

Fatigue Correstion Behavious of AISI 304 Stainles Steel in 3.5% NaCl Solution

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Abstract. Failure due to corrosion fatigue is a phenomenon that often occurs in the structure associated with a corrosive environment. Step use of materials such as AISI 304 stainless has been done, but failure due to corrosion fatigue phenomena still occur and can not be understood and explained by the experts. This study focused on assessing changes in behavior of AISI 304 stainless steel are experiencing repeated loading in corrosive environment. The behavior changes observed with fatigue testing in laboratory air and 3.5% NaCl solution, using a fatigue testing machine type rotary bending, specimens were made according to ASTM E-466 and ASTM F-1801 for corrosion fatigue testing. Fatigue testing presented in S-N curve and fracture patterns observed, observed in 3.5% NaCl solution and constant stress 369.53 MPa pit growth measurements done on seven levels and four levels of cycles for corrosion potential and current measurements a represented in the polarization curve. The results show that the endurance limit of the laboratory air environment at stress 323.34 MPa and 3.5% NaCl solution decreases, up to stress 277.15 MPa at 1.7×10^7 cycles. Ductile fracture pattern is in the air and 3.5% NaCl solution is brittle. Pits and cracks growth, failure is dominated by crack propagation and increase the number of cycles resulting in decreased surface potential and corrosion current density increases.

Keywords: 3.5% NaCl, AISI 304, fatigue behavior, pit growth, polarisation curve, S-N curve.

Introduction

Fatigue failure is a phenomenon that is very important because it is estimated 50-90% of the causes of mechanical failure due to fatigue failure. Failure due to fatigue is more dangerous than the static failure because failure occurred without warning, suddenly and thoroughly (ASM, 1997) Corrosion fatigue had first expressed 60 years ago and more concentrated on the damaged cables under the sea. A more integrated investigation of this phenomenon conducted 10 years later and the term was coined due to corrosion fatigue. Today reports of damage due to corrosion fatigue and increasing corrosion fatigue phenomena currently considered as one of the causes of failure of the structure. It's certainly a lot going on in the area of marine waters where conditions are very aggressive and frequent load/stress repeatedly (Murdjito, 2010).

AISI 304 stainless steel is a type of material that is widely used extensively in industries such as petrochemical industry, thermal power plants, boilers, pressure vessels, construction equipment and transport in the field of engineering. Extensive use of stainless steel is due to the physical and mechanical properties and excellent corrosion resistance (McGuire, 2008).

Stainless steel applications in the construction and transportation both air and seawater is very at risk of failure. Therefore, appropriate treatment is necessary for early detection of failures that may occur in stainless steel AISI 304 type so the failure that may occur can be anticipated well, one of the ways to do is to know the fatigue strength of materials. Fatigue strength of AISI 304 stainless steel in laboratory air and 3.5% NaCl study was the relationship stress and cycle presented in the S-N curve and observations of fracture patterns, in a 3.5% NaCl and constant stress 369.53 MPa studied is the cycle effect cycle effect of the pit growth and polarization curves.

Materials and Methods

Materials used are stainless steel AISI 304 derived from PT. Gitamulia Cemerlang the percentage chemical composition 18.28Cr, 8.1Ni, 1.71Mn, 0.44Si, 0.042C, 0.036P, 0.008S. The mechanical properties of tensile yield strength 563.30 N/mm² 219.20 N/mm² elongation of 67%. The size and dimensions of the specimen using the standard ASTM E466-96 (tangentially Blending Fillets), see Figure 1.

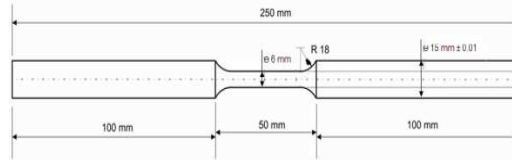


Figure 1. Size of specimen fatigue corrosion

Fatigue testing machine used type rotary bending frequency of 50 Hz and 2900 rpm and stress ratio $R = -1$. Testing done with surface roughness random system (2 specimens) done with a random system, to ensure grinding and polishing system are done according with ASTM E-466 (the maximum surface roughness $2 \mu\text{m}$) loading from the highest load level 12 Kgf ($0.9 \times$ Tensile Strength) to lowest on fatigue limit of the material (Julie A. Bannantine et. Al, 1990:5) and dipresentasi the SN curve environment in laboratory air and 3.5% NaCl and fracture patterns observed in stress 369.53 MPa. Set-up of fatigue testing machine with a circulation of corrosive media in accordance with ASTM F1801-97 shown in Figure 2.

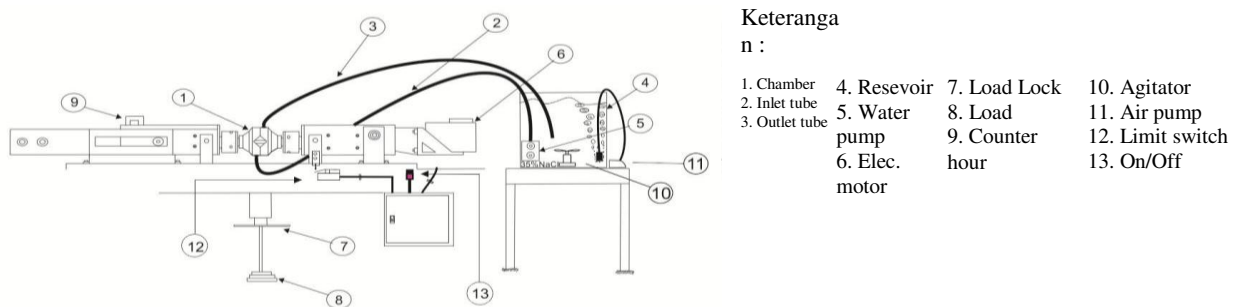


Figure 2. Set-up fatigue testing machine with a circulation of corrosive media

Pit and crack growth measured at cycles 120×10^3 , 220×10^3 , 320×10^3 , 420×10^3 , 520×10^3 , 620×10^3 , 720×10^3 . Electrochemical polarization measured at cycle $0,250 \times 10^3$, 500×10^3 , 750×10^3 . With constant stress 369.53 MPa and 3.5% NaCl environment. Using an optical microscope Olympus and Hokuto Denko galvanostat HA-301 and oscilloscope Tektronik TDS304. Set-up of electrochemical polarization measurements shown in Fig. 3.

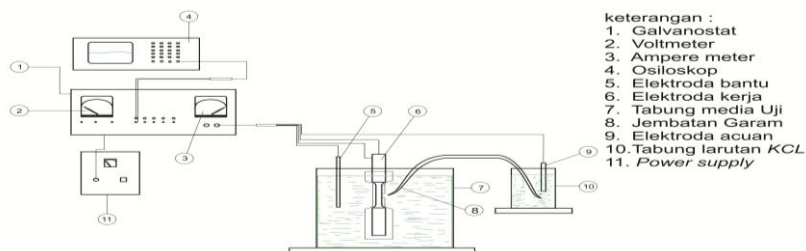


Figure 3. Set-up polarization measurements

Results and Discussion

Surface Roughness

Test results of surface roughness of stainless steel AISI 304 type are shown in Table 1. The results of the surface roughness measurements showed the surface roughness number range between 0.044 and 0.056 μm , this indicates that the surface roughness of the specimen is still under the surface roughness standards are allowed.

Table 1. Test results of surface roughness

| Number | Spesimen Number | Surface Roughness Value (μm) |
|--------|-----------------|---|
| 01 | 01 | 0,056 |
| 02 | 07 | 0,044 |

Fatigue Test

Research on the fatigue strength of AISI 304 stainless steel has been done on the laboratory air and 3.5% NaCl environment, using machine type rotating bending fatigue testing displayed in the form of SN curve as shown in Figure 4.

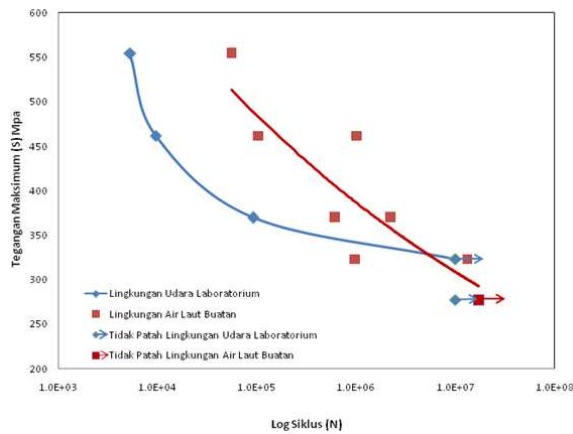


Figure 4. S-N curve for AISI 304 stainless steel in laboratory air and 3.5% NaCl

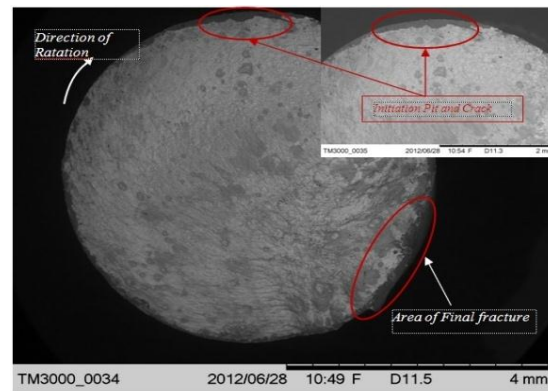


Figure 5. Failure pattern AISI 304 stainless steel in laboratory air and 3.5% NaCl at stress 369.53 MPa

Figure 4 shows the SN curve of stainless steel AISI 304, shows that the curves in the laboratory air environment fatigue limit (endurance limit) 323.34 MPa, whereas in 3.5% NaCl the fatigue strength of steel decreases, up to 277.15 MPa stress at 1.7×10^7 cycles. This shows that the fatigue strength of steel is affected by the environment in which it operates steel. Special phenomenon indicated by the AISI 304 stainless steel in 3.5% NaCl environment at stress above 369.53 MPa, which increased fatigue strength up to 10 times the fatigue strength in laboratory air environment. Further decreases with decreasing stress and cut off the air environmental curves towards 277.15 MPa stress.

This phenomenon occurs in 3.5% NaCl environment due to 3.5% NaCl solution serves as a cooling medium so that the plastic deformation due to shear stresses that occur less. Rupture occurring exhibit brittle failure pattern from the beach marks are shown in Fig. 10. AISI 304 stainless steel in air environment is resilient, plastic deformation and shear stresses are so great it can be seen from the testing process before breaking temperatures which increase over time in the area of the test specimen Figure 6.



Figure 6. Visual temperature increase for test area of AISI 304 stainless steel at stress 369.53 MPa

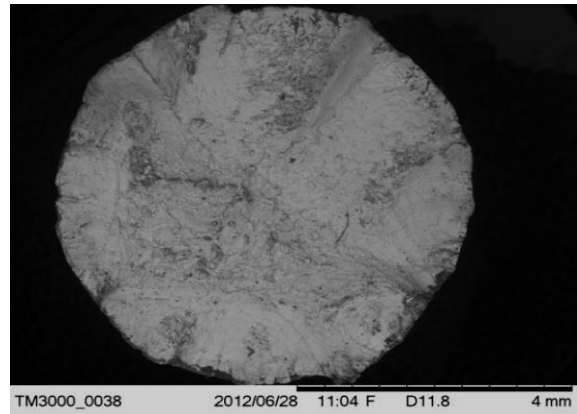


Figure 7. Figure 12. Failure pattern AISI 304 stainless steel in laboratory air at stress 369.53 MPa

Photo fracture surface also show a pattern of ductile failure as shown in Figure 7. From the results above show that the AISI 304 stainless steel is used in both 3.5% NaCl environment, particularly for applications for the low stress on the cycle of planing tools and planning short-lived machines that require re-scales on the components likely receive great stress during use, which will increase fatigue strength up to 10 times the power of the air exhausted. For applications that are relatively smaller stress factor of 3.5% NaCl environment can reduce the life of fatigue strength of steel to lower the endurance limit.

Pit and Crack Growth

Figure 8 indicates that the pits have grown and evolved at 120×10^3 cycle with an average size of pits and pit continues to $27.275 \mu\text{m}$ grown to 420×10^3 cycles with an average pit size $137.91 \mu\text{m}$, show that the maximum stress 369.63 MPa pit size growth is very short and failure is dominated by crack propagation from cycle 720×10^3 to 520×10^3 . The ratio between the length and width of the growth seen significant pit where pit and crack growth is dominated by the growth of crack length.

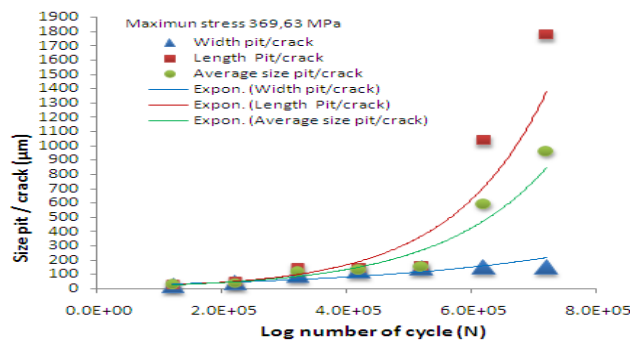


Figure 8. Relationship between pit/crack and cycle in 3,5% NaCl at stress 369,63 MPa

Electrochemical Polarization

From the test results of anodic-cathodic galvanostatic polarization for specimen AISI 304 stainless steel are presented in graphical form such as anodic and cathodic polarization curves log scale as Fig 9. This figure showed that the number of fatigue cycles affect the potential changes that occur on the surface of the specimen, where the greater the number of fatigue cycles that resulted in a decreased value of the specimen surface potential and corrosion current density increases.

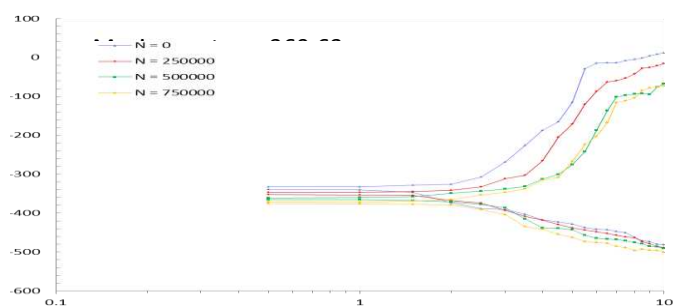


Figure 9. Anodic and cathodic polarization curves

Conclusions

S_{Nc} curve behavior of AISI 304 stainless steel with a laboratory air environment fatigue limit 323.34 MPa and 3.5% NaCl environment decreases, up to stress 277.15 MPa at 1.7×10^7 cycles. Fracture patterns in stress 369.63 MPa for the air environment is ductile and 3.5% NaCl is brittle. Stress failure to 369.63 MPa dominance it size and crack growth by crack propagation, the length and width of the crack length. Improved cycle that has resulted in a decreased value of the specimen surface potential and corrosion current density increases.

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