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The Effect of the Gap Distance on The Corrosion Rate of SS400 Steel and C27000 Bras

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ABSTRACT

Crevice corrosion occurs due to differences in oxygen concentration inside and outside the gap. These experiments are conducted on the crevice formed by SS400 Steel and the C27000 Brass based on gap-distance parameters in the polluted ammonia environment. Such crevice often found in boiler joints, turbines, and machinery parts. The corrosion rate of SS400 steel when it stands alone in the ammonia environment is 0.7554 mpy, while the interface potential is -130 mV VS Cu/CuSO4. The corrosion rate of C27000 Brass when standing alone at related ammonia environment is 20.144 mpy, and the interface potential is -1191 mV VS Cu/CuSO4. When both metals combine to form a crevice, the corrosion rate of steel increased by 28% averagely. The tests include a gap where the two metals were mating each other (no distance), forming a distance of 0.239 mm and 0.398 mm. The interface potential of both metals when touching -518 mV VS Cu/CuSO4, -288 mV when formed a gap distance 0.239 mm and 0.398 mm. On the contrary, the corrosion rate of Brass C27000 decreases significantly up to 60% when joining to create a gap with steel. The interface potential of Brass C27000 when forming a gap with no distance with steel is – 632 mV VS Cu/CuSO4.

Keywords: *Crevice corrosion, gap distance, SS400 Steel, C27000 Brass.*

1. BACKGROUND

Crevice corrosion is becoming very important in the industry, heat exchangers, and power plants nowadays, regarding the impact that can occur in the form of the production losses and the factory's sufficient running hours [1,2]. Crevice corrosion is mostly found in the gap areas of two surface metal, where the oxygen concentration between the inside and the outside gaps is different [3].

Many factors influence the rate of crevice corrosion, including the followings [4]:

a. The Gap type, between same metal, metal to different metal, and metal to non-metal.
b. The Gap width, the gap with the touch surface, and the gap with a certain distance.
c. The area of both metal surfaces.
d. The electrolyte around the gap, the polluting agents, the temperature, and the fluid flow.

Each of the factors affects the rate of crevice corrosion. Following the above considerations, the experiments must specify and limited to eliminate their impacts on the corrosion rate [5].

2. CREVICE CORROSION MECHANISM

It is believed that crevice corrosion resulted from the differences in metal ion and oxygen concentration inside the crevice and its surroundings. Usually, if a riveted plate section immersed in aerated seawater, the reaction involves the dissolution of metal inside the gap and reduction of oxygen to hydroxide ions outside the crevice [6,7].

Metal dissolution: $M \rightarrow M^+ + e^-$
Oxygen reduction: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

These normal reactions will change when the oxygen ran out in the gap. The oxygen was difficult to enter the gap because the metals oxide formed at the outside of crevice make it strictly tight. The continuous metal dissolution inside the gap will attract the small size of negative ions to enter the gap, i.e., chloride to balance [7,8].

$$M^+Cl^- + H_2O \quad \leftrightarrows \quad MOH\swarrow + H^+Cl^-$$

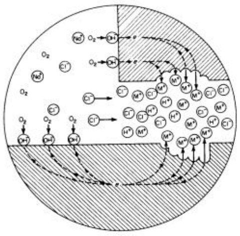

Figure 1. Crevice corrosion at later stage [1].

The entrance of chloride ions into the gap will promote the dissolution of metal inside the crevice and brought the corrosion process into the stage of catastrophic.

3. THE METHOD OF EXPERIMENTS

The experiments are already conducted to measure how influent the gap distance of two metals surface to their rate of corrosion. The measurements are compared to the metal corrosion rate when they stand alone and when they formed a gap [9].

The gap formed consist of three kinds, i.e., both surfaces touch each other; both metal surface form the gap width of 0.239 mm and 0.398 mm. The metals used is SS400 Steel and Brass of C27000. The density of SS400 Steel is 7.86 gr/cm^3. The density of C27000 Brass is 8.47 gr/ cm^3. The chemical composition of SS400 steel was measured by Positive Material Identification (PMI) device (Table 1). Regarding the carbon content, the Steel SS400 classified as high carbon content, where the composition lies between 0,6% - 1,4% [10–12]. The chemical composition of Brass of C27000 identified with a spectrograph device and the results as in table 2.

Table 1. Chemical composition of SS400 Steel

Elements	Wt%	Elements	Wt%
Fe	96,7	Co	0,0616
C	0,772	Cu	0,0219
Si	0,353	Nb	0,105
Mn	0,747	Ti	0,0189
Cr	0,115	V	0,0478
Mo	0,0773	W	0,619
Ni	0,0983	Pb	0,0952
Al	0,152		

Table 2. Chemical composition of C27000 Brass.

Elements	Weight percentage (%)
Cu	64,54
Zn	35,41

Regarding the percentage of composition content, the C27000 Brass identified as Alpha-Betha (Muntz) Brass, where the Cu contents lie between 65% – 55% and the Zn contents lie between 35% – 45%.

The measurements are done on the base of weight loss. The specimens are prepared, cleaned, and evaluated as ASTM G1 Standard [13]. The size of both samples are 40 x 50 x 2 mm and form gaps in the following type::

Type 1: Each metal stands alone in the water with ammoniac contamination of 2% (Fig.2).

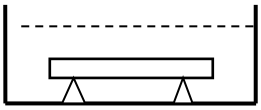

Figure 2. The specimen stand alone in the electrolyte. The support at ends are intended to prevent the effect of aeration differential cell at the bottom.

Type 2: Both metals mating each other with no gap width (Fig.3).

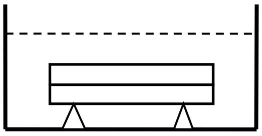

Figure 3. Both metal surfaces are touching one another.

Type 3: Both metals surface make a gap of 0.239 mm and 0.398 mm wide without an electrical contact (Fig.4).

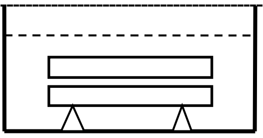

Figure 4. Both metal surface form gap with specified width with no electrical contact one another.

All kinds of the gap are entirely immersed in pure water contaminated by 2% of ammoniac volumetrically. The fluid pH is 6. The immersions last for 168 hours, 336 hours, and 504 hours. The period of immersion time is determined by the intention of studying the behavior of oxides formed on the surface of metals in related solution. The compactness of oxides formed on metal surfaces will show by the corrosion rate of each metal from time to time. The weighting is done before and after the immersion and the results are as follows.

4. RESULTS AND DISCUSSION

The results show that the corrosion rate of SS400 Steel tends to decrease when the gap width enlarged. It indicates that the enlarge width gap will reduce the oxygen concentration difference inside and outside the crevice. These results strengthen the theoretical point of view, where the large gap enables the oxygen ion to enter the gap and control the corrosion rate inside the crevice.

The weight loss of SS400 Steel and C27000 Brass tends to increase by immersion time. It shows that the oxide of both metals is porous and unable to decrease the metal dissolutions. In this case, C27000 Brass tend to corrode regarding the existence of ammoniac in the electrolyte severely.

Table 3. The weight loss of metals when stand alone in 2% ammoniacal polluted water.

Immersion (hours)	SS400 Steel (gram)	C27000 Brass (gram)
168	0.0072	0.2156
336	0.0069	0.4773
504	0.0386	1.4008

Table 4. The weight loss of SS400 Steel when form gap.

Immersion (hours)	No gap width (gram)	Gap width 0.239 mm (gram)	Gap width 0.398mm (gram)
168	0.051	0.049	0.043
336	0.126	0.122	0.113
504	0.146	0.123	0.084

Table 5. The weight loss of C27000 Brass when form gap.

Immersion (hours)	No gap width (gram)	Gap width 0.239 mm (gram)	Gap width 0.398mm (gram)
168	0.103	0.095	0.092
336	0.194	0.195	0.189
504	0.397	0.396	0.381

The corrosion rate of metals is calculated by the formula as in ASTM G31-72, 2004 [5]

$$MPY = \frac{K \cdot W}{D \cdot A \cdot T} \qquad (1)$$

Where :
K= 3,45 x 10^6
W = Weight loss (gram)
D = Density of metals (gram/cm3)
A = Corroded surface area (cm^2)
T = Immersion time (hours)

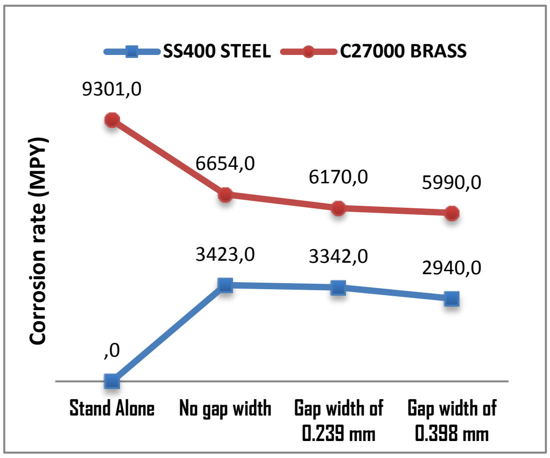

Figure 5. Corrosion rate of metals at varying position after 168 hours of immesion

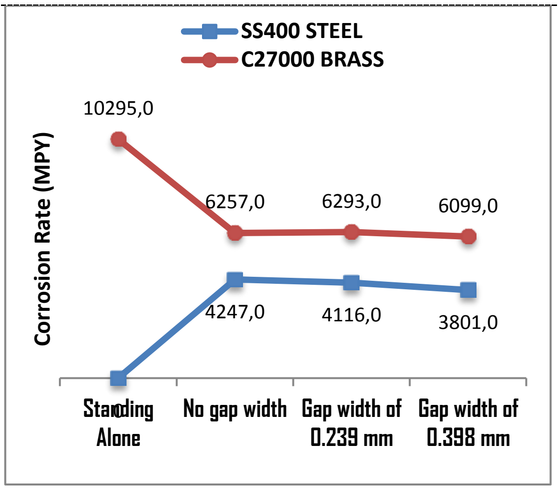

Figure 6. Corrosion rate of metals at varying position after 336 hours of immersion.

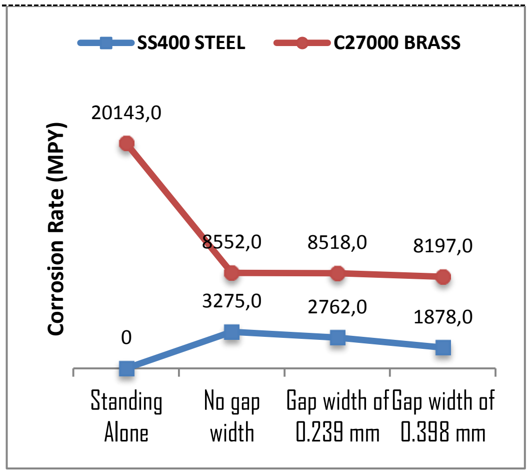

Figure 7. Corrosion rate of metals at varying position after 504 hours of immersion.

The measurement results show that the SS400 Steel and the C27000 Brass tend to corrode proportional to immersion time continually. The steel shows a tendency to resist to corrosion attack in the ammoniac contaminated fluid. The interface potential of steel when standing alone in the kind electrolyte is in Table 6.

Table 6. The interface potential of metals in 2% polluted ammoniac water (VS CuSO4).

Elements	Potential (V)
SS400 Steel	- 130 mV
C27000 Brass	- 1191 mV

The value of both interface potential shows how anodic C27000 Brass in an ammoniacal fluid. On the other hand, SS400 steel tends to cathodic in the represent electrolyte. This value of potential is supported the corrosion rate of both metals proportionally, as illustrated in Figure 5, Figure 6, and Figure 7.

When the metals form a crevice with no gap, the interface potential change significantly (Table 7), when both metals electrically contacted, their interface potential will polarized time by time and tend to same at last.

Table 7. The interface potential of metals when both are electrically contacted in 2% polluted ammoniac water (VS Cu/CuSO4).

Elements	Potential (V)
SS400 Steel	- 518 mV
C27000 Brass	- 632 mV

When both metals make an electrical contacted, the interface potential of metals will be polarized, where the values tend to approach each other. This phenomenon directly shows how anodic are both metals in the kind electrolyte. These potential interface values explain why Figure 5, Figure 6, and Figure 7 show an increase in the corrosion rate of SS400 Steel and a decrease in the corrosion rate of C27000 Brass.

Table 8. The interface potential of SS400 Steel and C27000 Brass when both metals make a gap of certain width with no electrical contact one another (VS Cu/CuSO4).

Elements	Gap width 0.239 mm	Gap width 0.398 mm
SS400 Steel	- 288 mV	- 289 mV
C27000 Brass	- 560 mV	- 604 mV

The graphs in Figure 5, Figure 6, and Figure 7 show the behavior of oxide on SS400 Steel and C27000 Brass in the ammoniacal polluted water, where the corrosion rate tends slightly to decrease. It shows that the oxide of both metals tends to resist corrosion over time.

5. CONCLUSION

The C27000 Brass is tended to anodic, and the SS400 steel tends to cathodic in the represent electrolyte. The enlarge width gap will decrease the oxygen concentration difference inside and outside of the crevice. The large gap enables the oxygen ion to enter the gap and control the corrosion rate inside the crevice.

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