Metallurgical and Corrosion Analysis on the USS Arizona

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Objectives

- Determine effects of pH value in salt water on corrosion rate of steel from the USS Arizona
- Evaluate characteristics of the steel using metallographic techniques
- Determine presence of crevice corrosion mechanisms and the effects on corrosion rates
- Compile and analyze factors affecting corrosion rates from test results

Figure 1: Image of Potentiostat and Flat Cell Apparatus

Procedures

- Corrosion Rate Analysis
  -Samples were cut, polished, cleaned, and put in a Flat Cell (See Figure 1) for potentiodynamic cathodic and anodic polarization testing
- Microscopy
  -Samples were cut, mounted, polished, and observed under a microscope for microstructures (See Figures 3 & 4)
- Crevice Corrosion Analysis
  -Rivets were removed from plate A-6 (See Figure 2,) then oxidation samples were gathered, pulverized, and subjected to X-ray diffraction testing and elemental analysis via scanning electron microscope
- Macroetching
  -A large sample from plate A-6 was submerged in an HCl acid bath for an hour, cleaned, and observed to find areas affected by crevice corrosion and surface structural properties.

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Abstract

This poster describes the metallurgical and corrosion-based testing used to analyze six samples of the USS Arizona. Microscopy and macroetching was done in order to characterize the metal, while corrosion rate testing and crevice corrosion identification was done in order to analyze corrosion rates. We found that the USS Arizona steel was medium carbon steel with high amounts of inclusions. Also, the steel showed a propensity to corrode independently of pH while in pH 4 through 7 with drastically increased corrosion rates noted below pH 4 and the A-6 samples revealed at least one crevice corrosion mechanism at work. Future work may include reliable quantitative corrosion rate testing and advanced evaluation of the effects of crevice corrosion on the USS Arizona.

Table 1: Corrosion Rate Testing Results

Sample	Corrosion Rate (mpy) based on pH		
	pH 7	pH 4	pH 2
Plate A-1	19	6.8	180
A-2	12	7.9	430
A-3	11	17	290
A-4	17	5.1	45
A-5	9.0	10	250
A-5 rivet	19	11	93
A-6 top of rivet	0.6*	20	250
A-6 middle of rivet	8.0	9.8	290
A-6 bottom of rivet			
A-6 Plate 1	12	1.1	
A-6 Plate 2			
A-6 Plate 3			

* Results are tentative due to less than perfect testing conditions

Figure 2: Macroetch of Plate A-6

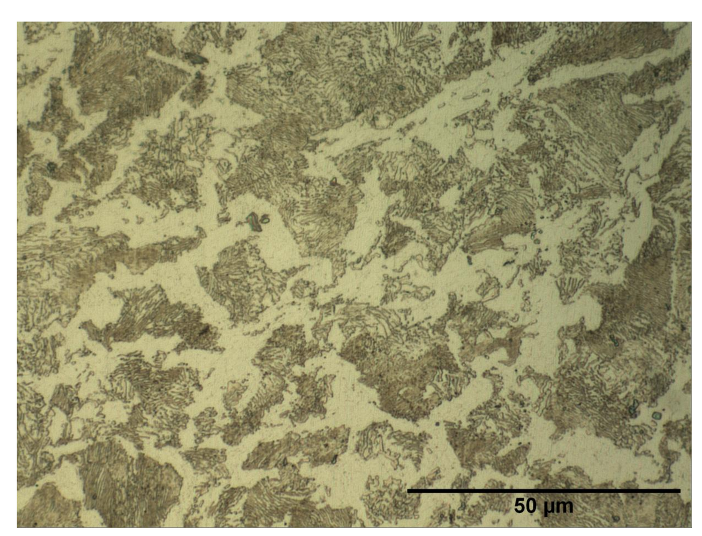

Figure 3: Micrograph of Plate A-5

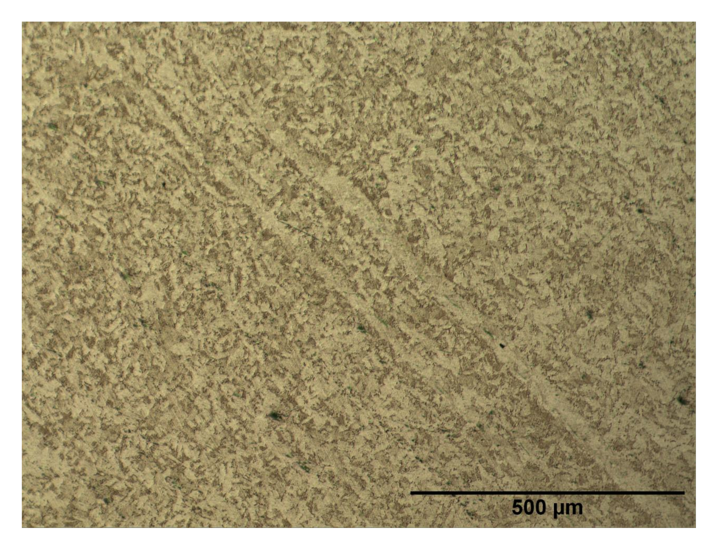

Figure 4: Micrograph of Plate A-4

Future Work

- Conduct more potentiodynamic polarization tests to get averaged results
- Analyze extent of crevice corrosion and effects on structural integrity
- Test corrosion rates of USS AZ specimens and obtain reliable quantitative data
- Conduct advanced evaluations of micrographs in relation to metal characteristics

Results

- Table 1 shows the results of the corrosion rate analysis.
- The steel samples from the USS Arizona were confirmed to be medium carbon steel with a high amount of inclusions.
- The optical micrographs showed that the steels samples were hypoeutectoid in carbon content. Fine and coarse pearlite were observed in the structure along with proeutectoid acicular ferrite at the prior austenite grain boundaries.
- Macroetching showed that the rivets from plate A-6 had plastic deformation near the bottom and top of the rivet and the shaft of the rivet showed vertical banding.
- From the crevice corrosion analysis, we confirmed there was magnetite and goethite present in the oxidation samples from the rivet-plate interfaces (Figure 5.)

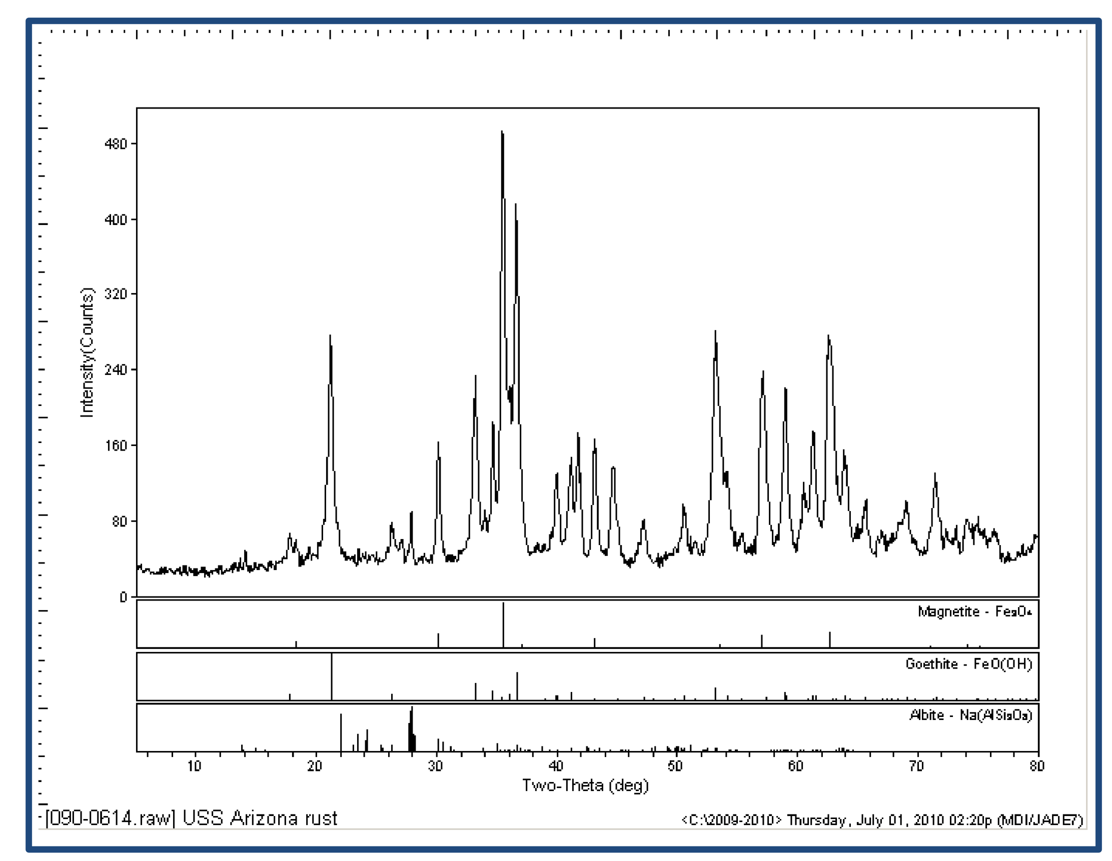

Figure 5: X-ray Diffraction Mineral Analysis of Crevice Oxidation Sample

Conclusions

The natural waters of Pearl Harbor serve no threat to the structural integrity of the USS Arizona as far as pH is concerned. While some areas on the ship might be exposed to water with an artificially low pH caused by microorganisms living on the ship, the extent of the lower pH is not known. The corrosion rate of the USS Arizona is nearly independent of pH value between pH 4 and 7, however there are many other natural and man-made factors affecting the corrosion rates of the USS Arizona. Crevice corrosion might be a large contributor in the degradation process and is worth looking into based off of the qualitative results we found. Also, while the metal from the ship has many impurities, it behaves much like clean medium carbon steel. There is plenty of future work to be done in regard to more quantitative studies related to corrosion rates, especially if pieces taken recently from the underwater portion of the ship could be tested because this would provide optimal testing specimens.