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Case Study: Wind Turbine Spring Failure

By

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Subject

Visual examination of a broken, zinc plated spring from a wind turbine to determine the cause of failure. The broken spring caused malfunctioning of the wind turbine. This spring failed shortly after being installed, and may have been cycled once or twice. The spring was manufactured from oil tempered spring wire, ASTM A229.

Visual Examination

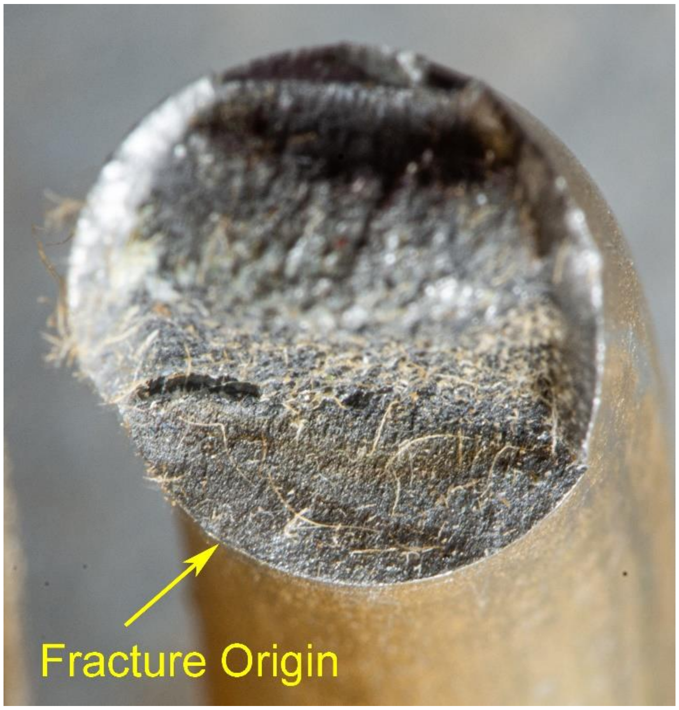

Figure 1 – Fracture Surface

Figure 1 shows the fracture surface of the broken spring. The fracture origin is indicated. There were no material defects found at the fracture origin. Only the flat fracture area is in focus in the photo, but the crystal structure of the steel is apparent. Changing the light angle shows glittering on the fracture surface. There are two fracture modes that will have glittering on the fracture surface: cleavage, and intergranular fracture. The likelihood of cleavage occurring in oil tempered spring wire is very low. The likelihood of intergranular fracture in zinc electroplated oil tempered spring wire is relatively high.

Intergranular fracture in zinc electroplated spring wire is the result of hydrogen embrittlement. To avoid hydrogen embrittlement after electroplating oil tempered spring wire, it is necessary to bake the plated spring wire at 395^o F. +/- 5^o within four hours of plating. Minimum baking time is eight hours. Because high carbon steel is used for oil tempered spring wire, baking temperatures exceeding 400^o F. will form methane in a reaction between carbon in the steel and hydrogen from the plating process. This causes methane embrittlement, which is identical to hydrogen embrittlement.

Painting is an alternate method of corrosion protection. For painting, a light phosphate coating needs to be applied before painting for assure good adhesion. This coating process produces hydrogen, but a correctly maintained bath chemistry neutralizes the hydrogen.

Conclusion

The most likely cause of the failure of this spring was hydrogen embrittlement.

Recommendation

Existing plated springs can be tested for hydrogen embrittlement by stressing them at 80% of yield strength for a week. Any springs that do not break during that time can be assumed to have very low levels of hydrogen, and will not likely break in use. This test is not an absolute guarantee, however.