Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steels Used in Dry Cask Storage Systems in A Simulated Marine Environment

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Abstract

Austenitic stainless steel is the regular material used in the canister of dry storage casks, including Type 304, 304L, 316L stainless steel. When the spent fuel storage installations located at the coastal sites, these types of austenitic stainless steel are prone to chloride induced stress corrosion cracking (CISCC) in aggressive environment. CISCC has complex interactions associated with environment, stress and material properties. Therefore, the objective of this work is to evaluate the susceptibility to chloride induced stress corrosion cracking of candidate canister materials by using U-bend tests in a simulated marine atmospheric environment containing sodium chloride (NaCl) or magnesium chloride ($MgCl_2$) and keeping constant relative humidity of 40 percent. Prior to the U-bend tests, samples were prepared and underwent various pretreatments, including solution annealing and thermal sensitization.

After the tests, the samples were examined with the scanning electron microscope (SEM) in order to measure and quantify the cracks. According to the results, there are more cracks observed on sensitized samples at higher temperature in the presence of sodium chloride, and the length of cracks measured in all circumstances are in the range of 0-20 um. The results of quantitative analysis indicated that the number of cracks increases with temperature at constant humidity, and there is no significant influence on the test duration. Subsequently, magnesium chloride was also used for investigating the influence of different salt on the tendency of chloride induced stress corrosion cracking. More cracks were induced and observed on the surface due to $MgCl_2$ deposition. The cross section will be observed with optical microscope to measure the depth of cracks in the future.

Keywords

chloride induced stress corrosion cracking; dry cask storage system; austenitic stainless steel; U-bend test

Introduction

Austenitic stainless steel performs predominant corrosion resistance because of the passive film enriched chromium content. Therefore, austenitic stainless steels are widely used in various industrial applications, even as candidate materials for dry storage canister, like type 304, 304L, 316L stainless steels, all of them are usually used with dry storage systems as interim storage. As the dry storage system located at coastal environment, the sufficient chloride ions will induce depassivation of stainless steel, and then lead to corrosion on the canister, including pitting, stress corrosion cracking[1-3]. Therefore, it needs to attach importance to the susceptibility of chloride induced stress corrosion cracking on the canister. Airborne sea salts will become moist by absorbing water from the atmosphere, and then form a thin aerosol layer of chloride or droplet type in a large range of relative humidity. Chloride in thin film or droplet is able to be concentrated due to the evaporation when relative humidity decrease. According to the composition of sea salt as shown in Table1[4], the amount of magnesium chloride ($MgCl_2$) is the second major chloride in simulated seawater, only second to sodium chloride (NaCl). However, the concentration of chloride depends on the relative humidity which is controlled by temperature and the deliquescence relative humidity, these environmental factors are closely linked and all affected by the type of chloride salt. Since $MgCl_2 \cdot 6H_2O$ is a stable Mg-chloride hydrate over the entire temperature range and deliquesces at 33%[5], the most aggressive chloride salt under low temperature is the $MgCl_2 \cdot 6H_2O$, as previous reports[6-9]. This object of this study is using quantitative analysis to evaluate the susceptibility of CISCC accumulated by periodic spraying of NaCl and $MgCl_2 \cdot 6H_2O$ solution on the austenitic stainless steels.

Experimental

Materials and Methods

The candidate materials of dry storage canister used in this study are 304, 304L, 316L stainless steel. The chemical compositions of specimens are shown in table 1. Plate stainless steels were used to prepared rectangular shape with dimensions of 80 x 20 x 2.5mm (L x W x T) according to ASTMG30-97[10].

There were two holes for fixing the U-bend samples with diameter of 10mm, and the distance between them was 50 mm, which were center-symmetrical. Two heat treatments were applied, which are referred to as solution annealed (SA) and sensitization (SEN). These specimens were annealed at 1050^{o}C for 40 minutes and then quenched in water. Some of the solution-annealed specimens were sensitized at 650 ^{o}C for different duration depending on which type of stainless steels.

Table 1 Compositions of 304, 304L, 316L stainless steels analyzed by spectrometer (wt%)

Element	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	V	Mg
304	0.032	0.34	1.09	0.028	0.019	8.02	17.86	0.35	0.43	0.07	0.15

304L	0.0215	0.49	1.53	0.03	0.0026	8.36	17.96	0.29	0.46	0.06	0.11
316L	0.0267	0.39	1.43	0.031	0.015	12.45	16.79	2.15	0.3	0.04	0.18

Table 2 Summary of heat treatments applied to solution annealed (SA) and sensitization (SEN)

Materials	Solution annealing			Sensitization		
304	1050 °C	40 minutes	Water quanching	650 °C	24 hours	Furnace cooling
304L					48 hours	
316L					100 hours	

Summary of heat treatments is shown in table 2. The sensitization at 650 °C was chosen to simulate the condition of welded components in the dry storage canister. The heat-treated samples were ground by silicon carbide paper from 80 to 4000 grit, and then cleaned ultrasonically in both deionized water and methanol. The plate, rectangular test pieces were bent into U-shape by a special-designed tool, which is suggested by ASTM G30-97, and the fixtures were clamped to maintain constant tensile stress. After the test pieces bent into U-bend, the radius of the upper semicircle is 5mm. By the equation: $\varepsilon = T/2R$, the strain of the specimens is 25%.

Deposition procedures and simulated system

To simulate the aerosol deposition on the surface of the canister, the 3.5% Sodium Chloride NaCl and Magnesium Chloride $MgCl_2 \cdot 6H_2O$ solution will be sprayed in four days period during the whole testing. After spraying, U-bend samples will be placed into a temperature and humidity-controlled chamber, and a hydrometer is also used to monitor the condition in the testing chamber.

To ensure the amount of salt deposition is more than the threshold value for stress corrosion crack 0.1g/cm^2, plate ITO glass specimens will be conducted the same deposition procedure with other U-bend specimens, and then placed into the monitored chamber at the same time. Before the next spraying time, the ITO specimens will be heated to remove the moisture content of the aerosol deposition, and then magnesium chloride crystal will precipitate, which amount can be examined with EX Analytical Balances.

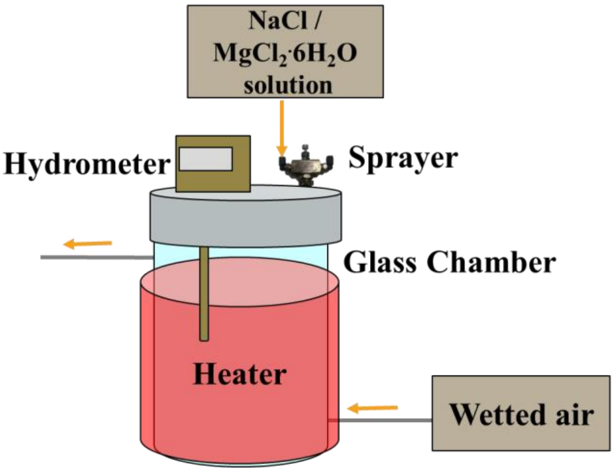


Figure 1 Schematic diagram of system for simulating coastal environment at controlled temperature and humidity. There are 304,304L, and 316L with annealed and sensitized samples put in the chamber.

Morphology and Continuous images

Every 500 hours, U-bend and plate specimens were taken out from the chamber for cleaning by the deionized water and acetone in ultrasonicator. The morphology would be observed by field emission scanning electron microscope (JSM-7610F). The Observation of specimen surface focuses on ensuring whether the length of cracks and the diameter of pits would increase or not within the whole testing duration. About 150-200 continuous images were also taken by FE-SEM to measure the length of each crack on an area about 5.7-6.3 mm^2. All the quantitative result would do the standardization to compare each sample under different conditions in a constant area. By the AZ-tec version 3.1 of oxford instruments Nano analysis, continuous images on the centered top side of U-bend specimens are edited into a montage with the constant area, as shown in figure 12.

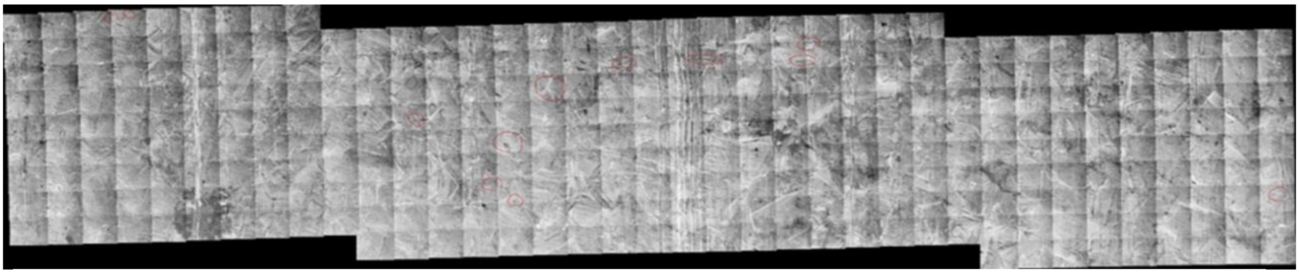


Figure 2 A montage of continuous images

Results and discussion

DL-EPR test

In order to ensure that sensitized heat treatments can achieve severe sensitization of stainless steels test pieces, the DL-EPR measurement was performed, and the results of the DL-EPR test is shown in figure 3. In the reverse scanning, an obvious increase of active dissolution current density was observed for the sensitized specimen. The degree of sensitization was calculated by the ratio of active peak current density at the reverse scanning (i_r) to the peak current density at anodic scanning (i_a) [11-13].

This value represents a fraction of the depassivation caused by chromium depletion, the sensitization degree is shown in the table 2. For the sensitized Type 304 and 304L stainless steel samples, a calculated value 0.379 and 0.195 indicated high sensitization susceptibility. A calculated value 0.058 for the sensitized 316L stainless steel indicated a medium degree of sensitization, but for the type 316L is a relatively high degree of sensitization.

Table 3 Degree of sensitization of 304, 304L, 316L stainless steels.

Materials	DOS(%)
Type 304	37.9
Type 304L	19.5
Type 316L	5.8

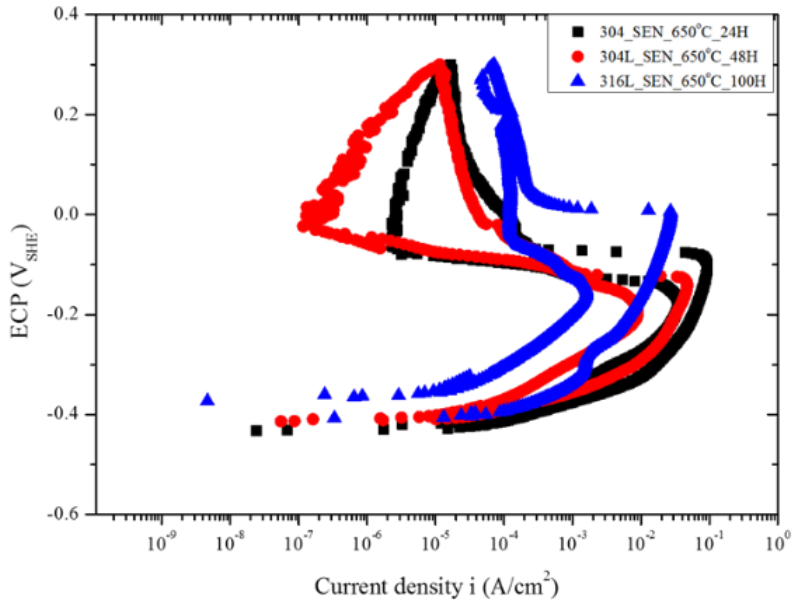


Figure 3 DL-EPR curves for sensitized 304, 304L, 316L stainless steels.

Morphology observation and quantitative analysis

Relation between pitting and stress corrosion cracking

Pitting usually acts as the one type of initiation of crack [14-18]. When the rate of pitting generation is fast enough, it will transfer into stress corrosion cracking within a high propagation rate. After 1000 hours of periodic spraying 3.5% $MgCl_2{\cdot}6H_2O$ solution at 40°C, there were several pits located along a crack, which observed on sensitized 304 stainless steel U-bend specimen, as shown in figure 4 (a). Figure 4 (b) was taken with FE-SEM in the same magnification 500X, and then these continuous images were edited by the AZ-TEC software. There were pits and breaches observed along a crack.

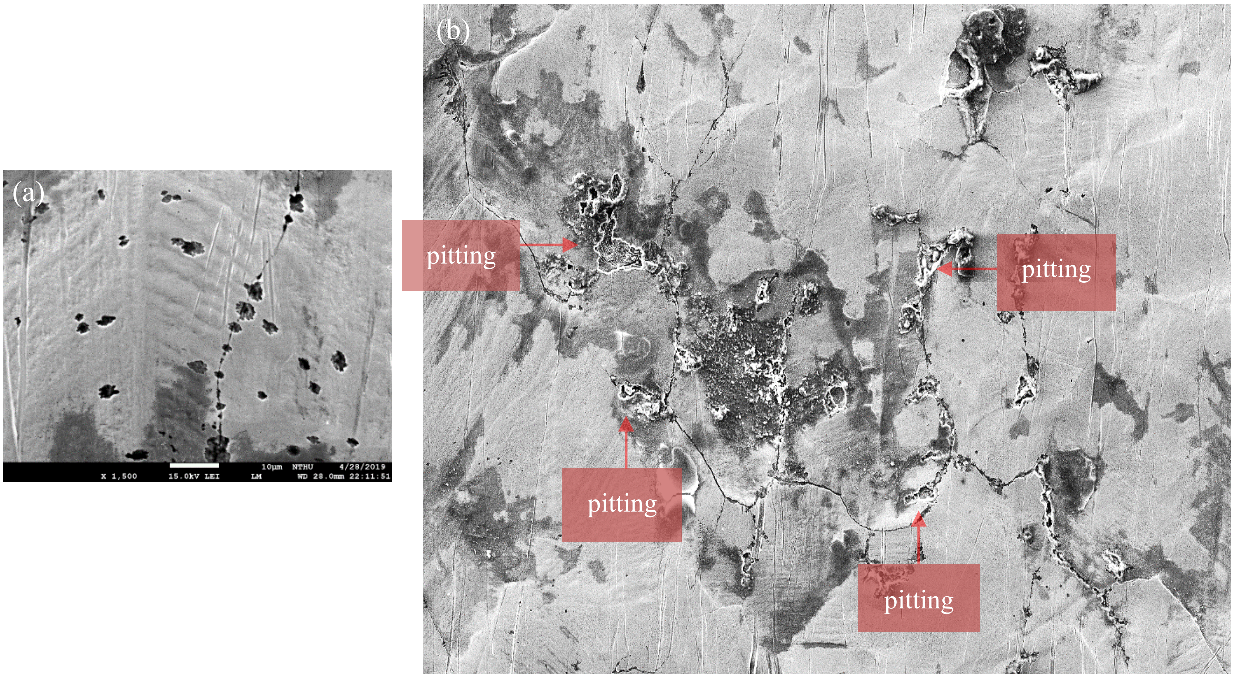


Figure 4 (a) Pitting and stress corrosion cracking on the sensitized 304 stainless steel U-bend specimen_1500X. (b)Sensitized 304 stainless under periodic spraying $MgCl_2{\cdot}6H_2O$ solution at 40°C for 1000 hours. (b) continuous images_500X

Difference of salt deposition

There were two kinds of chloride solution applied in this experiment, including sodium chloride (NaCl) and magnesium chloride ($MgCl_2{\cdot}6H_2O$). The concentration of sodium chloride and magnesium chloride was 3.5%. According to the record of salt deposit in each periodic spraying, both of them were much more than the threshold value of stress corrosion cracking 0.1 g/m^2[19].

After 1000 hours of periodic spraying of NaCl solution at 50 °C, the cracks perpendicular to the direction of tensile stress were observed on the sensitized 304L and 316L specimens, the length of these cracks was in a range of 20-70μm, as shown in figure 5 (c), (e). But on the sensitized 304 U-bend specimens, the crack with 51.5μm was not perpendicular to the tensile stress. It may be caused by multi-axial stress during the bending procedure.

After 1000 hours of periodic spraying $MgCl_2{\cdot}6H_2O$ solution at 40°C, the grain boundary preferential corrosion cracking was observed both on the sensitized 304 and 304L stainless steels, the morphology is shown in figure 5. There was a 62μm crack on the sensitized 316L stainless steel, a slim crack connected two irregular shaped pits, as shown in figure 5.

Comparing the observation of specimen surface under two kinds of chloride solution periodic spraying, there was a significant difference. More severe intergranular corrosion was observed on the specimens under the periodic spraying $MgCl_2{\cdot}6H_2O$ solution. It was related to that the chloride concentration was different due to the different chloride solution spraying under the same relative humidity 40% RH. Sodium chloride deliquesces at about 76% of relative humidity and the magnesium chloride deliquesces at 37-24% of relative humidity over the whole temperature. Based on the above, the $MgCl_2{\cdot}6H_2O$ would almost deliquesce at the 40%RH to generate a large amount of chloride ions on the specimens, which would cause the more serious chloride induced stress corrosion cracking on the sensitized specimens.

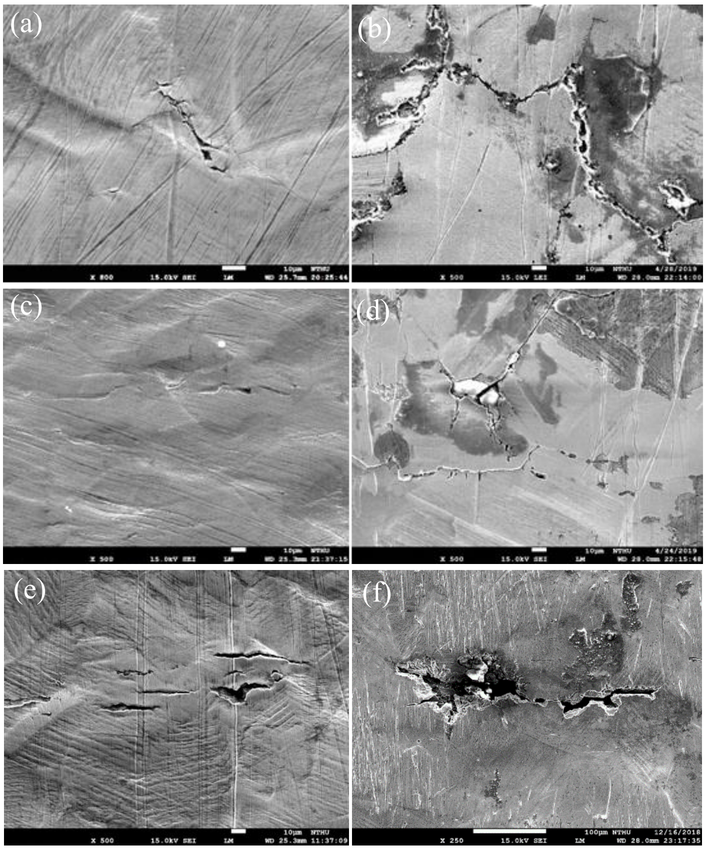


Figure 5 (a), (b)304_SEN; (c), (d) 304L_SEN; (e), (f) 316L_SEN. (a), (c), (e) were under the periodic spraying of NaCl solution at 50 °C, and (b), (d), (f) were under periodic spraying of $MgCl_2{\cdot}6H_2O$ solution at 40 °C for 1000 hours. (a)-(f) U-bend samples.

The influence of temperature

When the controlled temperature increased up to 80 °C, it would take less time to dry the chloride deposition. The results of three stainless steels at 50 °C and 80 °C after 1500 hours of periodic spraying NaCl solution temperature indicated that the relative humidity required for the deliquescent of salt is higher, which decrease the concentration of chloride ions and susceptibility of chloride induced stress corrosion cracking (CISCC). On the sensitized 304L U-bend sample, general corrosion occurred under periodic spraying of NaCl solution at 80°C, as shown figure 6. From the EDX analysis of the sample surface, obvious oxidation was observed, and the edge of breach had chromium and oxygen signals. Few signal of iron indicated that oxide was formed in the breach. Figure 7 shows the results of three types stainless steels at 50 °C and 80 °C after 1500 hours of periodic spraying NaCl solution. The total number of cracks at 80 °C was much more than that at 50 °C, especially the number of small cracks with a length of 0-20μm. Moreover, this phenomenon occurred no matter which heat treatment applied on the testing samples. It was coincided with the previous observation of morphology that the oxidation would become serious and the total number of cracks increased at higher temperature 80°C. As the temperature increases, the driving force for pitting and stress corrosion cracking is also improved, accelerating the rate of chloride-induced stress corrosion cracking.

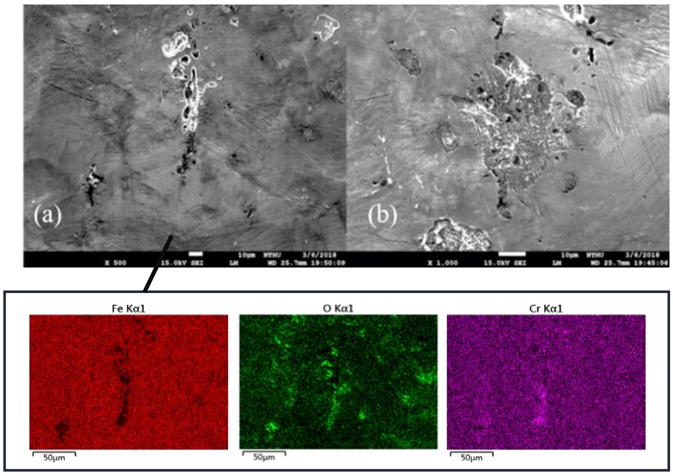


Figure 6 The EDX analysis of 304L U-bend sample at 80°C under periodic spraying of NaCl solution.

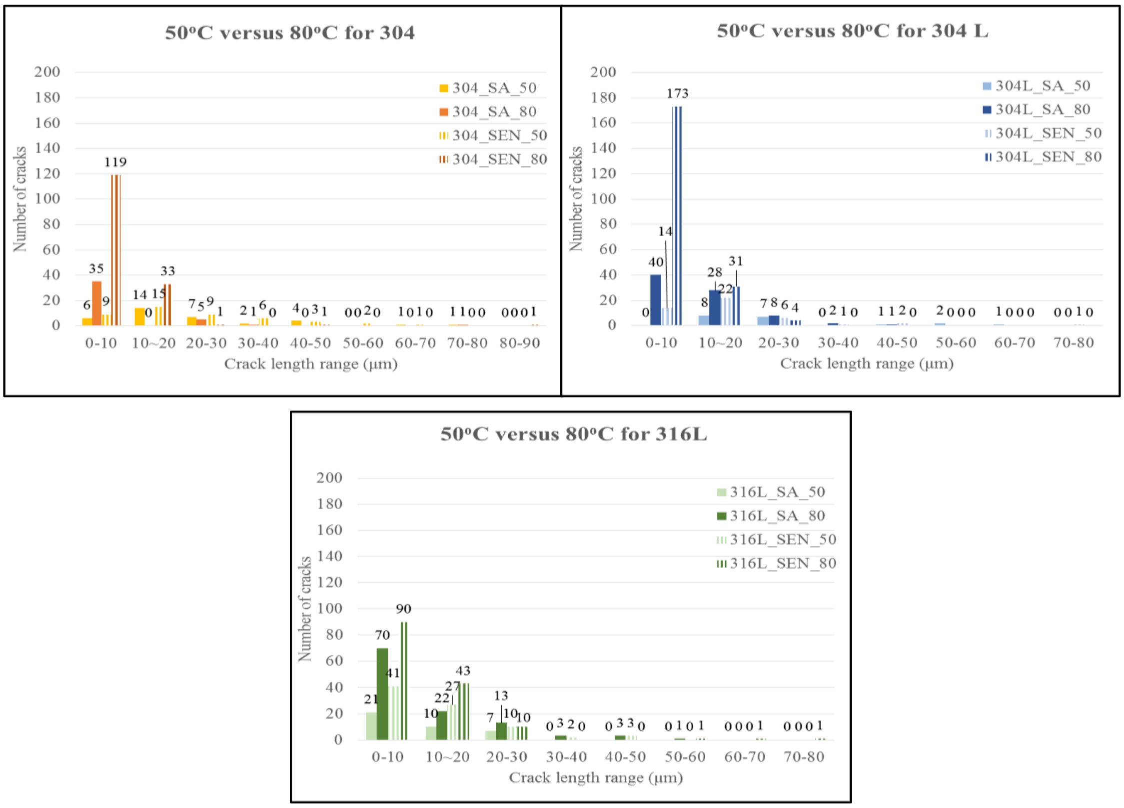


Figure 7 The quantitative results of different temperatures.

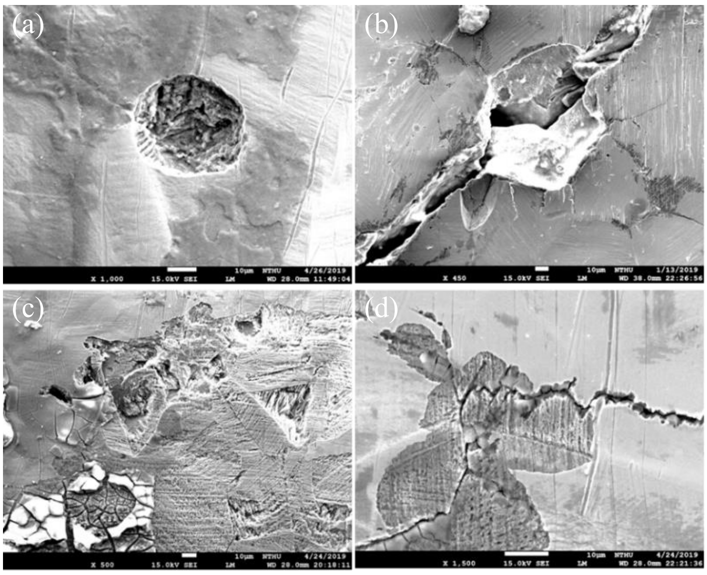
The influence of sensitization

After 1000 hours of periodic spraying $MgCl_2 \cdot 6H_2O$ solution at 40 °C, hole or irregular shaped of pitting was observed on solution-annealed 304, 304L, 316L U-bend specimens, as shown in figure 8 (b), (d), (f). From the SEM images, the pits observed on the solution annealed 304, 316L specimens were deeper than those on the 304L specimen. Obviously, grain slightly detached from the substrate because of the preferential intergranular corrosion.

After 1000 hours of periodic spraying NaCl solution at 50 °C, not only hole shape defects but longer and slim cracks were observed on the sensitized 316L U-bend specimens. And the length of these cracks was in the range of 24-70μm. Comparing to the sensitized specimens, the diameter of the pits observed on the annealed samples were in the range of 1.25-10μm, as shown in figure 9 (a), (b). The results of 304L stainless steel after 1500 hours of periodic spraying of NaCl solution at 80 °C were shown in figure 9 (c), (d), there were more hole shape pitting generated on the sensitized specimens than annealed specimens.

Pitting corrosion was the major corrosion behavior on the solution-annealed 304, 304L, 316L stainless steel U-bend specimens, since there was no stress corrosion cracking observed. On the other hands, besides pitting corrosion, intergranular corrosion was also found on the sensitized 304, 304L, 316L stainless steels U-bend specimens.

Plate samples indicated similar difference between two heat-treated samples. In figure 10, only hole shape pitting with averaged diameter of 40-50μm was found on the morphology annealed 304 specimens. The pitting of sensitized 304 was crystal-like, which indicated intergranular corrosion. The depth of pitting and cracks will be detected by confocal microscope in the future. The change of the depth may be a trend within the whole testing duration.



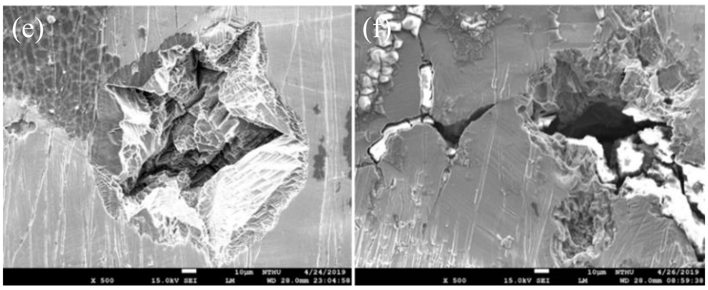


Figure 8 (a), (c), (e) annealed 304, 304L, 316L sampled. (b), (d), (f) sensitized 304, 304L, 316L samples.

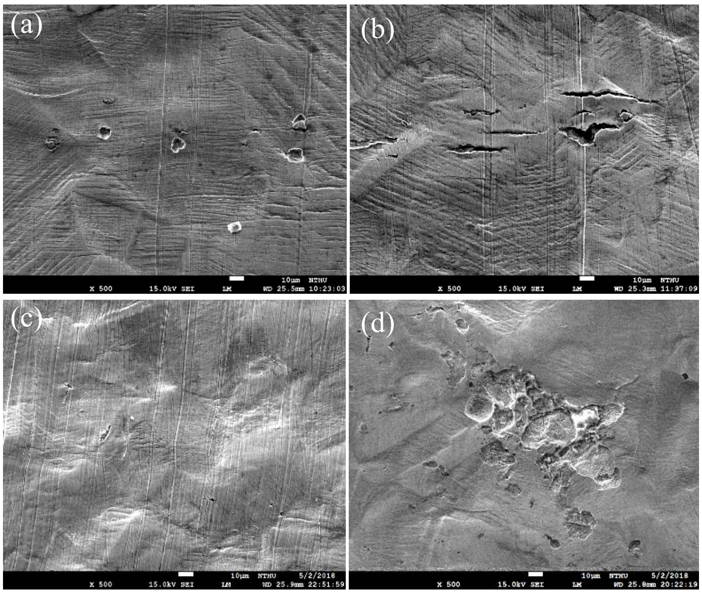


Figure 9 (a), (b) 316L_SA, SEN at 50ºC for 1000 hours, and (c), (d) 304L_SA, SEN at 80ºC for 1500 hours. (a)-(d)500X.

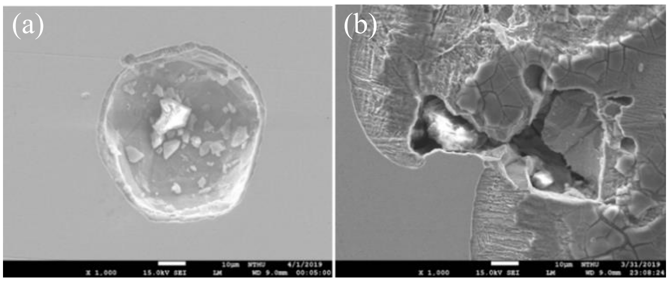
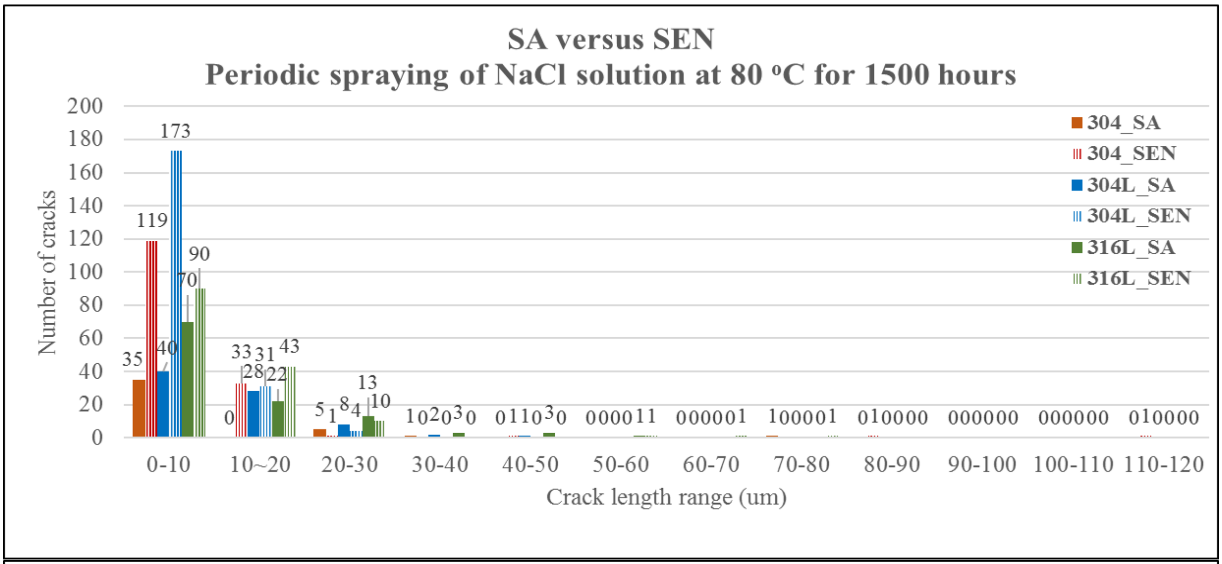


Figure 10 (a) solution annealed 304 stainless steel, (b) sensitized 304 stainless steel. (a)-(b) plate specimens.

The total number of cracks is shown in Table 4, and detailed number in each length interval is shown in figure 11. After 1500 hours of periodic spraying NaCl solution at 50 ºC and 80 ºC, the cracks were longer, and the total number of cracks were much more on the sensitized specimens than annealed specimens. The presence of periodic spraying of $MgCl_2 \cdot 6H_2O$ solution, the number of cracks and pits under 50μm on the sensitized 304 and 304L specimens were about 2.5-3 times that of annealed 304, 304L specimens. On all sensitized specimens can find cracks longer than 50μm because of chloride induced stress corrosion cracking. Some of the intergranular cracks were even longer than 500μm on the sensitized 304 and 304L specimens, which could work in concert with the morphology. There was a few difference between type 316L and two types stainless steels as mentioned above. On the sensitized 316L specimens, the cracks number under 50μm only added one more than annealed specimens. However, the cracks number in the range of 50-100 on the sensitized specimens was more than solution annealed specimens.



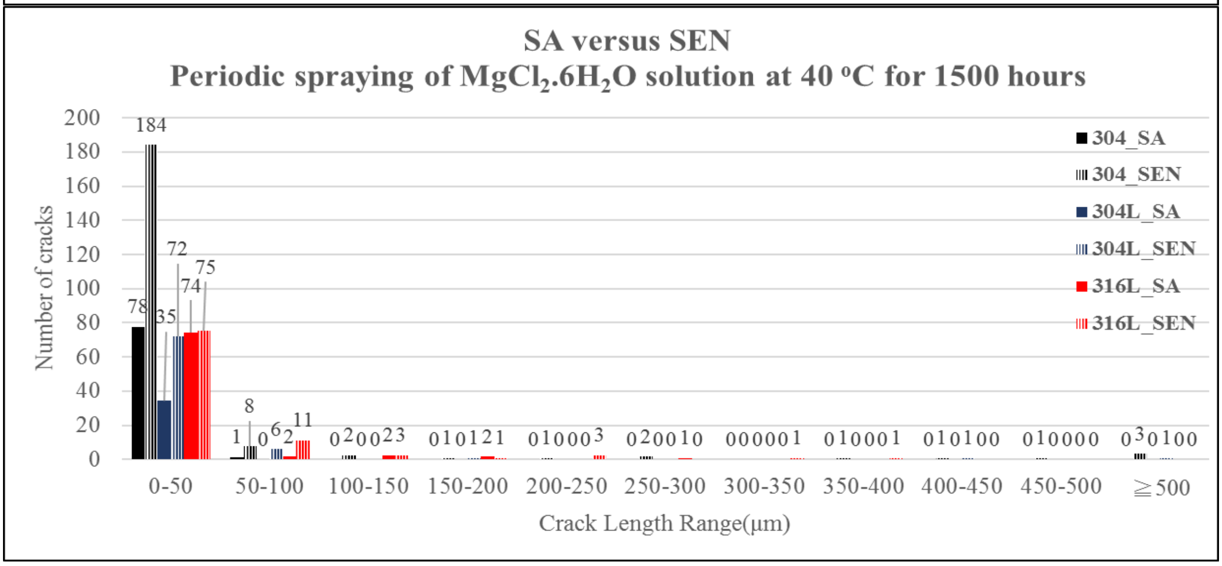


Figure 11 The quantitative results of different testing conditions for comparing the difference between two heat treatments.

Table 4 Total number of cracks in a constant area.

Condition	After 1500 hours of periodic spraying NaCl solution at 50 °C					
SS	304_SA	304_SEN	304L_SA	304L_SEN	316L_SA	316L_SEN
Total number	35	45	21	46	38	83

Condition	After 1500 hours of periodic spraying NaCl solution at 80 ^{o}C					
SS	304_SA	304_SEN	304L_SA	304L_SEN	316L_SA	316L_SEN
Total number	42	156	79	208	112	146
Condition	After 1500 hours of periodic spraying $MgCl_2{\cdot}6H_2O$ solution at 40 ^{o}C					
SS	304_SA	304_SEN	304L_SA	304L_SEN	316L_SA	316L_SEN
Total number	79	208	35	97	81	110

<u>The influence of testing duration</u>

In this study, the total testing duration was 1500 hours. For the evaluation of the influence of duration on the growth rate of chloride induced stress corrosion cracking, the same cracks or pits would be kept tracking every 500 hours.

From figure 12, the morphology of the specimen was similar and the length of the same cracks was not greater, even the testing duration increased. Figure 12 (a) and (b) shows that after 500 hours and 1000 hours of testing, the depth of pitting corrosion on the solution-annealed 316L U-bend specimen did not increase significantly, and the pitting corrosion area also did not spread out after. By the length measurement of the cracks in figure 12 (c) and (d), the crack with the length of 80.8μm on the 1000 hours specimen increased to 81.5μm after another 1500 hours testing, only increased by 0.7μm. Using the measurement tool of AZ-tec software, there will be some tiny error in each shot, so the change in length was not obvious. Under the NaCl deposition procedure after 1500 hours, the morphology was similar. It was surmised that the testing duration of 1500 hours is not enough to make the crack on the surface grow evidently. In the future, we will continue tracking the change of crack morphology in more aggressive environment, containing periodic spraying $MgCl_2{\cdot}6H_2O$ solution at 60^{o}C and 80^{o}C.

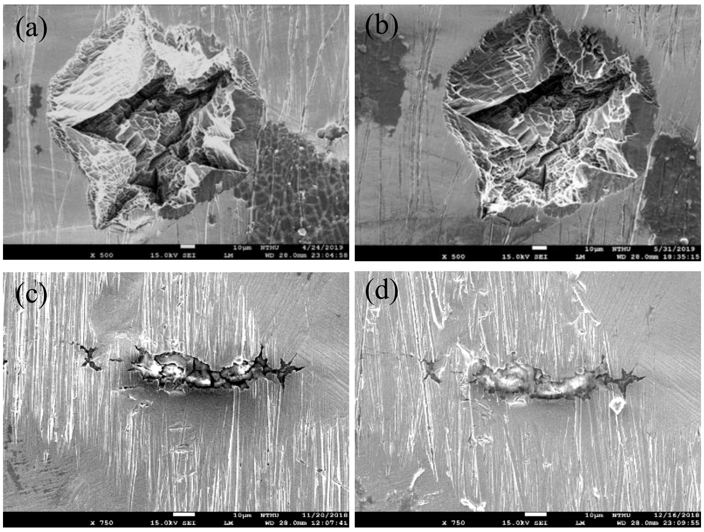


Figure 12 Solution-annealed 316L U-bend specimens after (a) 1000 hours and (b) 1500 hours of $MgCl_2{\cdot}6H_2O$ solution procedure, Sensitized 316L U-bend samples after (c) 1000 hours and (d) 1500 hours of $MgCl_2{\cdot}6H_2O$ solution procedure.

Table 5 shows the quantitative results of two testing conditions, including NaCl solution procedure at 80^{o}C and $MgCl_2 \cdot 6H_2O$ solution procedure at 40^{o}C. In most of U-bend specimens, the number of cracks under 50μm was increased with test duration. It may be related to the evident pitting corrosion in all 500 hours specimens, as shown in figure 13 (a). However, some of them had different trends in the duration interval from 500 hours to 1000 hours on the 316L specimens under $MgCl_2 \cdot 6H_2O$ solution procedure at 40^{o}C. The number of cracks under 50μm decreased from 500 to 1000 hours. It was speculated that some pits or micro-cracks were merged by larger pits with diameters about 100μm, as shown in figure 13 (b).

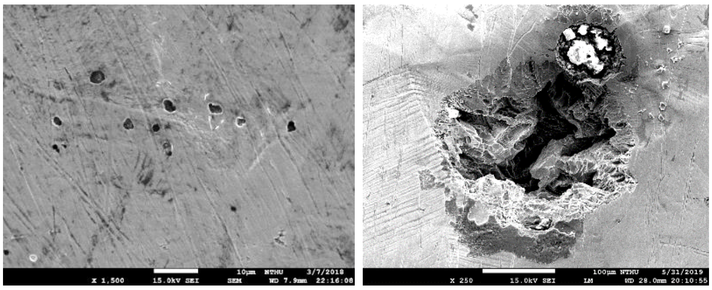


Figure 13 (a) Sensitized 304 specimen after 500 hours of periodic spraying NaCl solution. (b) Solution-annealed 316L specimen after 1000 hours of periodic spraying $MgCl_2 \cdot 6H_2O$ solution.

The reason was based on that these large pits did not be found after 500 hours of periodic spraying of $MgCl_2 \cdot 6H_2O$ solution, and yet three large pits with about 100μm were found on the solution-annealed 316L specimens after 1000 hours. Sensitized 316L specimens had similar results, there were more pits with large diameters observed after 1000 hours of periodic spraying $MgCl_2 \cdot 6H_2O$ solution at 40^{o}C than after 500 hours. Though the type 316L stainless steels have good pitting corrosion resistance because of the molybdenum content increased the film stability by decreasing the number of point defects in the passive film [19-24], but the presence of MnS inclusions increase the susceptibility of stainless steels to pitting corrosion [25]. From the EDX analysis, the manganese and sulfur elements were detected in a crack, as shown in figure 14. That was the possible reason why pits or cracks still generated on the 316L stainless steel specimens. However, no matter which heat treatment applied on the 316L specimens, no crack longer than 500μm was observed after 1500 hours of $MgCl_2 \cdot 6H_2O$ spraying procedures, the results demonstrate that the molybdenum still improve the corrosion resistance of type 316L stainless steels to the chloride induced stress corrosion cracking.

In addition, it is worth noting that much longer cracks can be found under longer duration within 1500 hours. The possible reason is that the concentration of chloride ions in the local area was sufficient to accelerate corrosion behavior on the stainless steels U-bend specimens, which leaded to chloride induced stress corrosion cracking on type 304 and 304L U-bend specimens.

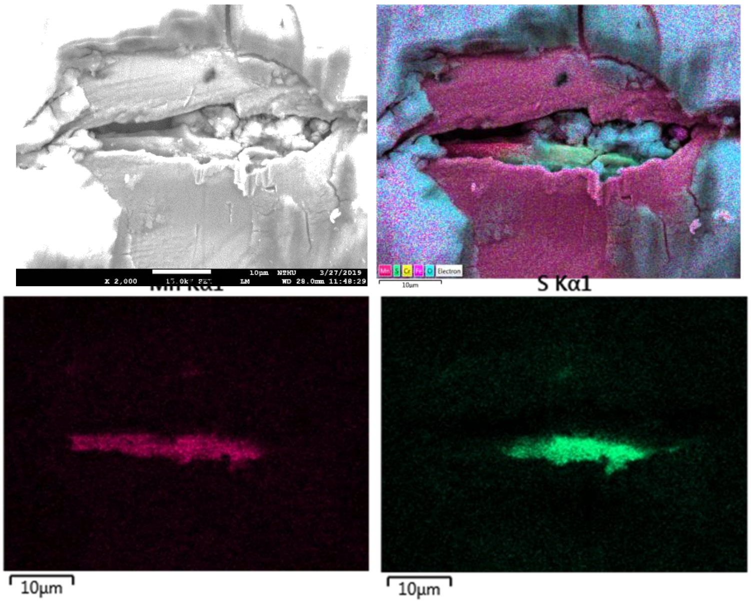


Figure 14 EDX mapping analysis of the solution-annealed 316L specimen after 500 hours of periodic spraying $MgCl_2 \cdot 6H_2O$ solution.

Table 5 The quantitative results of different testing conditions within the whole testing duration 1500 hours.

CONDITION	**Periodic spraying NaCl solution at 80 ℃**																	
SS	304_SA			304_SEN			304L_SA			304L_SEN			316L_SA			316L_SEN		
DURATION	500	1000	1500	500	1000	1500	500	1000	1500	500	1000	1500	500	1000	1500	500	1000	1500
0-10	16	40	35	68	84	119	25	42	40	84	160	173	14	70	70	24	93	90
10~20	10	13	-	5	21	33	13	23	28	30	17	31	19	39	22	31	28	43
20-30	2	3	5	-	4	1	10	6	8	3	1	4	6	12	13	8	6	10
30-40	-	2	1	-	2	-	2	4	2	3	1	-	6	4	3	3	-	-
40-50	-	-	-	1	1	1	1	-	1	2	-	-	1	1	3	2	1	-
50-60	-	1	-	1	-	-	-	-	-	1	-	-	-	-	1	-	1	1
60-70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
70-80	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
80-90	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
90-100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100-110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
110-120	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	28	59	42	75	112	156	51	75	79	123	179	208	47	126	112	68	129	146

CONDITION	**Periodic spraying $MgCl_2 \cdot 6H_2O$ solution at 40 ℃**																	
SS	304_SA			304_SEN			304L_SA			304L_SEN			316L_SA			316L_SEN		
DURATION	500	1000	1500	500	1000	1500	500	1000	1500	500	1000	1500	500	1000	1500	500	1000	1500
0-50	25	25	78	61	190	184	36	34	35	59	56	72	92	34	74	89	56	75
50-100	1	-	1	8	9	8	1	-	-	-	8	6	-	2	2	4	6	11
100-150	-	1	-	6	4	2	-	-	-	-	2	-	-	2	2	1	3	3
150-200	-	-	-	3	1	1	-	-	-	-	-	1	-	-	2	3	2	1
200-250	-	-	-	2	1	1	-	-	-	-	3	-	-	-	-	-	-	3
250-300	-	-	-	2	2	2	-	-	-	-	-	-	-	1	1	-	-	-
300-350	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1
350-400	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1
400-450	-	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-
450-500	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
≧500	-	-	-	-	1	3	-	-	-	-	-	1	-	-	-	-	-	-
TOTAL	26	26	79	84	209	203	37	34	35	59	68	80	92	38	81	97	68	94

Conclusion

The purpose of this experiment is to evaluate the stress corrosion cracking phenomenon of the austenitic stainless steel canister in the simulated coastal environment. The crack morphology, length, and the quantitative analysis of type 304, 304L and 316L stainless steels were discussed. The following were conclusions:

(1) Under the sodium chloride periodic spraying test, all specimens were not found out visible cracks after 1500 hours of experiment, and most cracks were below 120μm. On the other magnesium chloride periodic spraying test, except for sensitized 304 samples, no cracks larger than 500μm were observed in the other U-bend specimens.

(2) When the experimental temperature increases, more aggregation oxidation will be found on the surface of the specimens. This phenomenon can be observed by naked eyes.

(3) The difference of resistance to CISCC between solution annealed and sensitized specimens is very obvious. The number of cracks on the sensitized samples are more than solution-annealed ones, mainly from the increasing of the micro-cracks and pits.

(4) Comparing the results of morphology and quantitative analysis, it can be known that even if the experimental time increased, the length and number of cracks are not significantly increased, except the duration from the initiation of testing to 500 hours. It is surmised that the total experimental duration is not enough to make cracks propagate on the specimen surface.

However, the strain of the U-bend specimens was much larger than the true strain of dry storage canisters, and the amount of chloride deposition in this experiment is much more than the actual environment. Based on the above reasons, applying austenitic stainless steels to dry storage canister located at coastal environment is feasible. Among them, 304L and 316L stainless steels have better resistance to stress corrosion cracking.

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