Failure Analyses on Corrosion of Hot Water Tank Storage Made from Stainless Steel

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Abstract. Hot water storage tank that was made from stainless still was investigated in this case. The tank was found failure in service due to corrosion in welded section. Corrosion also was found at the bottom part of the storage tank. The tank was used for no longer than one year but unfortunately severe corrosion was found. The purpose of this research is to find the reason why the tank easily corroded especially at the bottom part and at the welding section. The research was carried out by conducting metallographic examination directly in situ by utilizing portable metallographic microscope. It is found from investigation that the corrosion was happen due to galvanic corrosion. Investigation by using X ray fluorescence also agree that the composition of the bottom part of the tank was different with the wall, and upper section. The welding filler also was found not correctly prepared that make pitting corrosion to occur. It is suggested to conduct advance research to investigate the correct composition for the filler during welding.

1. Introduction

Corrosion is material damage caused by reaction with the environment. Corrosion can cause various problems such as the emergence of small holes that cause leakage of liquids or gases, also cause a decrease in the strength of the material because the area of the cross section is reduced due to corrosion. In addition, corrosion causes a decrease in the quality of surface appearance. The main disadvantage due to corrosion is the appearance of rust which can contaminate products especially for food and beverage products [1].

The availability of hot water cannot be avoided by industrial entrepreneurs in the hotel sector. Most foreign tourists come from subtropical areas who are accustomed to using warm water when cleaning or bathing. To save energy, water is heated in large quantities and stored in a hot water storage tank to ensure that the needs are met. The water stored in storage is close to the boiling temperature so there is not much material that can be used for hot water storage tanks. During this time the storage process is mostly done in tanks made of stainless steel, especially of type 304. Stainless steel 304 is one type of stainless steel from austenitic stainless steel which has a single phase with face centered cubic (fcc). This structure can be formed from equilibrium of the alloying conditions which causes the austenite phase to become stable at room temperature [2].

Because of the large size of the tank, the manufacturing process during manufacture cannot be freed from the welding process. Also the process of making stainless steel plates is not easy when
compared to making regular steel because stainless steel contains various additives which theoretically are difficult to maintain its homogeneity.

Figure 1. The hot water tank is made of stainless steel which has a corrosion failure on the inside of the tank

Figure 2. Parts of the tank that have failed due to corrosion
This paper introduces a failure due to corrosion in hot water tanks (Figures 1 and 2) made of stainless steel. The tank was found to have experienced corrosion at the bottom and at the welded joint. The tank has not been used for more than a year but has caused various corrosion problems in its parts. From the outside of the tank no corrosion was seen. This study aims to examine the causes of corrosion in hot water storage tanks made of stainless steel 304 and provide suggestions for prevention in subsequent tank production.

2. Experimental

Water tank consists of three parts, namely the bottom cover, the middle tube and top cover. The third part is observed the microstructure by using a portable metallurgical microscope so that no need to cut the tube and the tube can still be used. In the part that will be observed, grinding, polishing and etching process are carried out to obtain the microstructure of the metal used. From the microstructure obtained then identified the type of stainless steel that was used, and analyzed whether in accordance with the microstructure of stainless steel 304 according to specifications at the time of purchase.

Metallurgical testing is carried out on the welding section as well by using a portable metallurgical microscope and analyzed the quality of welding and identified the microstructure obtained. The welding defects found were identified and sought to do with the corrosion that occurred.

3. Result and discussion

Figure 3 is the result of testing the microstructure at the top of the tank. This micro structure approaches the micro structure owned by stainless steel of type 316. Stainless steel 316 is also an austenitic stainless steel such as 304, but with the addition of Mo elements so that it has properties that are more resistant to pitting corrosion [2]. Thus it can be ascertained that the top of the tank is not made of stainless steel 304. The center of the tank turns out to have a micro structure similar to the top of the tank which has a micro structure that approaches stainless steel 316 as shown in Figure 4.

![Figure 3](image1.png)  
**Figure 3.** Photograph of the microstructure of the material on the top of the tank  

![Figure 4](image2.png)  
**Figure 4.** Photograph of the microstructure of the material in the center of the tank
But this is not the case with the material used on the bottom cover of the tank. From the results of testing with a microscope it turns out the material used in accordance with the specifications at the time of purchase is of 304 stainless steel type. Thus it is clear why at the bottom of the tank a case of severe corrosion occurs. This is caused by galvanic corrosion, which is corrosion caused by joining or connecting 2 different types of metals in the electrolyte environment. Connecting two types of stainless steel of different types can lead to a more severe type of corrosion, stress corrosion cracking [3].

The results of microstructure observation in the welding area provide information that the microstructure that is found approaching the microstructure of casting stainless steel 316 as shown in Figure 6.

Thus it can be ascertained that the weldment section was formed into cast stainless steel 316 and becomes dangerous if used to weld stainless steel 304 because it causes corrosion. If observed more
closely, Porosity is found in the weld area as shown in Figure 8. The porosity is a form of pitting corrosion [4, 5, 6] caused by flux during welding.

Tests using fluorescent X-rays such as those presented in Table 1 provide information that the three parts are not made of the same stainless steel. From microstructure observations it was found that only the lower part made of stainless steel 304 is characterized by the absence of Mo elements in the alloys as shown in Table 1.

For the future work, Destructive testing will be conducted after the tank experience fatal failure and can not operated any longer. Such destructive testing may involve indentation by using Vickers hardness test [7].

| Table 1. Result of investigation of composition by using X-ray fluorescence |
|---------------------------------------------------------------|
| elements         | Top cover of tank | Middle body of tank | Bottom cover of tank |
|------------------|-------------------|---------------------|----------------------|
| Mo               | 0.11              | 0.12                | -                    |
| Ni               | 8.45              | 8.11                | 8.4                  |
| Fe               | 70.69             | 70.33               | 70.78                |
| Mn               | 1.16              | 1.11                | 1.37                 |
| Cr               | 18.64             | 18.97               | 18.41                |
| Hr               | -                 | 0.34                | -                    |

4. Conclusion

By considering the test results and the discussion above, it can be concluded that the tank is suffering from corrosion due to the use of stainless steel of a different type so that galvanic corrosion occurs. While corrosion in the welding section occurs due to differences in the type of filler metal with welded metal which triggers galvanic corrosion. The use of welding fluxes causes pitting corrosion in the form of small holes which cause small porosity deposits.

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