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Case Study: Compression Spring Failure

By

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Subject

Failure analysis of compression springs to determine cause of failure. A broken spring and a new spring from inventory were examined to determine the cause of the defects that resulted in the spring breakage. The two springs were examined by hardness testing and metallographic examination. The spring was to be formed from 0.039 inch diameter music wire, per ASTM A228.

Hardness Test

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 that follows. The hardness readings were taken near the center of the wire.

Spring Hardness Data (Rockwell C Scale)					
Location	KNOOP	STD DEV	MAX VALUE	MIN VALUE	HARDNESS
Broken	592.00	18.54	618.00	563.00	52.85 RC
New	623.00	31.61	680.00	577.00	54.54 RC

The hardness of the two springs is similar to the hardness expected in 0.039 inch diameter music wire. The hardness of the wire was within specification. There was no evidence of plastic deformation in the broken spring.

Metallographic Examination

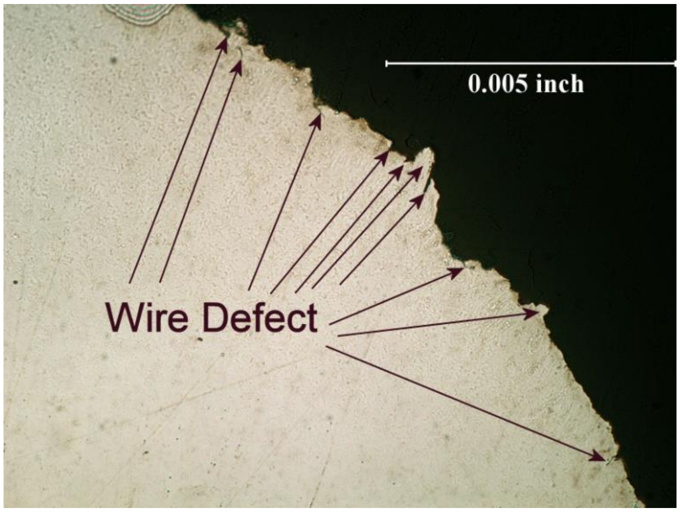

Figure 1 – 400X Wire Defects – Broken Spring

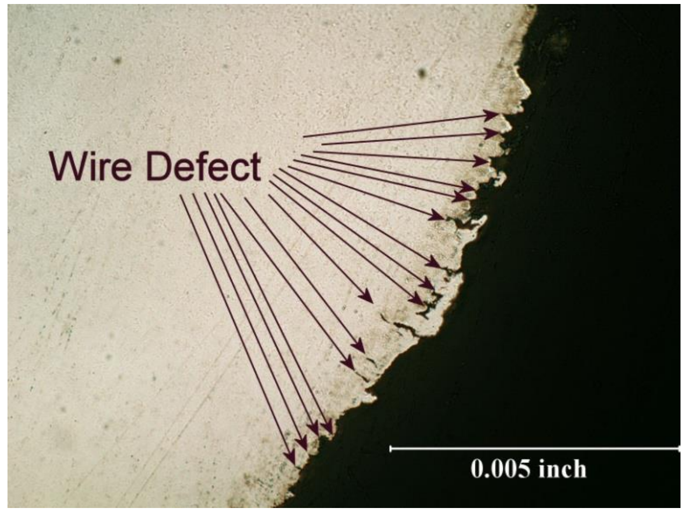

Figure 2 – 400X Wire Defects – Broken Spring

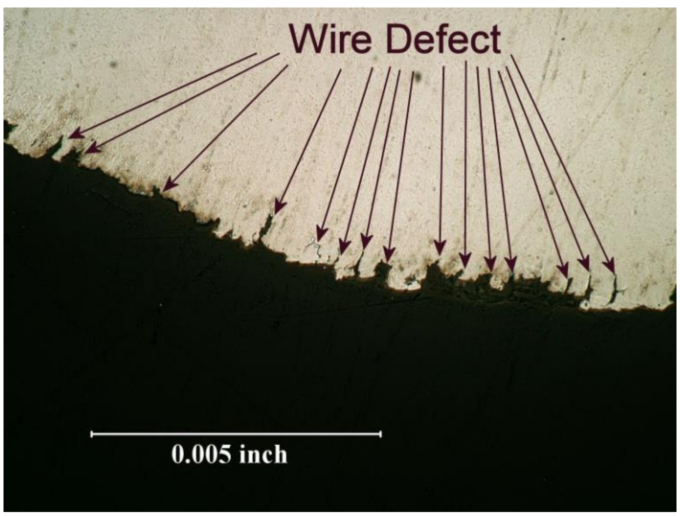

Figure 3 – 400X Wire Defects – Broken Spring

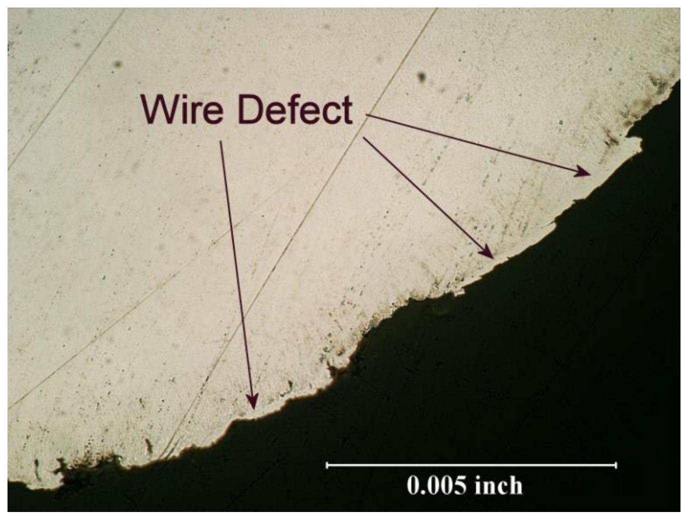

Figure 4 – 400X Wire Defects – Broken Spring

Figures 1 through 4 show wire defects on the surface of the broken spring. Any of the defects shown are capable of being a source of a fatigue crack. The broken spring failed by fatigue. Wire used for springs needs to be free of surface defects. Figure 4 shows three locations where white martensite is on the wire surface. White martensite on the surface of spring wire can be caused by friction during forming of the spring, or by redrawing of the spring wire.

The cause of failure of the broken spring was clearly defects on the surface of the spring wire. A sample of a new spring was examined to determine the source of the surface defects on the wire.

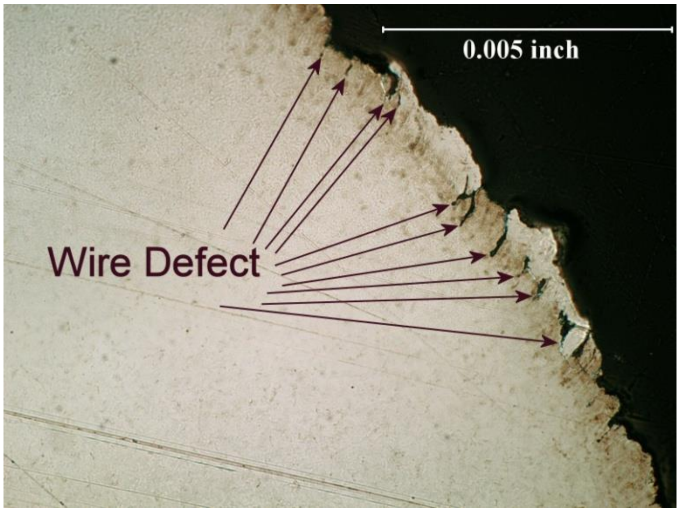

Figure 5 – 400X Wire Defects – New Spring

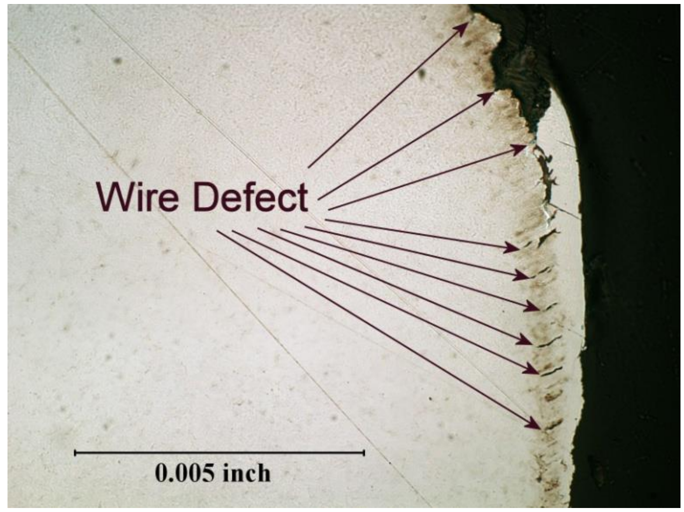

Figure 6 – 400X Wire Defects – New Spring

Figures 5 and 6 show numerous cracks and white martensite on the surface of the spring wire. These defects indicate that defective wire was used for making the spring. Figure 6 shows both surface cracks and white martensite.

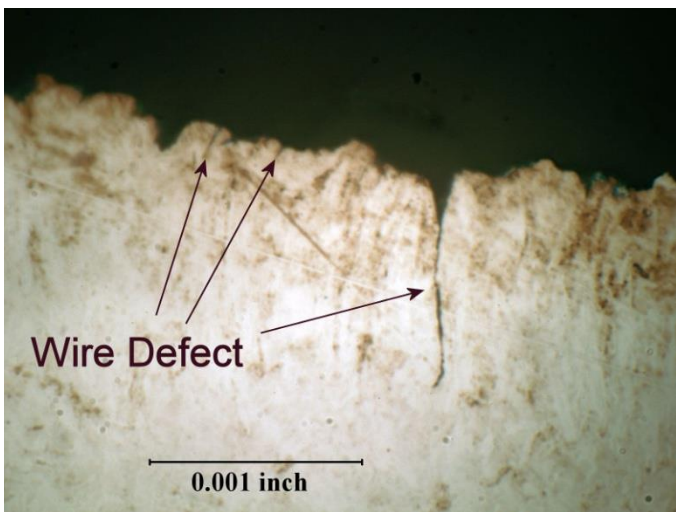

Figure 7 – 1500X Wire Defects – New Spring

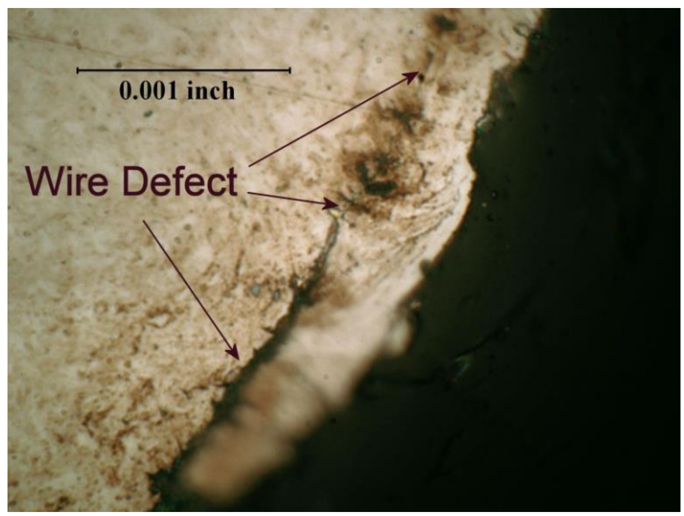

Figure 8 – 1500X Wire Defects – New Spring

Figure 7 shows three wire defects. The larger defect on the right was a compression crack. The lamellar microstructure running vertically at the surface indicates the wire was redrawn to the required 0.039 inch diameter size from a larger diameter wire, resulting in compression cracking at the surface.

Figure 8 shows highly sheared material on the wire surface. This shearing was likely caused during the redrawing operation. The shearing during redrawing was the cause of the white martensite.

The quantity and size of surface defects in this wire made the wire unsuitable for use as a spring. All springs made from this wire needed to be replaced. Premature failure in any spring made from this wire was highly likely.

Conclusions

1. The wire used to make the broken spring was determined to be defective due to the very large number of surface defects which rendered the wire unsuitable for springs.

2. The mostly likely cause of the wire defects was redrawing of the wire to the 0.039 inch diameter from a larger diameter.

3. All springs made from this wire had to be replaced.