Pit Growth Behavior of SUS443J1 in Atmospheric Environment

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Evaluation of the corrosion resistance of a new stainless steel, SUS443J1, in atmospheric environments is a significant issue. In this study, the growth behavior of pits on the surface of the ferritic stainless steel, SUS443J1, and an austenitic stainless steel, SUS304, were compared by field exposure tests and electrochemical measurements.

It is known that the pit growth rate can be approximated as \( X = a t^n \), where \( X \) is pit depth, \( t \) is time, \( a \) and \( n \) are constants. As a result of field exposure tests, pit growth rate values of approximately \( n = 0.2 \) were obtained for both 2B and HL surfaces of SUS443J1 and SUS304. From this, it could be predicted that the pit growth behaviors of SUS443J1 and SUS304 were mutually equivalent.

The pitting potential values \( V'_{\text{cp}} \) of SUS443J1 and SUS304 were almost equivalent, and the repassivation potential showed the same tendency. The pitting potential decreased with increasing the maximum valley depth \( R_v \) of the surface. The repassivation potential was affected by the turning current density, where the sweep of potential was reversed. The turning current density represents the degree of pit growth. It was suggested that a deep pit would expand at a larger growth rate than that of a shallow pit because the deep pit grows easily and repassivation is difficult in deep pits.

KEY WORDS: stainless steel; corrosion resistance; atmospheric environment; field exposure test; pit growth rate; surface roughness; electrochemical measurement.

1. Introduction

Owing to their superior corrosion resistance and metallic luster, stainless steels are used in various applications such as building roofs, entrances and so on.1,2) Recently, the share of ferritic stainless steel in the total amount of stainless steel used has shown an increasing tendency, while that of austenitic stainless steel has tended to decrease in order to reduce the material cost. The material cost of austenitic stainless steels is largely based on the price of nickel, which is used in large amounts in austenitic stainless steels in order to obtain the austenitic microstructure and superior corrosion resistance. The price of nickel is high and has been unstable in recent years. Moreover, molybdenum, which is known as an element which improves the corrosion resistance of stainless steels, has shown a price tendency similar to that of nickel. In response to these trends, steel makers have tended to reduce the use of these elements. Against this background, the resource-saving ferritic stainless steel SUS443J1 has been produced which does not contain nickel or molybdenum and has corrosion resistance equivalent to that of SUS304.1,3)

SUS443J1 is used in various items that were formerly made of SUS304. Most of these items are used in atmospheric environments. Depending on the severity of the environment, corrosion on stainless steel occurs easily and reduces the value of the stainless steel. Therefore, the corrosion behavior of SUS443J1 in atmospheric environments has been a concern.

The corrosion behavior of stainless steels in atmospheric environments has been studied in detail over many years, and many studies such as exposure tests have been reported.4–12) The results of those studies clarified some significant corrosion behaviors. For example, corrosion is dependent on the critical pitting potential and the corrosion area is proportional to the pitting index,10) the pit depth increases in proportion to the logarithm of time,11) corrosion of stainless steel is inactive during almost all periods and grows during a short period when sea salt is deposited,12) and so on.

However, because SUS443J1 is a recent product, there have been few long-term evaluations of corrosion resistance. In particular, no research has examined long-term corrosion resistance in consideration of the surface morphology. Therefore, in order to establish the suitable directions for this new ferritic stainless steel, in this study, the long-term corrosion behavior of SUS443J1 was evaluated considering its surface morphology.

2. Experimental Procedure

2.1. Materials

The ferritic stainless steel SUS443J1 and the most popular
austenitic stainless steel, SUS304, were used in this study. The chemical compositions of SUS443J1 and SUS304 are given in Table 1. Both sample materials were commercial products. The surface finishes studied here were 2B, which is the surface of the cold-rolled sheet with skin-pass rolling, and HL, which is the surface polished to a hair-line finish. The thicknesses of the 2B SUS443J1 and SUS304 were 1.5 mm, the thickness of the HL SUS443J1 was 1.2 mm, and the thickness of the HL SUS304 was 0.8 mm.

### 2.2. Exposure Test

A schematic illustration of a specimen for the exposure test is shown in Fig. 1. Specimens were cut from SUS443J1 and SUS304 to a width of 70 mm and length of 150 mm. On each exposure specimen, a hole with a radius of 5 mm was made 10 mm from the lower end at the center of width. The rolling direction and polishing direction were parallel to the lengthwise direction. The surface finishes of the specimens were 2B and HL. The specimens were exposed after ultrasonic degreasing in acetone. After the exposure tests, the central part of each specimen was divided into 25 areas with a 10 mm × 10 mm division, and pit depth in each area was measured. The maximum valley depth \( R_v \), which is based on JIS B 0601 (2001), was measured 3 times in the direction perpendicular to the rolling direction, and the average was calculated. Surforder SE-500 produced by Kosaka Laboratory Ltd. was used for the measurements of surface roughness. The evaluation length was 1.250 mm, and the cutoff value was 0.250 mm.

The exposure specimens were exposed facing in a southerly direction with an inclination of 30° at an exposure site in Uruma City, Okinawa, which is a subtropical coastal environment. The distance from the Pacific Ocean sea-coast was 20 m. The salt deposition ratio was 0.78 mg/d/dm², which was measured from August 2007 to July 2008. Bolts and nuts made of SUS304 were used to attach the specimens to exposure racks. Washers made of polycarbonate were used for the part touching the specimen. The exposure tests began in June 2006. Two specimens of each steel grade and surface finish were exposed. The exposure test of one specimen was finished after one year, and that of the other specimen, after five years.

After the exposure tests, the rust on the specimens was removed completely by repeating a process in which the specimens were immersed in 10% dilute nitric acid at 50°C for 3 600 s and cleaned with a nylon brush. After removing the rust, the surface morphology was observed in backscattering electron images by a Miniscope TM3000 scanning electron microscope (SEM) produced by Hitachi High-Technologies Corporation. The accelerating voltage was 15 kV.

As shown in Fig. 1, the central part of each specimen was divided into 25 areas with a 10 mm × 10 mm division. More than three of the deepest pits were chosen from each area and the pit depth was measured. The depth was measured on the line including the deepest point in the pit, and the pit depth was defined as the height difference between the flat part which was not corroded and the deepest point in the pit. A 1LM21W scanning laser microscopy produced by Lasertec was used for the pit depth measurements. The maximum pit depth of each area was defined as the largest one among the pit depths measured.

The maximum pit depth of each area was plotted on Gumbel probability paper. The return period was defined as 25, and the maximum pit depth which may occur in the area of 50 mm × 50 mm was predicted for each exposed specimen. EVAN-II, which is a software program for extreme value statistics analysis supervised by the Japan Society of Corrosion Engineering, was used for the maximum pit depth calculation.

### 2.3. Pitting Potential Measurement and Repassivation Potential Measurement

Specimens with dimensions of 20 mm × 20 mm were cut from the 2B SUS443J1 and SUS304 shown in Table 1. The surface of the specimens was polished with #1000 emery paper. A SUS304 wire with the size of 1 mmφ was spot-welded to the end of the specimens for electrical connection. The specimens were immersed in 10% dilute nitric acid at 50°C for 3 600 s as passivation treatment, after which the surface except 10 mm square evaluation area was covered with silicon sealant. Just before measurement, the evaluation area of each specimen was polished with #120,

| Surface | C   | Si | Mn | Cr | Ni | Cu | Ti | N   |
|---------|-----|----|----|----|----|----|----|-----|
| SUS443J1 | 2B  | 0.006 | 0.11 | 0.21 | 20.6 | 0.31 | 0.42 | 0.28 | 0.007 |
|         | HL  | 0.003 | 0.07 | 0.17 | 21.0 | 0.30 | 0.43 | 0.28 | 0.008 |
| SUS304  | 2B  | 0.057 | 0.41 | 1.12 | 18.0 | 8.06 | 0.19 | –   | 0.037 |
|         | HL  | 0.052 | 0.37 | 0.99 | 18.4 | 8.17 | 0.32 | –   | 0.031 |

Fig. 1. A schematic illustration of a specimen for the exposure test.
#600 and #1000 emery paper, respectively. The maximum valley depth $R_v$ was measured on the surface of the other specimens which were not used for electrochemical measurements after polishing to a #120, #600 and #1000 finish. The solution for pitting potential and repassivation potential measurement was 3.5% NaCl, which was degassed by Ar gas for more than 1800 s. A HZ-5000 potentiostat produced by Hokuto Denko was used for the measurements. The test temperature was 30°C. The counter electrode was platinum foil, and the reference electrode was a saturated KCl silver-silver chloride electrode. The potential of 42 mV was subtracted from the measured value to convert the measured value to the potential to a saturated calomel electrode.$^{13}$

The specimens were polished just before immersion in NaCl solution and held for 600 s at open circuit potential. The potential was then swept to the noble side at 0.33 mV/s sweep rate until it reached predetermined turning current density. Turning current densities were determined as 0.1 mA/cm$^2$, 1 mA/cm$^2$ and 10 mA/cm$^2$. When the current density reached the turning current density, the potential was swept immediately to the lower side at 0.33 mV/s sweep rate. The measurement was finished when the current density reached $10^{-5}$ mA/cm$^2$. The pitting potential was defined as the maximum potential at which the current density was $10^{-5}$ A/cm$^2$ on the noble side sweep, and the repassivation potential was defined as the maximum potential at which the current density was $10^{-5}$ A/cm$^2$ on the lower side sweep. After the measurements, the result was excluded from the data if crevice corrosion was observed by a magnifying glass. The measurements were 3 times, and the average of these 3 repetitions was defined as the pitting potential and the repassivation potential.

3. Results

3.1. Surface Morphology of Exposure Specimens

The surface morphology of the exposure specimens was observed in backscattering electron images by SEM. The surface morphology of the 2B and HL specimens of SUS443J1 and SUS304 is shown in Fig. 2 respectively. The surface morphology of 2B SUS443J1 was flat as compared with that of SUS304. Slight grooves along the rolling direction were observed on the surface of the 2B SUS443J1. On the surface of the 2B SUS304, grooves about 1 μm wide had been formed along the grain boundary. On the surface of HL of both SUS443J1 and SUS304, polished lines were observed along the polishing direction. However, no remarkable differences were observed between the polished lines on SUS443J1 and SUS304.

In order to evaluate the surface morphology quantitatively, the surface roughness was measured in the perpendicular direction to the rolling direction. The result of the surface roughness measurements are shown in Fig. 3. With

![Fig. 2. SEM images indicating surface morphology of the specimens before the exposure tests.](image)

![Fig. 3. Line profiles of surface roughness of the specimens before the exposure tests.](image)
the 2B surface, the surface morphology of SUS443J1 and SUS304 was different in spite of the fact that the surface finish was the same. The surface of the 2B SUS443J1 displayed grooves about 0.1 \( \mu \text{m} \) deep, while many narrow grooves about 0.5 \( \mu \text{m} \) deep were observed on the surface of the 2B specimen of SUS304. With the HL surface, the surface morphology of SUS443J1 and SUS304 was very similar, and the depths of the grooves formed by polishing were also similar.

With the 2B surface, the value of the maximum valley depth of SUS304 was 4.1 times that of SUS443J1. With the HL surfaces of SUS443J1 and SUS304, the values of the maximum valley depths of SUS443J1 and SUS304 were equivalent to each other.

3.2. Evaluation of Corrosion Behavior in Atmospheric Environment by Exposure Tests

The exposure tests were carried out at the exposure site in Uruma City, Okinawa. Figure 4 shows the appearances of the specimens after the exposure tests.

After the one year exposure test, the corrosion points of the 2B SUS443J1 were fine and few in number as compared with the 2B SUS304. With the HL surfaces of SUS443J1 and SUS304, corrosion along the polishing lines was observed, and the corrosion was severe in comparison with the 2B surface. No remarkable difference in corrosion was observed between the HL surfaces of SUS443J1 and SUS304.

After the five year exposure test, the corrosion of the 2B surface of SUS443J1 was severe compared with that after the one year exposure test, while the corrosion of SUS443J1 was slight compared with that of the 2B SUS304. With the HL surface, the corrosion of SUS443J1 and SUS304 did not increase remarkably from that after the one year exposure test, and there was no remarkable difference in corrosion conditions of SUS443J1 and SUS304 after the five year exposure test.

After the exposure tests, the rust on specimens was removed, and the shape of the pits was observed by SEM. Typical pit shapes are shown in Fig. 5. The 2B surface of SUS443J1 showed some pits which were more than 20 \( \mu \text{m} \) in diameter, but most of the observed pits were small and were about 10 \( \mu \text{m} \) in diameter. The pits shown in Fig. 5(a) were about 10 \( \mu \text{m} \) in diameter, and the dissolution inside the pits was slight. With 2B of SUS304, many pits about 20 \( \mu \text{m} \) in diameter were observed. The opening of the pits was circular and the inside was dissolved in a hemisphere form. Around the pits, dissolution by corrosion was observed along the grooves formed on the grain boundary. With the HL surfaces of SUS443J1 and SUS304, a large number of continuous pits along the polished lines were observed. With both 2B and HL surface of SUS443J1 and SUS304, the opening of the pits was an open form, and foxhole-like pits were not observed in these exposure tests.

![Fig. 4.](image)

![Fig. 5.](image)

| Year | SUS443J1 | SUS304 | SUS443J1 | SUS304 |
|------|----------|--------|----------|--------|
| 1    | 2B       | HL     | 2B       | HL     |
| 5    | 2B       | HL     | 2B       | HL     |

Fig. 4. Appearances of SUS443J1 and SUS304 after the exposure tests in Okinawa.
The shapes of the pits on the 2B surfaces of SUS443J1 and SUS304 after the five year exposure test are shown in Fig. 6. In general, all the pits had a hemispherical form, and detailed observation of the pit edge revealed that some hemispherical pits overlapped in the observed pit.

The rust on the specimens after the exposure tests was removed, the pit depths were measured in the 25 divisions shown in Fig. 1, and the maximum pit depths of each division were plotted on the Gumbel probability paper. The results are shown in Fig. 7. In these figures, the x-axis is the maximum pit depth of each division, and y-axis is the normalized variable \( y \), which is related to the cumulative probability \( F(x) \), as expressed by the following Eq. (1) [14-16]:

\[
F(x) = \exp(-\exp(-y)) \quad \text{......................... (1)}
\]

The pit depth was proportional to the normalized variable approximately independent of the steel grade and surface finish. Therefore, the pit depth in these exposure tests was well approximated by the Gumbel distribution. With the 2B surface, the pit depth of SUS443J1 tended to be small compared with that of SUS304 in both the one year and five year exposure tests. However, when the exposure period was extended from one year to five years, the inclination of the pit depth became small, and the distribution of the pit depth became wider. After the five year exposure test, pits whose depths were from 15 to 20 \( \mu \text{m} \) were observed on the surface of both SUS443J1 and SUS304, as in the one year exposure test. This result was attributed to the fact that pits with small depths at one year did not grow dramatically, while pits with large depths at one year grew much deeper. With the HL surface, the pit depths of SUS443J1 and SUS304 were approximated by almost an equivalent line in both the one and five year exposure tests. Therefore, these results confirmed that the two steel grades show equivalent pit growth behavior. With the HL surface, as with the 2B surface, the inclination of the pit depth became small and the distribution of the pit depth increased after the five year exposure test compared with the results after the one year exposure test.

It is known that the growth rate of the pit depth of stainless steel is approximated by the following Eq. (2) [11]:

\[
X = at^n \quad \text{.......................... (2)}
\]

In this equation, \( X \) is the maximum pit depth, \( t \) is time, \( a \) and \( n \) are constants. The growth behaviors of the maximum pit depth in the exposure tests are shown in Fig. 8. The maximum pit depths of each specimen were estimated by the Gumbel probability paper shown in Fig. 7. The return period was set at 25, which means the normalized variable, \( y \), was 3.20. The figures show the value of \( n \), which is an index of

![Fig. 6. SEM images indicating pit shapes after the exposure test for 5 years.](image)

![Fig. 7. Pit depth after the exposure tests evaluated by the Gumbel distribution.](image)
The pit growth rate. With the 2B surface, the maximum pit depth of SUS443J1 was smaller than that of SUS304, while the value of $n$ of both SUS443J1 and SUS304 was approximately 0.2. Therefore, with the 2B surface, it is estimated that the maximum pit depth of SUS443J1 could be smaller than that of SUS304 over a much longer exposure period. With the HL surface, the maximum pit depths of SUS443J1 and SUS304 were equivalent to each other, and the value of $n$ were approximately 0.2.

4. Discussions

4.1. Comparison of Pit Growth Behavior of SUS443J1 and SUS304 in Atmospheric Corrosion Environment

Pit growth behavior in an atmospheric corrosion environment was considered for the ferritic stainless steel SUS443J1 and the austenitic stainless steel SUS304.

In the comparison of pit depths shown in Fig. 7, with the 2B surface, the pit depth of SUS443J1 was smaller than that of SUS304, while with the HL surface, the pit depths of SUS443J1 and SUS304 were similar. It was thought that the difference in the pit depth by surface finish depended on the difference in the surface morphology. Therefore, the maximum pit depth was arranged for the maximum valley depth $R_v$ before the exposure tests. The results are shown in Fig. 9. The maximum pit depths of SUS443J1 and SUS304 were approximated to almost equivalent lines independent of steel grade, and, as shown in Fig. 8, the values of $n$ in Eq. (2) were approximately 0.2 independent of the surface finish and steel grade. These result suggested that the pit growth behaviors of SUS443J1 and SUS304 are mutually equivalent over an extended period of time if the maximum valley depths of these steels are equivalent. In actuality, with the HL surface, in which SUS304 and SUS443J1 had equivalent maximum valley depths, the pit growth behaviors of SUS443J1 and SUS304 were also mutually equivalent, as shown in Figs. 7 and 8.

In atmospheric corrosion environments, pit initiation and repassivation are the dominant factor in pit growth behavior due to the repetition of wet and dry conditions. Therefore, in order to consider the effect of surface roughness and steel grade on pit initiation and repassivation, the pitting potential and repassivation potential of SUS443J1 and SUS304 were measured with several surfaces roughness.

The representative polarization curves measured are shown in Fig. 10. In the figure, arrows indicate the potential sweep direction. The correlation between the pitting potential and the maximum valley depth $R_v$ is shown in Fig. 11.
the figure, the error bars show the maximum and the minimum values of three measurements. The pitting potential of SUS443J1 was almost equivalent to that of SUS304 in the range of the maximum valley depth $R_v$ in this examination. The pitting potentials of both SUS443J1 and SUS304 decreased with equivalent inclinations as the maximum valley depth $R_v$ increased. This result suggests that SUS443J1 and SUS304 have equivalent resistance to pit initiation if the maximum valley depth $R_v$ of these steels is equivalent.

Repassivation potential, which was measured with the turning current density set to 1 mA/cm$^2$, is shown in Fig. 12. The repassivation potentials of SUS304 and SUS443J1 were equivalent to each other and were independent of change in the maximum valley depth $R_v$. These results suggested that the surface morphology before pitting corrosion would not affect the corrosion behavior after pitting corrosion at points where pits formed.

However, according to the result of these exposure tests, as shown in Fig. 9, the maximum pit depths at one year and five years increased with increasing maximum valley depth before the exposure tests. Therefore, it was thought that the surface morphology before the exposure tests had a certain influence on the pit depth, in other words, on pit growth behavior.

Now, the pit growth behavior of stainless steel will be considered. The pit growth behavior of stainless steel can be approximated as Eq. (2), and is described by the constants of $a$ and $n$. It is known that the value of $n$ is constant in the same exposure environment independent of the grade of stainless steel. The value of $a$ is the pit depth at the time $t = 1$, which indicates the early stage of an exposure test. Therefore, in long-term exposure tests, it is thought that the pit depth would be decided by the value of $a$, that is, by the pit depth in early period. In these exposure tests, as shown in Fig. 8, the value of $n$ was approximately 0.2 independent of the steel grade and surface finish. However, the value of $a$ with the HL surface, which had a large maximum valley depth, was larger than that with the 2B surface, even though the steel grade was the same. As a result, the maximum pit depth with the HL surface was larger than that with 2B surface at all times during the exposure period. This result suggested that the pit depth in the early stage was affected by the surface morphology before the exposure tests, and long-term pit growth was not affected by the surface morphology before the tests but by an equivalent exponentiation index at the points where pits formed.

The mechanism by which the pit depth increases with increasing maximum valley depth in the early period is thought to be as follows. As shown in Fig. 11, as the maximum valley depth $R_v$ increases, pitting potential decreases remarkably. In atmospheric corrosion environments which are characterized by repetition of wet and dry conditions, the corrosion environment is severest when thin water film,

in which initiation and repassivation factors are the dominant factors for pit growth, SUS443J1 and SUS304 showed equivalent pit growth behavior.

4.2. Effect of Surface Morphology on Pit Growth Behavior

It is well known that surface morphology has a remarkable influence on the initiation of corrosion on stainless steel. As shown in Figs. 4 and 5, these exposure tests also confirmed that the corrosion behaviors of SUS443J1 and SUS304 differed depending on surface finish. However, there are few detailed studies about the effect of surface morphology on pit growth behavior.

As shown in Fig. 7, the pit depth at one year was about 10 µm at minimum, while the maximum valley depth on the specimens before the exposure tests was 1.5 µm or less, as shown in Fig. 3. Therefore, it is appropriate to think that the groove, which was an initiating factor for pitting corrosion, had disappeared at the point where a pit formed. Furthermore, as shown in Fig. 12, the repassivation potentials of SUS443J1 and SUS304 were almost constant independent of the surface morphology before measurement. These results suggested that the surface morphology before pitting corrosion would not affect the corrosion behavior after pitting corrosion at points where pits formed.

Therefore, in long-term exposure tests, the pit depth would be decided by the value of $a$, that is, by the pit depth in early period. In these exposure tests, as shown in Fig. 8, the value of $n$ was approximately 0.2 independent of the steel grade and surface finish. However, the value of $a$ with the HL surface, which had a large maximum valley depth, was larger than that with the 2B surface, even though the steel grade was the same. As a result, the maximum pit depth with the HL surface was larger than that with 2B surface at all times during the exposure period. This result suggested that the pit depth in the early stage was affected by the surface morphology before the exposure tests, and long-term pit growth was not affected by the surface morphology before the tests but by an equivalent exponentiation index at the points where pits formed.

The mechanism by which the pit depth increases with increasing maximum valley depth in the early period is thought to be as follows. As shown in Fig. 11, as the maximum valley depth $R_v$ increases, pitting potential decreases remarkably. In atmospheric corrosion environments which are characterized by repetition of wet and dry conditions, the corrosion environment is severest when thin water film,
which is formed by rain, dew condensation or the like, dries on the surface. Pits are also initiated at the time of water film drying. Since pits are initiated early in the drying process on a surface with a low pitting potential, an extended period of time is necessary to arrest corrosion by complete drying of the water film. Therefore, large pits can grow on surfaces with a low pitting potential, and for this reason, pits with a large depth were initiated in early period on the surface with the large maximum valley depth $R_v$.

Next, the effect of large pit depth on pit growth behavior will be considered. As shown in Fig. 7, the distribution of the pit depth at five years was wider than that at one year. This result suggests that the pit depth increases more rapidly if the pit depth is large.

The pit depth is $10^{-6}$ or more at minimum, and is larger than the maximum pit depth $R_v$ before initiation of the pit. Therefore, initiation of pits increases the maximum pit depth $R_v$. As shown in Fig. 11, there is a correlation between pitting potential and the maximum pit depth $R_v$. Therefore, initiation of pits is promoted by the increase of the maximum valley depth $R_v$ due to initiation of a large pit in the early period. As shown in Fig. 6, many pits which were formed by some overlapped pits were observed on the surface after the five year exposure test. This result indicates that other pits were initiated and grew in an existing pit which had stopped growing. Therefore, this result supports the consideration mentioned above.

The reason why increase of maximum valley depth promotes initiation of pits is thought to be as follows. As shown in Fig. 13, A polarization occurs between the valley bottom and the steel surface due to the difference of the oxygen supply. This polarization becomes severe as the valley depth increases. The polarization dissolves gradually iron and chromium ion in the liquid of valley bottom. And, this dissolution increases chloride ion and hydrogen ion through the hydrolysis of iron and chromium ion in the liquid of valley bottom. Therefore, it is thought that the change of the corrosion environment promotes initiation of pits at the valley bottom.

In atmospheric environments with repeated dry and wet conditions, a pit which is initiated in the water film drying process repassivates rapidly because the water film finishes drying rapidly in the drying process. Therefore, the effect of pit depth on repassivation was evaluated by repassivation potential measurements.

The results are shown in Fig. 14, where the repassivation potentials with the #600 polished surface were measured at various turning current densities from 0.1 to 10 mA/cm². The repassivation potentials of SUS443J1 and SUS304 were equivalent to each other and decreased remarkably with increasing turning current density. An increase of the turning current density means growth of the pit. In other words, as the turning current density increases, the depth of the pit which should repassivate also becomes greater. The fact that the repassivation potential decreased with increasing turning current density suggests that repassivation of a grown pit did not occur easily.

Therefore, since an already-grown pit itself serves as an initiating factor for new pitting corrosion, and repassivation is suppressed in grown pits, the pit depth of a large pit increases more rapidly than that of a small pit.

As shown above, a low pitting potential promotes initiation of pitting corrosion on the surface with the large maximum valley depth $R_v$. The depth of a pit which is formed rapidly in the early period increases because the pit is kept in the growth condition for an extended period until a water film on the surface finishes drying. In the growth process of the pit, the influence of the surface morphology before pit initiation disappears. Furthermore, the pit depth of large pits increases more rapidly than that of small pits. As the result, a deep pit formed in the early period will grow greatly on the surface with the large maximum valley depth $R_v$ in comparison with a small pit formed in the early period on the surface with the small maximum valley depth.

5. Conclusions

The corrosion behaviors of ferritic stainless steel and austenitic stainless steel were evaluated by exposure tests of SUS443J1 and SUS304 in an atmospheric corrosion environment. In addition to the results of the exposure tests, the effects of the surface morphology of these stainless steels on pit initiation and repassivation were evaluated by electrochemical measurements. As a result, the following
conclusions were obtained.

(1) In these exposure tests, the maximum pit depth of SUS443J1 with the 2B surface was smaller than that of SUS304, and the maximum pit depth of SUS443J1 with the HL surface was equivalent to that of SUS304. The values of $n$ of both SUS443J1 and SUS304 were approximately 0.2 independent of the steel grade and surface finish. Therefore, the pit growth behaviors of these stainless steels were also mutually equivalent in the long-term exposure test. It was predicted that SUS443J1 and SUS304 have equivalent corrosion resistance.

(2) Pitting potential depends on the maximum valley depth $R_v$. At equivalent values of $R_v$, the pitting potentials of SUS443J1 and SUS304 were also substantially equivalent. Repassivation potential was substantially constant independent of $R_v$, and the repassivation potential values of SUS443J1 and SUS304 were essentially equivalent. Repassivation potential decreased with increasing turning current density, and no difference in the repassivation potential between steel grades was observed. The results of electrochemical measurements indicated that the corrosion resistance of SUS443J1 is equivalent to that of SUS304.

(3) The maximum pit depth in the early period increased with increasing maximum valley depth $R_v$ before the exposure tests. In addition to suppressing repassivation, a pit with a large pit depth itself served as initiating factor for new pitting corrosion. Accordingly, pits with a large pit depth displayed large growth compared with small pits. As a result, the maximum pit depth also increased more rapidly in the long-term exposure test when the steel sheet had a surface with a large maximum valley depth and pits with large pit depth in the early period.

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