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

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Abstract. Failuredue to corrosion fatigue is a phenomenon that often occurs in the structure associated with a corrosive environment. Stepuse ofmaterialssuch as AISI 304 stainlesshas been done, buta failuredue to corrosion fatigue phenomena still occur and can not be understood and explained by the experts. This study focused on assessing changes in behaviorof AISI 304stainless steelareexperiencingrepeatedloadingincorrosive environment. The behavior changes observed with fatigue testing in laboratory air and 3.5% NaCl solution, using a fatigue testing machine typerotary bending, specimens were madeaccording to ASTME-466 andASTMF-1801 for corrosionfatiguetesting.Fatigue testing presented in S-Ncurve and fracture patterns observed, observed in3.5% NaCl solution and constantstress 369.53 MP apitgrowth measurements done on sevenl evels and four levels of cycles for corrosion potential and current measurements a represented in the polarization curve. The results showe dthat the endurance limit of the laboratoryair environment at stress 323.34MPa and 3.5% NaCl solution decreases, up to stress 277.15 MPa at1.7x10^7cycles. Ductile fracture pattern is in the airand 3.5% NaCl solutionis 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% ofthe causes of mechanical failure due to fatigue failure. Failuredue tofatigue is more dangerous than the staticfailure because failure occurred without warning, suddenly and thoroughly (ASM, 1997) Corrosion fatigue hadf irst expressed 60 years ago and more concentrated on the damaged cables under the sea. A more integrated investigationof this phenomenon conducted 10 years later and the term was coineddue to corrosionfatigue. Today reports of damagedue to corrosion fatigue and increasing corrosionfatigue phenomena currently considered as one of the causes of failure of the structure.It's certainly alot going on in the area of marine waters where conditions are veryaggressive and frequentload/stressrepeatedly(Murdjito, 2010).

AISI 304stainless steelis atype of materialthat is widely usedextensivelyin industriessuch aspetrochemical industry, thermal power plants, boilers, pressure vessels, constructionequipmentand transportin the field ofengineering. Extensive useof stainless steelisdue tothe physicalandmechanical propertiesandexcellent corrosionresistance (McGuire, 2008).

Stainlesssteel applicationsin the constructionand transportationbothairandseawateris veryat risk offailure. Therefore, appropriate treatmentis necessary for early detection off failures that may occur instainless steel AISI 304 type so the failurethat may occurcan beanticipated well, one of the waysto dois to know thefatigue strengthof materials Fatiguestrength ofAISI 304stainless steelin alaboratoryairand 3.5% NaCl study was the relationshipstress andcyclepresentedin theSNcurveandobservations offracturepatterns, in a3.5%NaClandconstant stress369.53MPastudiedis the cycle effectcycleeffectsof the pit growthandpolarizationcurves.

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/mm^2 219.20 N/mm^2 elongation of 67%.The size anddimensions ofthe specimenusing the standardASTME466-96 (tangentially BlendingFillets), see Figure1.

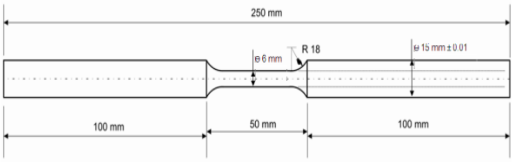
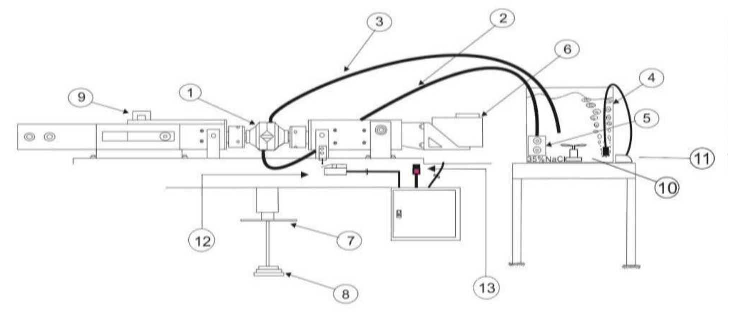


Figure 1. Size of specimen fatigue corrosion

Fatiguetesting machine used type rotary bending frequency of5 0 Hz and2900rpm and stress ratioR= -1. Testingdone withsurfaceroughnessrandomsystem(2specimens) donewitha randomsystem, to ensure grinding andpolishingsystemare done accordingwith ASTME-466 (the maximum surface roughness2μm)loading from the highest load level 12 Kgf (0.9 x 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 369.53MP. Set-up of fatiguetesting machinewith acirculation ofcorrosivemediain accordance with ASTMF1801-97 shown in Figure 2.



Keterangan :

1. Chamber
2. Inlet tube
3. Outlet tube
4. Resevoir
5. Water pump
6. Elec. motor
7. Load Lock
8. Load
9. Counter hour
10. Agitator
11. Air pump
12. Limit switch
13. On/Off

Figure2. *Set-up*fatigue testing mechinewith acirculation ofcorrosivemedia

Pitandcrackgrowth measured atcycles 120x10^3, 220x10^3, 320x10^3, 420x10^3, 520x10^3, 620x10^3,720x10^3. Electro chemical olarization measured at cycle 0,250x10^3, 500x10^3, 750x10^3. With constant stress3 69.53 MPa and3.5% NaClenvironment. Usingan optical microscope Olympusand Hokuto Denkogalvanostat HA-301 and ossiloscopeTektronikTDS304. Set-up of electro chemical polarization measurements shown in Fig. 3.

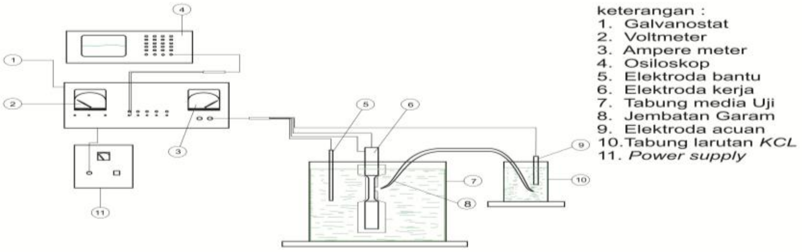


Figure 3. Set-up polarizationmeasurements

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.

Table1.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.

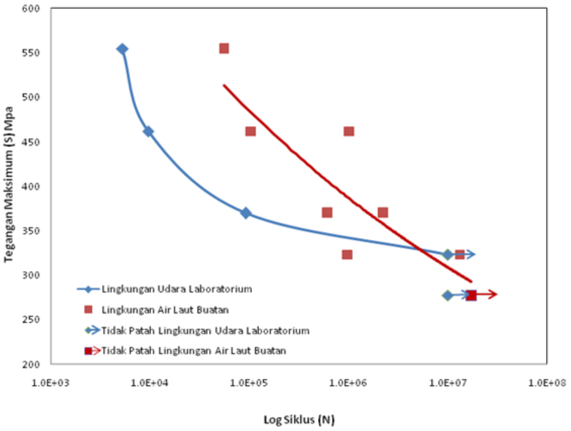


Figure 4. S-N curve for AISI 304 stainless steel inlaboratory air and 3.5% NaCl

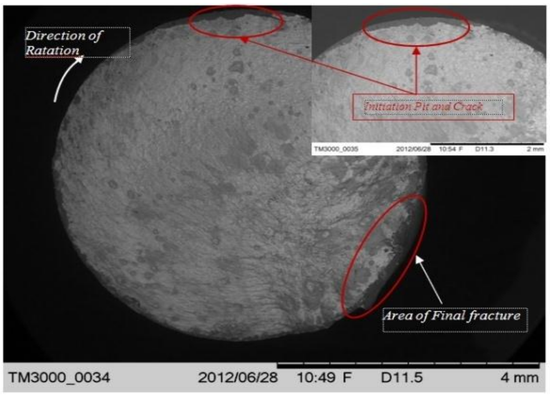


Figure 5. Failure pattern AISI 304 stainless In laboratory air and 3.5% NaCl at stress 369.53 MPa

Figure 4 shows the SN curve of stainless steel AISI 304, shows that the curvesinthe laboratoryair environmentfatiguelimit(endurance limit)323.34MPa, whereas in 3.5% NaCl the fatigue strengthof steel decreases, up to 277.15MPa stressat 1.7cyclesx107. This shows that the fatigue strength of steel is affected by the environment in which it operates steel. Special phenomenon indicated by theAISI 304 stainless steelin 3.5%NaC lenvironmentat stress above 369.53MPa, which increased fatigue strengthup to 10 times the fatigue strength in laboratory air environment. Furtherdecreases with decreasing stress and cut offthe air environmental Ncurvesuptowards 277.15MPa 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 form 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.

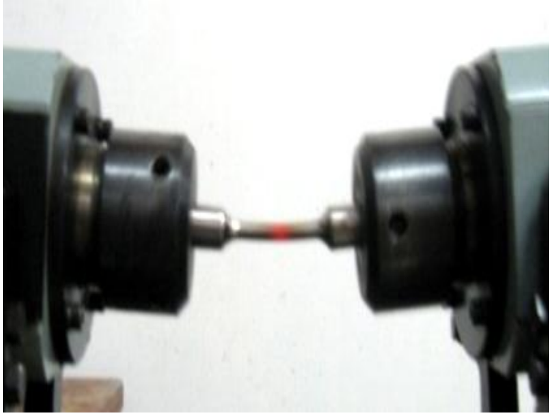


Figure 6. Visual temperature increase for test area of AISI 304 stanless steel at stress369.53 MPa

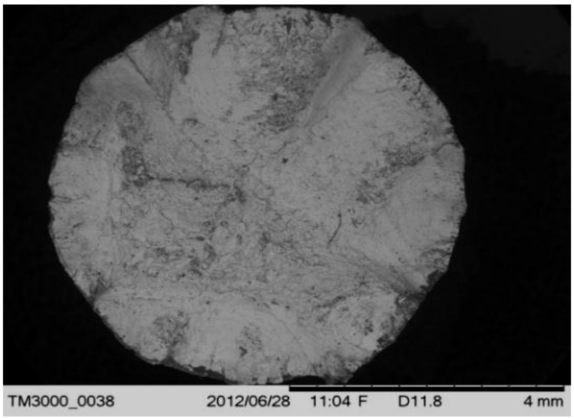


Figure 7. Figure 12. Failure pattern AISI 304 stainless steelin laboratory airat stress369.53 MPa

Photo fracture surface also show a pattern of ductile failure as shown in Figure 7. From the resultsaboveshow that theAISI 304stainlesssteelis used in both 3.5% NaCl environment, particularly for applications for the low stress on the cycle of plan ingtoolsand planning short-lived machines that requireper-scales on the components likely receive great stress during se, 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 indicatesthat thepithas grown and evolvedat120x103cyclewithan averagesize ofpitsandpitcontinues27.275µmgrown to420x103cycleswithan averagepitsize137.91µm, showsthatthemaximum stress369.63MPapitsizegrowthis veryshortandfailureis dominated bycrack propagationfrom cycle720x10^{3}520x10^3. The ratiobetween the lengthand width of thegrowthseensignificantpitwherepitandcrackgrowthis dominatedby the growth of crack length.

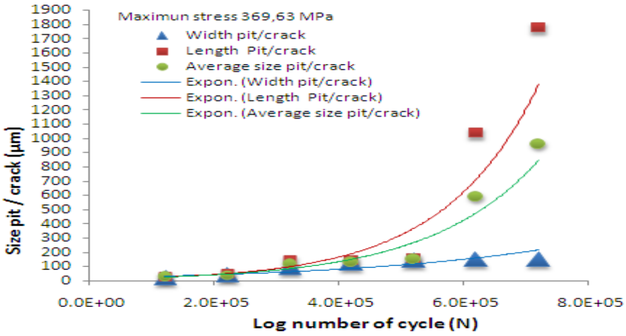


Figure 8. Relationship between pit/crack and cycle in 3,5% NaCl at stress 369,63 MPa

Electrochemical Polarization

From the test results of anodic-cathodic galvanostatik 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 sthat the number offatiguecyclesaffect thepotential changes thatoccuron the surface of the specimen, wherethe greater the number of fatigue cycles that resulted in a decreased value of the specimen surface potential land corrosion current density increases.

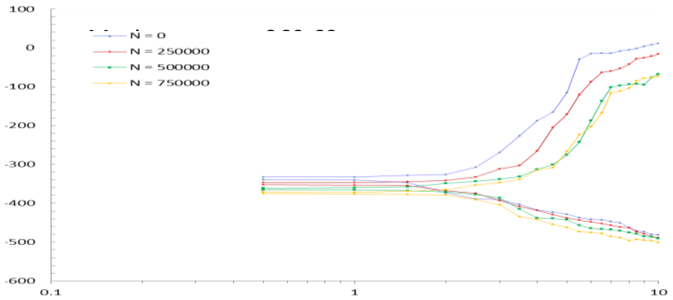


Figure 9. Anodic and cathodic polarization curves

Conclusions

SNc urve behavior of AISI 304 stainless steel with a laboratoryair environment fatigue limit 323.34 MPa and 3.5% NaCl environment decreases, up to stress 277.15 MPa at1.7x10^7 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. Improvedcycle that has resulted in adecreased value o fthe specimen surface potential and corrosion current density increases.

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