Cautionary Tales Part XXII Ductility of spring wires

In response to questions from two spring manufacturers, I have been asked to discuss problems of formability of stainless steel spring wires.

In Cautionary Tale VIII figure 1 (repeated here) showed that the plastic deformation range (ductility) for hard drawn spring wires (carbon or stainless steel) is much reduced after stress relief heat treatment, and for this reason all severe forming operations are undertaken by the spring manufacturer before stress relief. However, the ductility of spring wires can be described in various ways, and figure 1 describes tensile ductility, which is very similar for both carbon and stainless steel. Another measure of ductility is the wrap test, applied to wires in the size range 0.3 – 3.0mm in which wire is wrapped eight times around itself, and again the ductility requirements are the same for carbon and stainless steel spring wire. It might reasonably be expected therefore that the torsional ductility of both wires would be similar, and sometimes it is, but the point of this cautionary tale is that sometimes it is not. Torsional ductility is usually measured by a twist to failure test such as that specified in ISO 7800, and for carbon steel and music wire at 2.0mm (0.078") 22 twists minimum is required for a gauge length of wire 100x its diameter (i.e. 200mm for 2.0mm wire). Carbon steel always passes this test and results of 30 – 35 twists are typical for this size of music wire – that is to say that a length of wire one hundred times its diameter can be twisted at least 22 times through 360° before it fractures, and when it does fracture there will be no splitting of the wire and the fracture will be at 90° to the axis. Oil tempered wire exhibits very good torsional ductility, albeit not quite so good as hard drawn carbon steel wire.

The torsion test is always missing from international specifications for stainless steel spring wire. The reason is that some wires behave in a similar way to carbon steel, but other wires do not twist evenly and they start twisting locally, as shown in figure 2. Recent tests at *IST* showed that local twisting occurs in 4.00mm and 0.50mm wires – the fractures were ductile and perpendicular to the wire axis as they would be if the wire had twisted evenly, but failure occurred at 2 - 10 twists compared with 20+ twists if the wire had twisted uniformly along its length. Usually in this column I try to give explanations, but in this instance I would be grateful if any reader could provide an explanation of why stainless steel spring wire starts twisting locally as this is not understood at *IST.*

The practical importance of this observation to spring manufacturers is that they have to be careful when forming stainless steel springs to avoid this local torsioning – lifting end hooks on extension springs is one operation in which great care is required with stainless steel. In forming end hooks, or making any other sharp bends that are in a different direction to previous wire forming processes, the wire should be plastically deformed in bending, or twisted as uniformly as possible. If local torsioning occurs and the spring manufacturer doesn't notice, his customer certainly will when the spring fails on assembly.

In order to try and learn more about this subject *IST* have tried stress relieving wires to see how this affects the number of twists to failure. As expected, carbon steel gave just less than half the number of twists when stress relieved at 250°C (380°F), and examination of the wires after test showed that there was additional twisting at the point of failure. Stainless steel wires that gave only three twists did not improve if they were stress relieved at 450°C (840°F), but stainless steel wires that gave more than 20 twists before stress relief, only gave three twists after. So it is clear that torsional ductility is reduced by stress relief heat treatment, but it is still not clear why stainless steel shows local torsioning to a much more marked extent than carbon steel does,

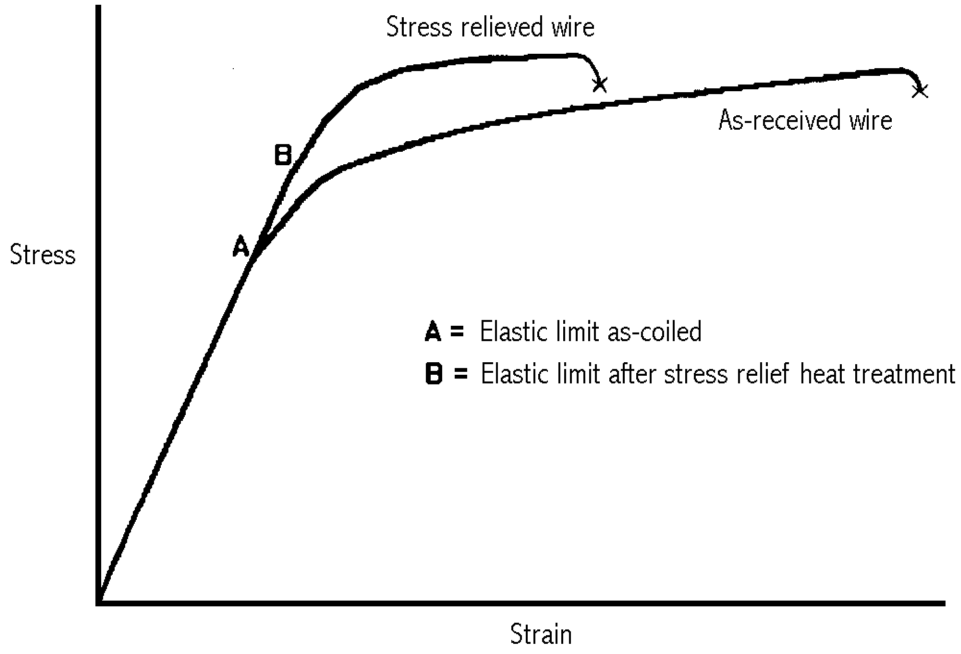

Figure 1: This tensile test diagram shows the benefits of strain age hardening, which raises the elastic limit of the carbon or stainless spring steel, but reduces the tensile ductility.

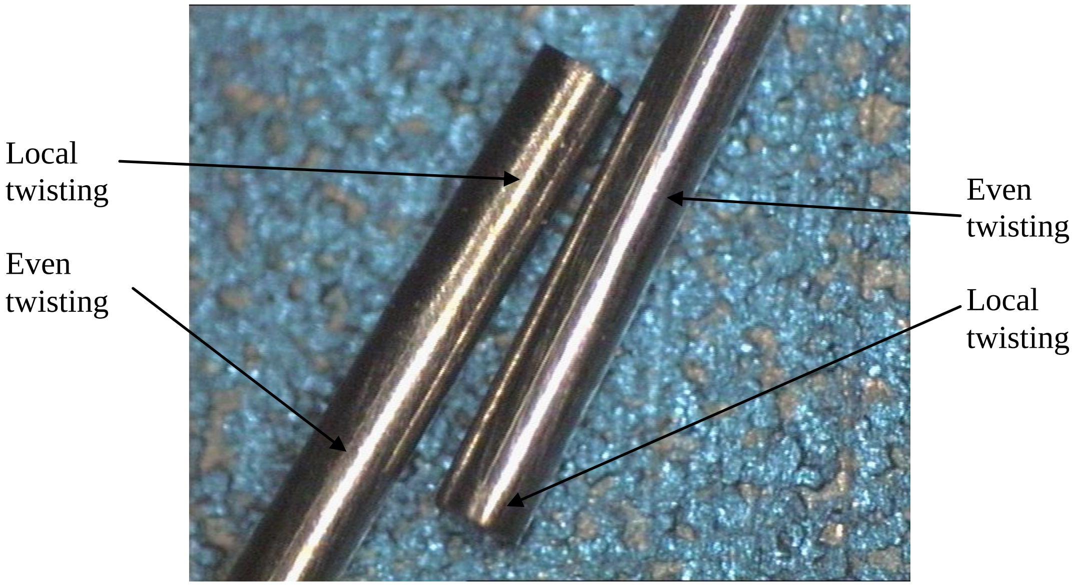

Figure 2 x 25

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Readers are encouraged to contact him with comments about this cautionary tale, and with subjects that they would like to be addressed in future tales, by telephone at (011) 44 114 252 7984 (direct dial), fax (011) 44 114 2527997 or e-mail at m.hayes@ist.org.uk.