pumps and valves) and as wrought pipes, fittings, plate, bar, fasteners and forgings. Where higher strength than the solution annealed product is required, e.g. for fasteners, Zeron 100 is also available as lightly cold worked bar in the FG condition. This has equivalent mechanical properties to B7 steel (ASTM A193). The minimum mechanical properties are 725 MPa 0.2% proof stress and 860 MPa tensile strength and the bars are available in sizes from 0.5” to 2.5” diameter.

Zeron 100 is fully weldable by all the common arc welding processes. It can be welded with Zeron 100M consumables, where post weld heat treatment is to be carried out. The alloy is most commonly welded with Zeron 100X overalloyed consumables, for use in the as-welded condition. Material thickness is not an issue and joints are in service from 1mm to 63mm thick. Like all high alloy stainless steels, Zeron 100 requires care in welding. It is important to use qualified welders working to approved procedures.

3.0 CORROSION RESISTANCE

3.1 Seawater

Swimming pools are usually chlorinated and the resistance to crevice corrosion of stainless steels in this environment has been assessed by a number of workers (e.g. refs 1 and 2). Figure 1 shows the maximum depth of attack for several stainless steels in chlorinated seawater at 16° C [2]. Alloy 904L suffers crevice corrosion under these conditions, but generally to a lesser depth than 22% Cr duplex.

The maximum chloride content before crevice corrosion becomes a significant problem, can be calculated using the Corrosion Engineering Guide [3]. These limits are shown in Figure 2. It can be seen that even at ambient temperature, 316L has only a limited tolerance for chlorides. Both 904L and 22% Cr duplex may be used in slightly more brackish waters, but only superduplex can be used in waters of higher chloride content. Seawater has typically about 18,000 to 25,000 mg/l chloride. The limits for 6% Mo austenitic stainless steel are similar to those for Zeron 100.

As the temperature increases, the susceptibility of stainless steels to crevice corrosion increases. Figure 3 shows the maximum depth of crevice corrosion for some stainless steels in chlorinated seawater at 40° C [2]. Only Zeron 100 was totally resistant to attack.

3.2 Stress Corrosion Cracking

When stainless steels are stressed in the presence of chlorides, stress corrosion cracking is normally seen only at elevated temperatures. However, the failure of some swimming pool roofs held up with 300 series stainless steel bolts and wires, prompted a laboratory study of the problem[4]. It was found that strong solutions could condense on the metal supports in the swimming pool roof due to the presence of chlorine in the water and very low pH's could develop. It was shown that 316L stainless steel would suffer stress corrosion cracking in simulated condensed waters, similar in appearance to the service failures. Weir Materials has tested both 316L and Zeron 100 in the same simulated environments. Figure 4 shows a microsection of 316L exposed to a simulated condensed water for seven days and stress corrosion cracking is clearly visible. Figure 5 shows a microsection of Zeron 100, also exposed for seven days. There was no stress corrosion cracking and just a little surface corrosion. This equated to a low corrosion rate that would not lead to premature failure, unlike 316L.

4.0 SERVICE EXPERIENCE

Zeron 100 has been used in seawater and high chloride brine swimming pools for a variety of fittings, including hand rails and ladders. Zeron 100 bolting has been used to fasten a variety of pool equipment in place. Figure 6 shows Zeron 100 furniture manufactured from plate and pipe for a hydrotherapy pool (seawater at 40° C) in Tenerife. Mechanical polishing produced a high quality finish for this application.

Zeron 100 has also been used for tie bars in swimming pool roofs. Figure 7 shows the pool roof of the Bedale Leisure Complex (UK), with the original 316 tie bars clearly visible. Figure 8 shows the 316 tie bars being removed and the Zeron 100 replacements awaiting installation.

5.0 CONCLUSIONS

1) Zeron 100 offers a combination of high strength and corrosion resistance, superior to that of 316L austenitic stainless steel.

2) Zeron 100 will resist corrosion in chlorinated swimming pools up to 40°C.

3) Zeron 100 resists chloride stress corrosion cracking under the high chloride/low pH solutions that can condense in swimming pool roofs.

REFERENCES

1) P. Gallagher, R. E. Malpas and E.B. Shone, Paper 113, Corrosion ’89, New Orleans, LA, USA. April 1989, NACE International.

2) R. Francis, Stainless Steels ’87 , York, UK. 1987, IOM, page 192.

3) Corrosion Engineering Guide, version 2.0, Nickel Institute.

4) J. W. Oldfield and B. Todd, Brit. Corr. J. 26 (1991) 173.

TABLE 1 The nominal composition of some common stainless steels.

TYPE	COMMON NAME	NOMINAL COMPOSITION (wt %)							PREN*
		Fe	Cr	Ni	Mo	N	Cu	W	
Austenitic	316L	Bal	17	10	2	-	-	-	24
	904L	Bal	20	25	4.5	-	1.5	-	35
	6% Mo	Bal	20	18	6	0.2	0.7	-	43
Duplex	22% Cr	Bal	22	5	3	0.16	-	-	35
	Zeron 100	Bal	25	7	3.5	0.25	0.7	0.7	>40

Bal = balance
* PREN = % Cr + 3.3 x % Mo + 16 x % N

TABLE 2 The minimum mechanical properties at room temperature of some common stainless steels.

TYPE	COMMON NAME	0.2% PROOF STRESS (MPa)	TENSILE STRENGTH (MPa)	ELONGATION (%)
Austenitic	316L	170	485	40
	904L	220	490	35
	6% Mo	300	650	35
Duplex	22% Cr	450	620	25
	Zeron 100	550	750	25

FIGURE 1 Maximum depth of crevice corrosion in seawater plus 1mg/l chlorine at 16°C

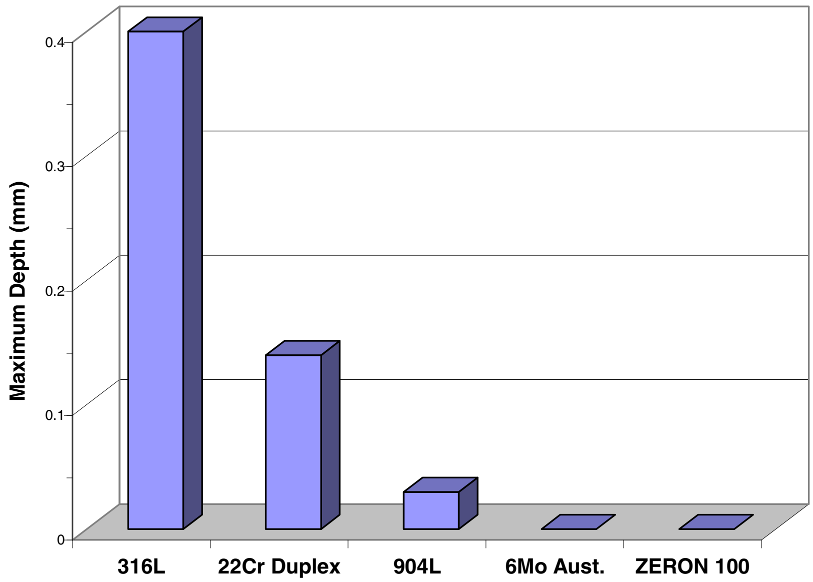


FIGURE 2 Chloride limits to resist crevice corrosion for some stainless steels

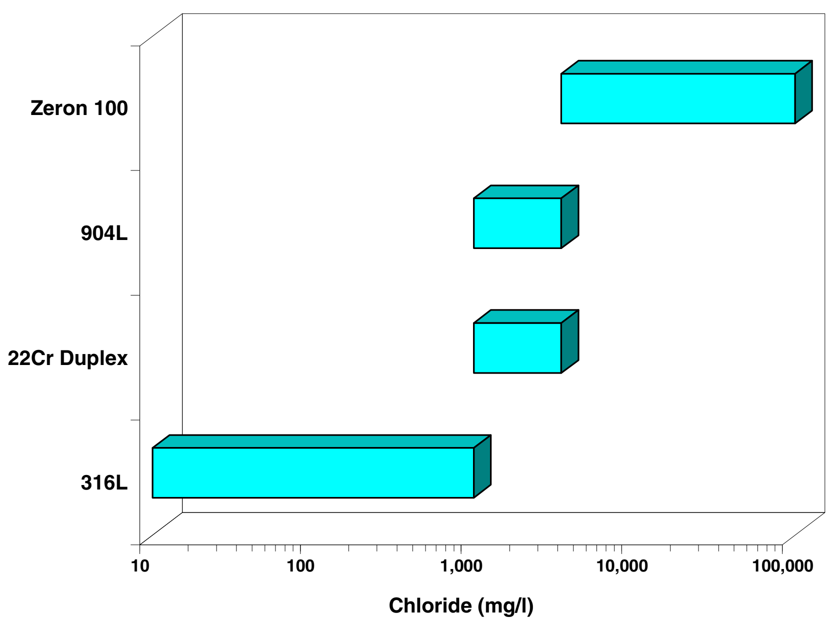
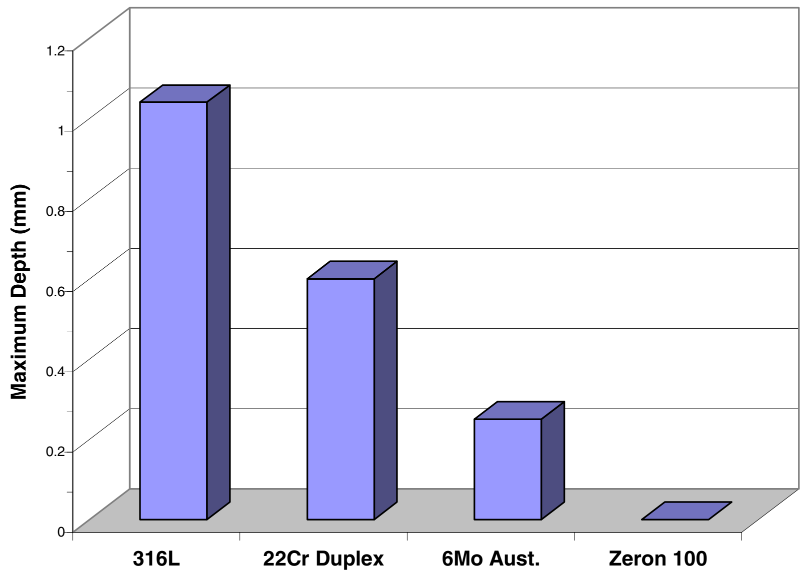
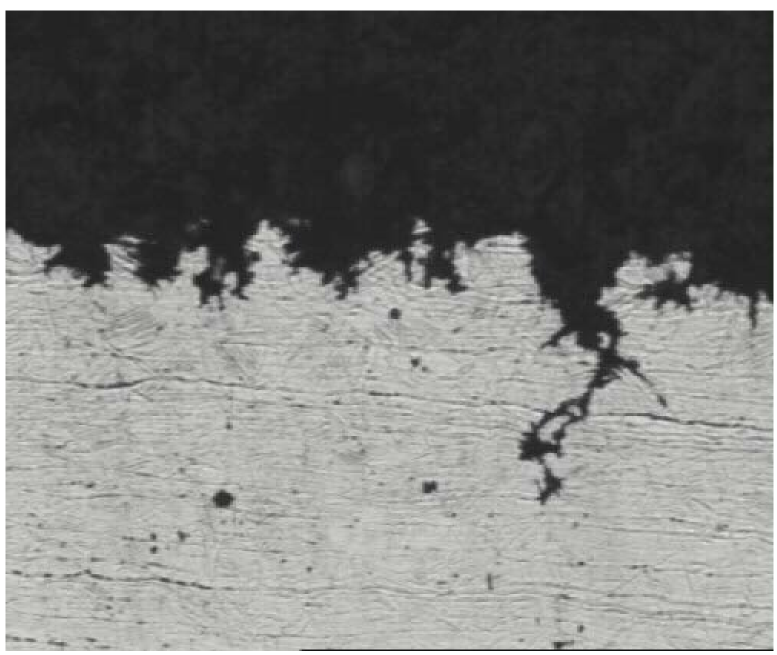


FIGURE 3 Maximum depth of crevice corrosion in seawater plus 1mg/l chlorine at 40°C





20µm

FIGURE 4 Microsection showing SCC of 316L exposed to simulated condensed water.

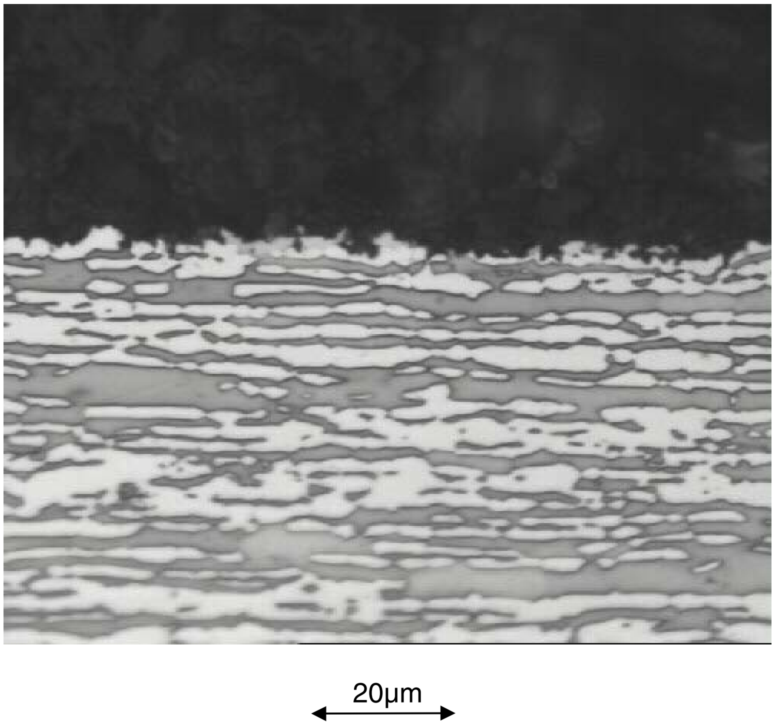


FIGURE 5 Microsection showing slight corrosion of Zeron 100 exposed to a simulated condensed water.

FIGURE 6 Polished Zeron 100 furniture for a hydrotherapy pool in Tenerife.

FIGURE 7 Roof of Bedale Leisure Complex swimming pool showing 316 tie bars.

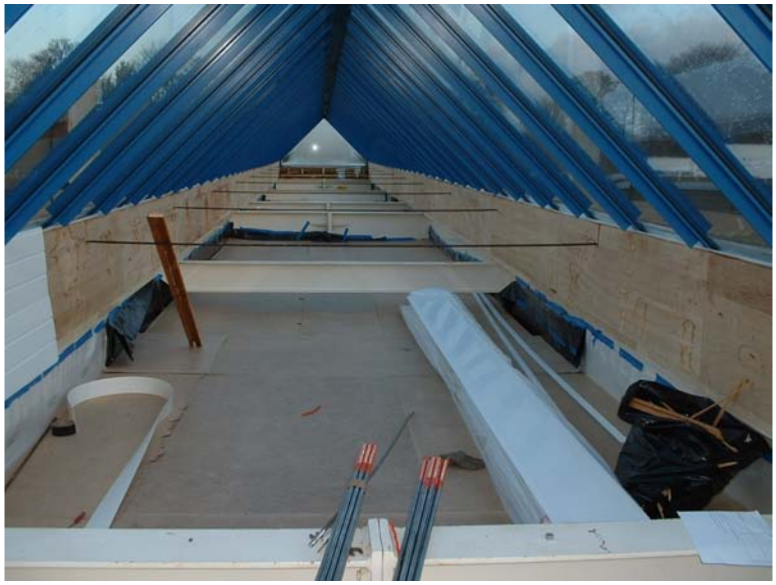


FIGURE 8 Zeron 100 tie bars awaiting installation in swimming pool roof.