November 2009

# WearSox Silver Corrosion Testing Summary

Several standardized corrosion tests were conducted on WearSox Silver in order to better characterize its corrosion resistance. These tests include a stress-corrosion cracking (SCC) test, a salt-spray (fog) test, an intergranular corrosion test, and a pitting corrosion test. In addition to the standardized tests outlined above, a non-standardized salt water immersion test was developed and conducted at Devasco International, Inc.

## Autoclave stress corrosion cracking (SCC) test

An autoclave SCC test (NACE TM0177-96 Method "B" as modified by ASTM G39-05) was conducted in order to determine the susceptibility of the coating (~15% alloy content) to stress-corrosion cracking. Below (Figure 1) is an image of the sample after testing. The test was conducted at 80% stress level at 1,000 psi (50 psi $H_2S$, 400 psi $CO_2$, balance $N_2$) in a 5% NaCl solution and at a temperature of 350°F for a period of 7 days.

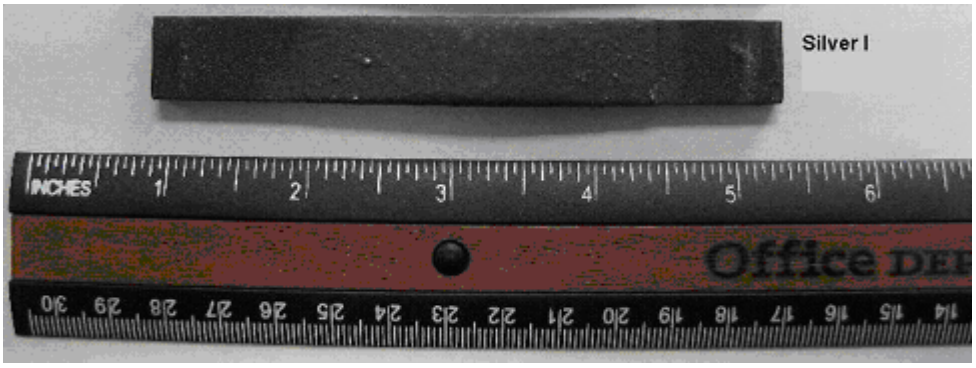


**Figure 1.** Thermal spray coating after autoclave SCC test

Scanning electron microscopy (SEM) was conducted in order to determine whether cracks developed during the testing period. No cracking or debonding between the WearSox coating and the base material was observed in the coating (Figure 2).

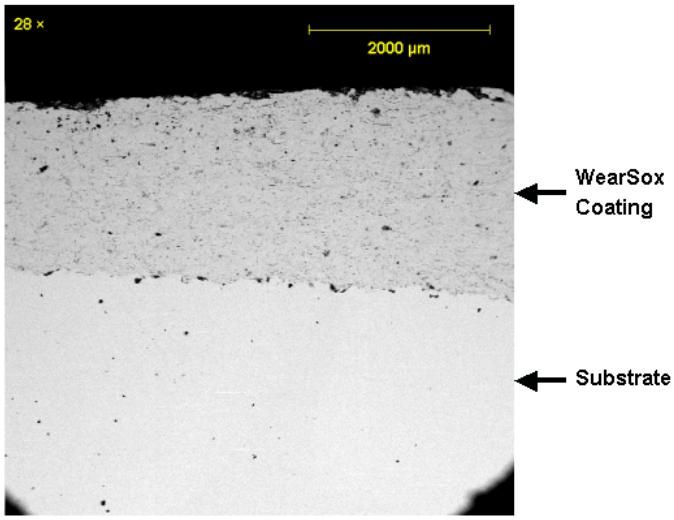


**Figure 2.** SEM image of cross-section of coating and base material after Autoclave SCC Test – no cracking was observed

## Salt spray (fog) test

A salt spray corrosion test (ASTM B117-09) was conducted on WearSox Silver in order to determine its susceptibility to salt water corrosion. The specimen was tested for a total of 312 hours. SEM analysis was conducted and only general corrosion was observed with no evidence of pitting or intergranular corrosion (Figures 3,4).


**Figure 3.** Thermal spray coatings after 312-hour salt spray (fog) test

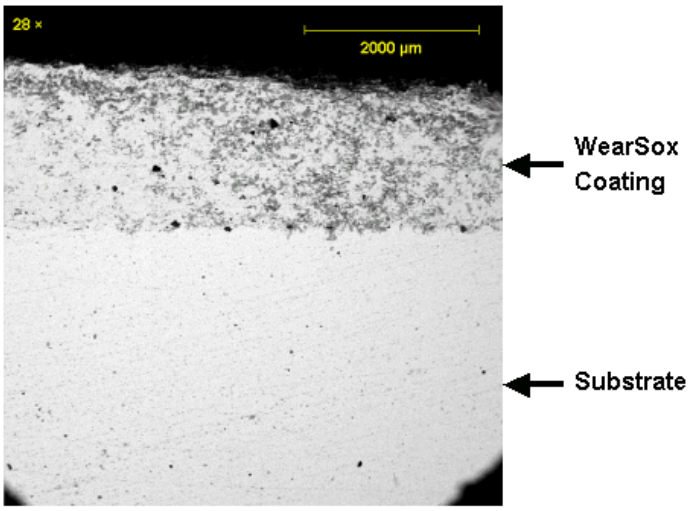


**Figure 4.** SEM image of cross-section of WearSox Silver coating and base material

## Intergranular Corrosion Test

An intergranular corrosion test (ASTM A262-02a Practice E) was conducted on WearSox Silver. The coating was deposited on a 625 nickel-based alloy. The coating failed upon 180° bending, which was expected (Figure 5).

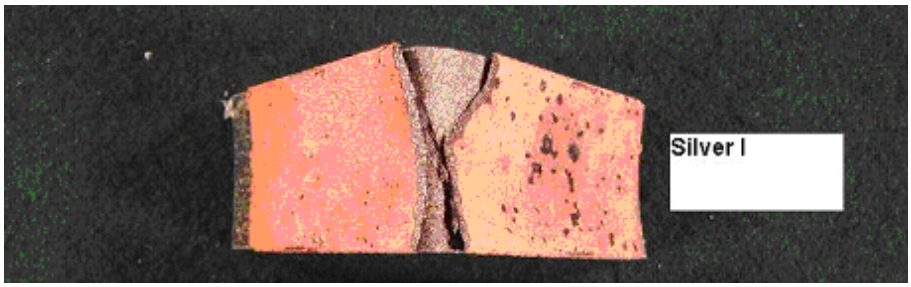


**Figure 5.** Photograph of the sample after bending 180°

There was some evidence of intergranular corrosion (Figure 6).

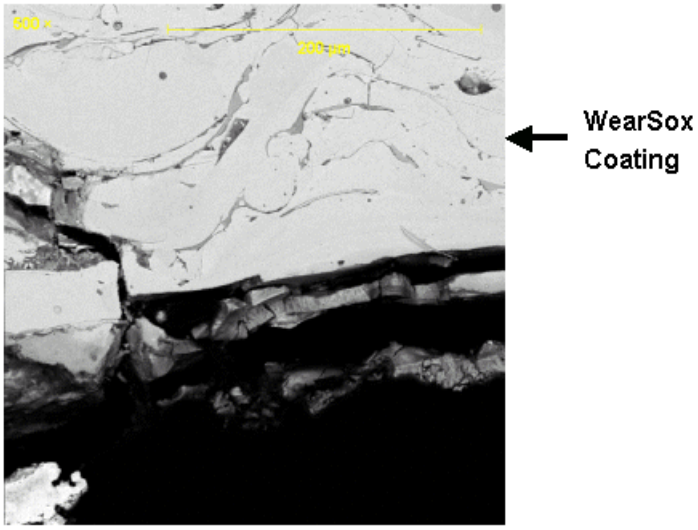


**Figure 6.** SEM image of WearSox Silver sample after testing – minimal evidence of intergranular corrosion observed

## Pitting Corrosion Test

A pitting corrosion test (ASTM A923-06 Method C) was conducted in order to determine the susceptibility of the coating to pitting. Although the WearSox Silver sample exceeded the maximum weight loss allowed to pass the test (which was expected), only general corrosion was observed (Figures 7).

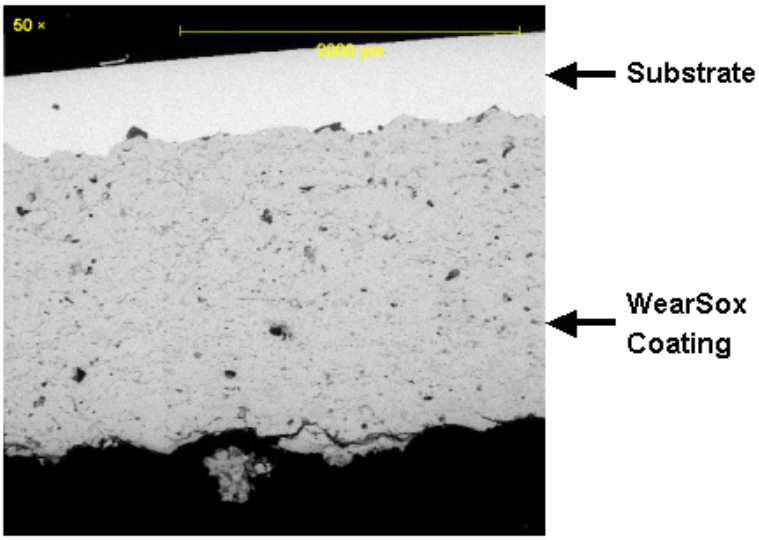


**Figure 7.** WearSox Silver sample after pitting corrosion test

## Custom-designed Salt-Water Immersion Test

A custom salt fog test was developed and conducted at Devasco International, Inc. WearSox Silver samples were placed partially submerged in salt water in order to observe the effect of the environment above, below, and at the water line (Figure 12). A 304 stainless steel rod was placed in each tank as a control. Two types of water were used during testing: a synthetic sea salt mixed with deionized water and salt-water taken from Galveston Bay. The water temperature of the tanks was held at approximately 34°C and the specific gravity was monitored and held at approximately 1.02. Samples were tested for a total of 25 days.

**Figure 12.** Photograph of custom-designed salt fog experimental arrangement

Only general corrosion was observed on the samples tested in synthetic seawater (Figures 13, 14) and natural seawater (Figures 15, 16). On both samples, regardless of environment, the predominant constituents of the surface scale were chlorine, oxygen, calcium and iron. These are indicative of deposited salts and corrosion products.


**Figure 13.** Synthetic seawater sample after 25 days in custom salt-spray test

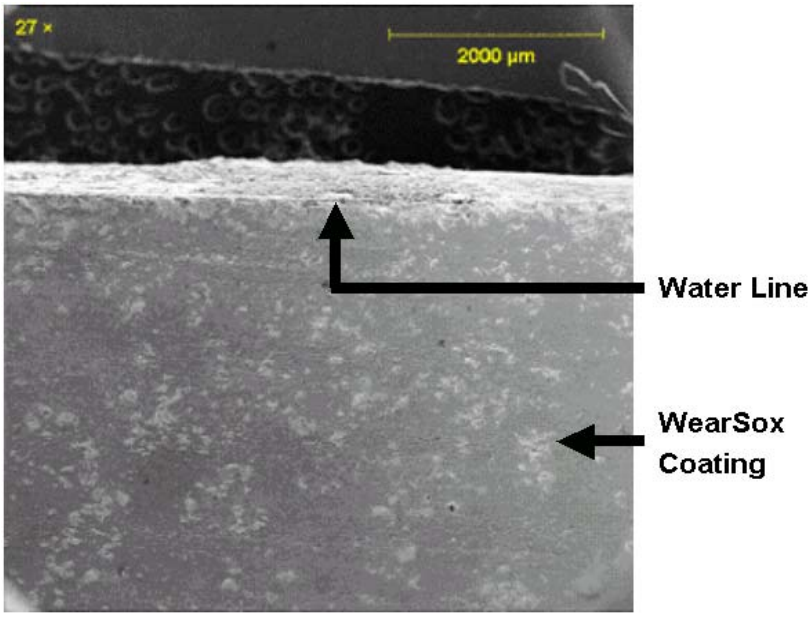


**Figure 14.** SEM image of the waterline of the sample tested in synthetic seawater

**Figure 15.** Natural seawater sample after 25 days in custom salt-spray test

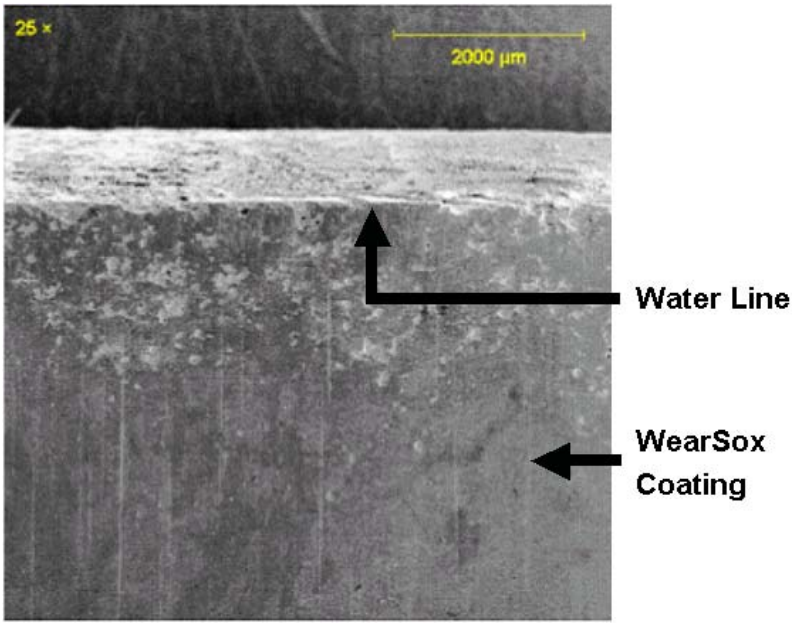


**Figure 16.** SEM image of the waterline of the sample tested in natural seawater