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Extension Spring Failure

By

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Subject

This music wire extension spring failed after being in service for a short period of time. This investigation was to determine the cause of the spring failure. The spring was examined by visual examination, hardness testing, scanning electron microscopic examination, fracture mechanics, and metallographic examination.

Visual Examination

Figure 1 – Broken Spring

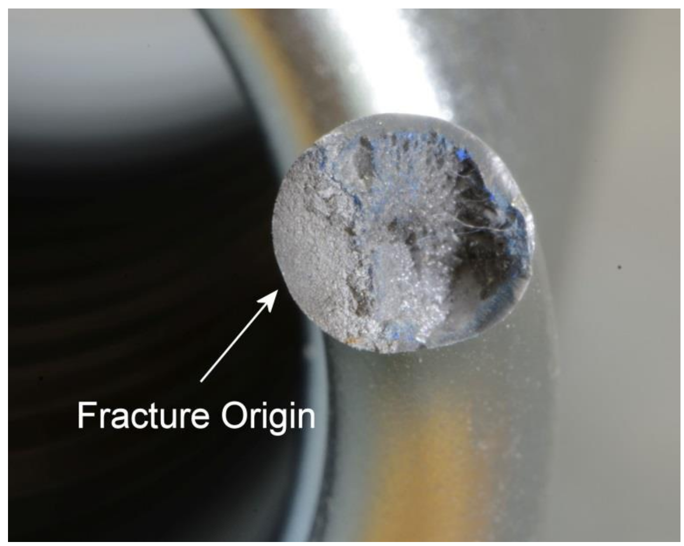

Figure 2 – Fractured End

The broken Extension Spring is shown in Figure 1. The broken end is on the left hand side of the photo. The location of the fracture origin is shown in Figure 2. Figure 3 shows a tool mark caused during forming of the spring. The tool mark was only on the broken end of the spring where the failure initiation occurred. The tool mark is a common manufacturing defect associated with springs.

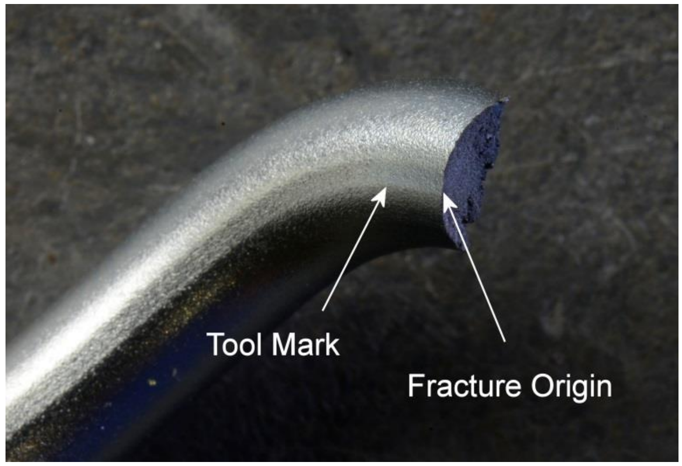

Figure 3 – Tool Mark Associated with Fracture Origin

The visual examination revealed a manufacturing defect associated with the fracture origin of the spring.

Hardness Testing

The hardness testing was done according to ASTM E384, using a Knoop indenter and a 500 gram load. The results of the testing are given in the table and chart that follow.

Average Hardness Data
(Rockwell C Scale)

KNOOP	STD DEV	MAX VALUE	MIN VALUE	HARDNESS
475.00	26.37	520.00	421.00	45.58 RC

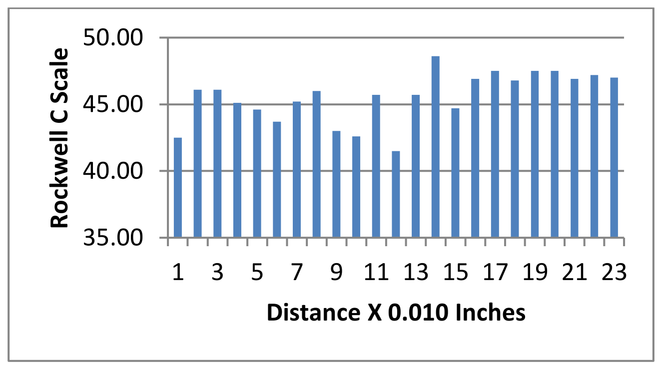

Figure 4 – Hardness Profile

The average hardness across the spring wire was 45.48 Rockwell C Scale. The hardness is in the correct range for spring wire of this diameter. The hardness profile, Figure 4, looks very good for formed music wire.

Scanning Electron Microscopic Examination

The fracture origin is shown in Figure 5. There is a depression in the wire surface that is noticeable at this location. An error in the forming of the wire caused the tool mark which indicated that the steel was highly cold worked. There was cracking and flaking of the music wire at the fracture origin.

Figure 6 shows fatigue striations near the fracture origin. There was some indication that triaxial stress may have been involved in the spring failure. The striation spacing was found to be 18.43 X 10^{-6} inches.

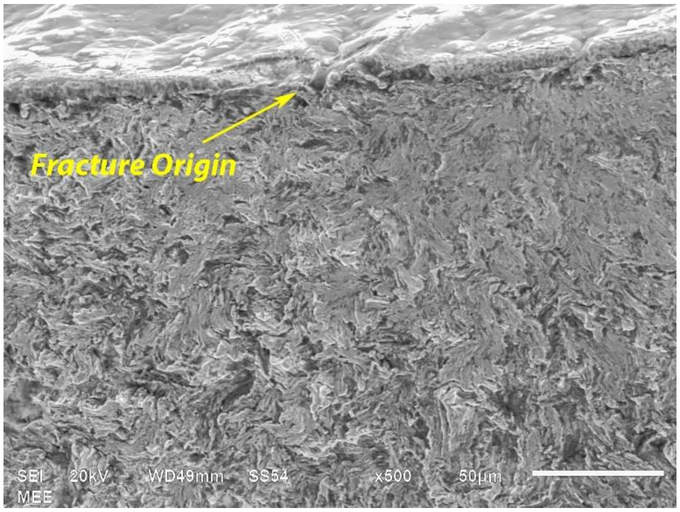

Figure 5 – 500X Fracture Origin

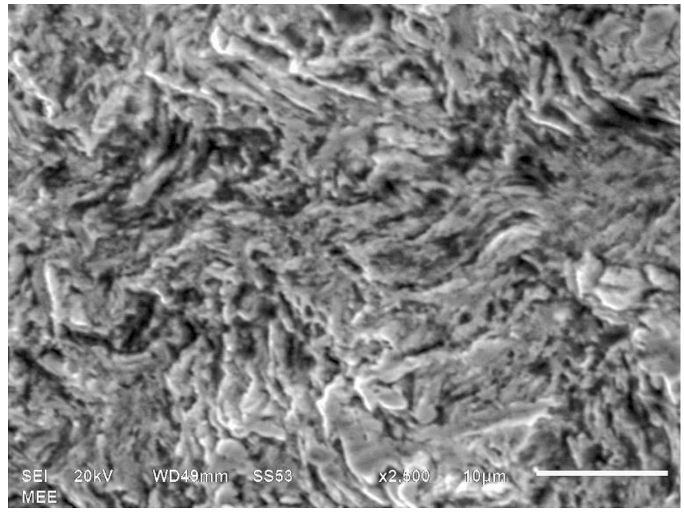

Figure 6 – 2000X Fatigue Striations near Fracture Origin

Fracture Mechanics

Fracture mechanics can be used to estimate the stress levels that were on the parts at the time of fracture. Knowing the location and spacing of the fatigue striations permits the estimation of the cyclic fatigue stress by the following equation: $\Delta\sigma = \frac{E\sqrt{\frac{spacing}{6}}}{Y\sqrt{a}}$. The terms are defined below:

$\Delta\sigma$	The applied cyclic stress.
E	The modulus of elasticity equal to 30,000,000 psi for steel alloys.
a	The distance the fatigue striations progressed from the fracture origin.
Y	A constant equal to 2.1. It is defined by the shape of the crack.

The measured value for "a", for the broken Extension Spring was 0.099 inches. Based on the measured "a" value and the fatigue striation spacing, the cyclic stress on the spring was estimated to be 80 ksi, which is typically considered to be the endurance limit for steels that have yield strengths higher than 160 ksi.

This spring should have had a very long life.

Metallographic Examination

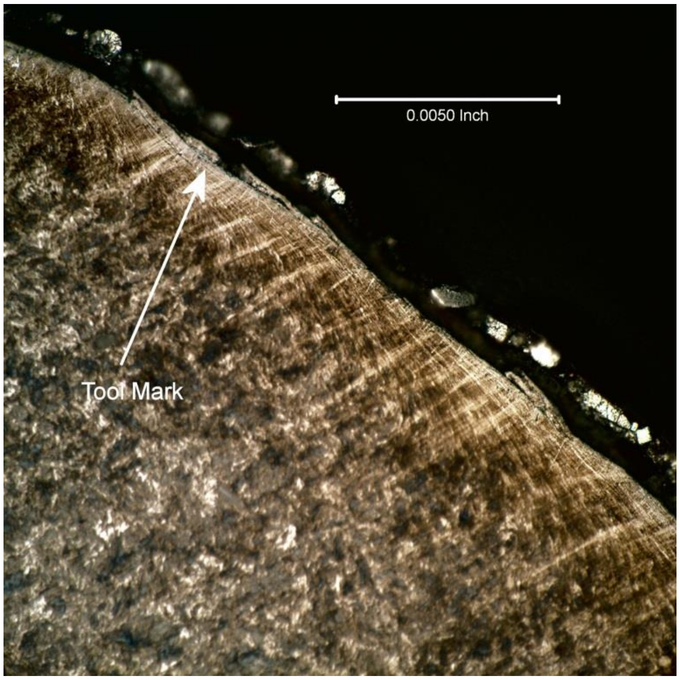

Figure 7 – 400X Tool Mark

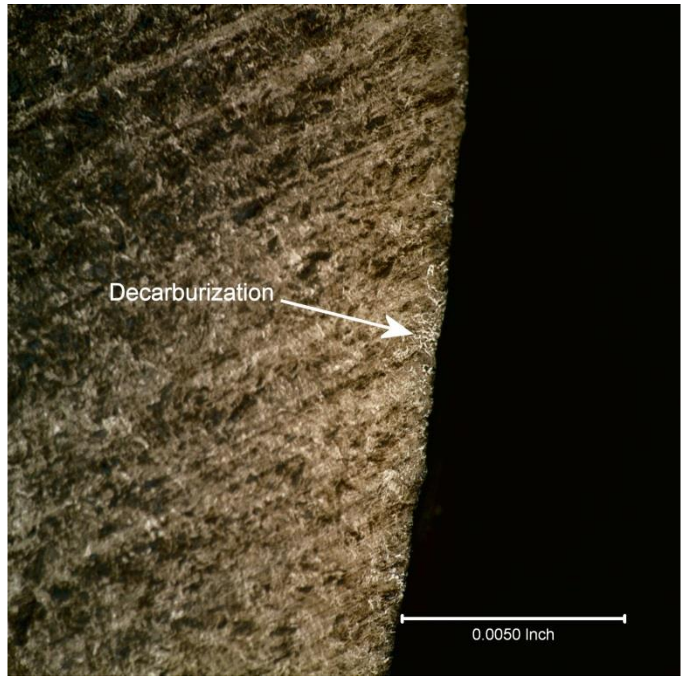

Figure 8 – 400X Surface Decarburization

Figure 7 shows the highly cold worked steel that resulted from the tool mark on the spring wire. There was also some cracking and flaking of the music wire resulting from the excessive cold working caused by the tool mark. There was also a small amount of surface decarburization present on the spring wire, Figure 8. The surface decarburization did not appear to have contributed to the spring failure.

Conclusion

Based on the findings given in this report, the spring failure was the result of cold working caused by the tool mark. Tool marks are common manufacturing defects that occur during the forming of a spring. Tool marks are also a common cause of premature spring failure.