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CORROSION EVALUATION OF A NAVY MK50 WEAPON STATION FRICTION BRAKE ASSEMBLY

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ABSTRACT

The presence of corrosion on or within structures is of major concern as corrosion reduces the integrity of the materials which could potentially result in large-scale failures of structures and equipment.[1] The United States Navy is an organization that actively works to prevent large equipment failure due to corrosion. One such problem is the corrosion of the friction brake assembly on the MK50 Weapon Station, which has recently been experiencing corrosion between the friction brake and its set screw preventing it from operating correctly. The friction brake was known to be stainless steel; however, the set screw was of unknown composition. Through elemental analysis it was determined that the MK50 Weapons Station friction brake set screw was similar in composition to commonly available black oxide coated steel screws. Electrochemical polarization measurements of the friction brake assembly components revealed that the set screw and the friction brake were electrochemically dissimilar metals which resulted in the galvanic corrosion of the assembly when out at sea. The electrochemical polarization measurements of a stainless steel screw showed a corrosion potential similar to that of the friction brake; therefore, replacing the current set screw with a stainless steel screw would decrease the galvanic potential difference between the set screw and the friction brake. This proposed solution is expected to slow or prevent further corrosion of the MK50 Weapon Station ensuring the combat readiness of the equipment.

Keywords: Corrosion, Navy, Electrochemical Testing, Spark Test

1. INTRODUCTION

Corrosion is the degradation of a metal due to its interaction with the surrounding environment. The presence of corrosion on or within structures is of major concern as corrosion reduces the integrity of the materials which could potentially result in large-scale failures of structures and equipment. This is of particular concern to the United States Department of Defense (DOD) as corrosion can put armed service members in harm's way due to a decrease in equipment readiness in preparation for battle. Maintaining equipment in preparation for use on the battlefield requires a significant amount of labor and material cost which the taxpayer ultimately funds. According to the National Association of Corrosion Engineers (NACE) IMPACT Study, the direct cost of corrosion maintenance to the DOD is estimated to be ~$20 billion per year (in fiscal year 2005 dollars).[2] Because of this the DOD is interested in finding, eliminating or at least mitigating costly sources of corrosion on DOD assets. One such asset is the 85' MKVI Patrol Boat used by the United States Navy to secure the shores near Guam. On the patrol boat is a MK50 Weapon Station that has a friction brake assembly, composed of the friction brake and a set screw, used to prevent large amounts of weapon recoil during combat. However, the friction brake assemblies recently installed on the MK50 Weapon Station have been beginning to experience large amounts of corrosion which could compromise the ability of the MK50 Weapon Station to fire during combat. Therefore, the Navy is interested in determining the cause of the corrosion and developing a solution to prevent the corrosion.

This work presents the characterization of the materials used in the MK50 Weapon Station friction brake assembly in order to understand the cause of the corrosion and proposes a material engineering solution to the design in hopes of preventing further corrosion and improving its readiness for battle. The friction brake component of the assembly is known to be stainless steel; however, the composition of the set screw is unknown. Therefore, elemental analysis using an emission spark test and energy dispersion X-ray spectroscopy (EDS) was performed on the set screw and other known steel components for comparison in order to determine the composition of the set screw. Additionally, the electrochemical activities of the friction brake and set screw were investigated in an artificial saltwater-like solution to mimic the environmental conditions that resulted in the corrosion of the friction brake assembly in Guam. Finally, we compared the electrochemical activities of the friction brake and set screw with similar components of different elemental compositions and propose a solution to the observed corrosion occurring in the friction brake assembly.

2. MATERIALS AND METHODS

2.1 Materials

The MK50 friction brake was taken from a United States Navy 85' MKVI Patrol Boat in Guam. The friction brake was composed of a stainless steel friction brake and a set screw of unknown composition. Known standards of 1018, 1045, and 1095 steel, as well as two different common types of steel screws (stainless steel and black oxide coated steel) were used as comparison standards for the elemental analysis of the friction brake components. Based on the results of the elemental analysis, the samples for electrochemical testing were narrowed down to the friction brake, set screw, stainless steel screw and the high carbon oxide steel screw were also used in electrochemical corrosion testing.

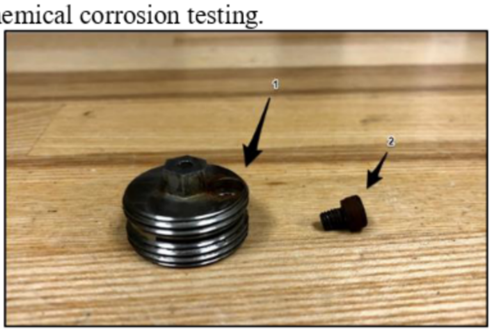

FIGURE 1: IMAGE OF MK50 WEAPON STATION FRICTION BRAKE ASSEMBLY SHOWING (1) THE FRICTION BRAKE AND (2) SET SCREW

2.1 Characterization and Setup

The identity of the steel used in the set screw was identified by comparison of its elemental analysis results with those of known samples. Elemental analysis was performed via spark test and EDX analysis. The spark test was performed using channel lock pliers to hold the sample while it was placed onto a grinding wheel. The spark pattern was collected via digital photography using an iPad. Samples were prepared for EDX analysis by adhering the samples to an SEM stub using double sided adhesive carbon tape. EDX analysis was completed using a Hitachi TM3030 Electron Microscope.

Electrochemical corrosion measurements were taken with a VSP multichannel potentiostat (Bio-logic) using a three-electrode configuration with the metal sample as the working electrode, a platinum mesh as the counter electrode, and a Ag/AgCl (4M KCl) reference electrode to which all measurements mentioned herein are referenced. The electrolyte for the experiments was an artificial seawater-like solution (0.41M NaCl, 0.03M $NaSO_4$, 0.002M $NaHCO_3$) which closely resembled the ASTM D1141-98 standard artificial seawater. The pH of the electrolyte was adjusted using small amounts of concentrated NaOH and H_2SO_4 until the solution reached a pH of 8.2. Before all electrochemical measurements the working, counter and reference electrodes were allowed to rest in the electrolyte for 5 minutes prior to testing to stabilize the open circuit potential. Electrochemical measurements were made by linearly sweeping the potential of the working electrode from -1.4 V vs. the open circuit potential to +0.7 V vs. Ag/AgCl at a rate of 100 mV/s.

3. RESULTS AND DISCUSSION

Upon arrival the set screw was covered with corrosion that could easily be sanded off using 320 grit sandpaper. Once the corrosion was removed, the screw was found to be black resembling a black oxide coated steel screw. To determine the composition of the set screw, a spark test using a grinding wheel was used to compare the carbon content of the set screw to 1095, 1045, and 1018 steel samples as well as an in-house available black oxide steel screw. Spark tests are used by metallurgists to determine the composition of ferrous metals based on the color, length, and directionality of the sparks given off by the ferrous metals.[3] Figure 1(a,b) shows the spark test pattern of the set screw, the black oxide screw, and the 1095, 1045, and 1018 steel samples. The spark pattern of the set screw and the black oxide coated steel screw are very similar with regard to the color and length of the sparks; however, the black oxide steel screw has a spark pattern consisting of more sparks. This indicates the set screw is a ferrous screw and that the compositions of the set screw and the black oxide steel screw are similar though not identical. Further comparison of composition was done by performing spark tests on 1095, 1045, and 1018 steel samples. Figure 2(c-e) shows the spark test of 1095, 1045, and 1018 steel. The spark pattern from the set screw with its long white-like color sparks most closely resembled the spark pattern of 1095 only with more sparks. Whereas the 1045 and 1015 spark patterns have shorter slightly straw-colored sparks. The large number of sparks generated by the 1045 steel indicates that the set screw may have a carbon concentration that is in between 1095 and 1045 due to the larger number of sparks generated by the set screw compared to 1095. Additionally, the black oxide steel screw is likely even closer in composition to 1045 than the set screw. Further elemental analysis using EDX found that the set screw had five times as much sodium and ten times as much chlorine compared to the black oxide steel screw likely due to consistent exposure to the ocean. This may have contributed to the difference in the spark patterns.

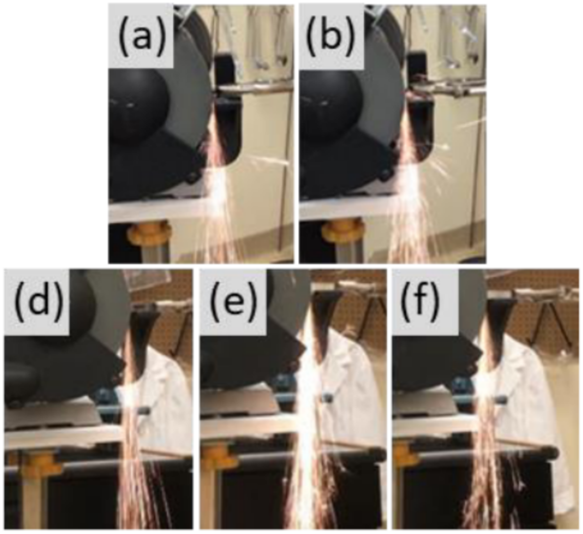

FIGURE 2: SPARK TEST IMAGES OF THE (a) SET SCREW (b) BLACK OXIDE SCREW, (c) 1095 STEEL (d) 1045 STEEL, AND (e) 1015 STEEL

Electrochemical polarization measurements were performed on the friction brake, set screw, stainless steel screw, and black oxide steel screw in an artificial seawater-like solution to measure the electrochemical performance of each material in a corrosive environment. Figure 3 shows the electrochemical polarization measurements of the friction brake, set screw, stainless steel screw, and black oxide steel screw. From the electrochemical polarization measurements, it can be seen that the source of corrosion developing on the friction brake assembly was due to the corrosion potential difference between the friction brake and the set screw. The potential of the set screw and the black oxide steel screw the potentials were found to be similar; however, the black oxide steel screw has a more anodic potential than the set screw. The stainless steel screw was found to have an open circuit potential that is very similar to that of the friction brake indicating that, if the set screw were composed of stainless steel, galvanic corrosion would be significantly decreased.

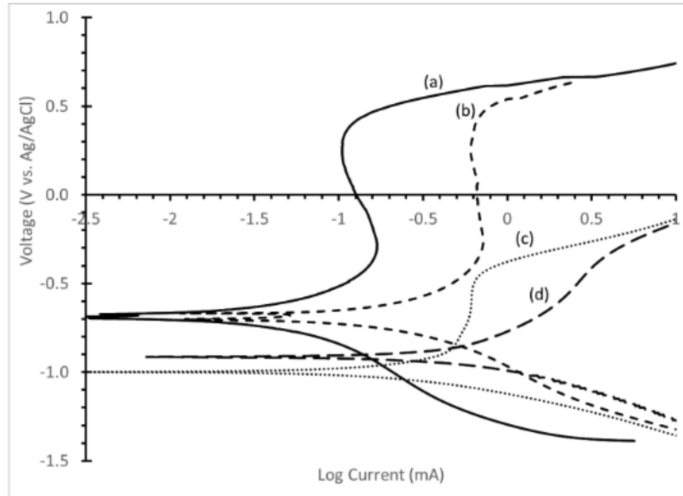

FIGURE 3: ELECTROCHEMCIAL POLARIZATION MEASUREMENTS OF THE (a) 316 STAINLESS STEEL SCREW, (b) FRICTION BRAKE, (c) BLACK OXIDE STEEL SCREW, AND (d) SET SCREW.

4. CONCLUSION

This study was able to determine using spark tests and EDX analysis that the unknown composition of the set screw on a MK50 Weapon Station friction brake is similar in composition to a common black oxide coated steel screw. Electrochemical polarization measurements showed the set screw and the friction brake are galvanically mismatched metals resulting in the observed corrosion. In order to prevent future corrosion, it is recommended that a stainless steel set screw or a screw that is less galvanically mismatched compared to the friction brake be used in order to slow or prevent further corrosion of the system.

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