Cautionary Tales
Part VIII, Heat Treatment – Stress Relief
By Mark Hayes

Having discussed 'Harden and temper' and 'Austemper' heat treatment processes in the last two Cautionary Tales, I will now deal with the low-temperature heat treatment that spring manufacturers apply to nearly all their cold-formed springs after forming – a process often called "stress relief."

The first word of caution that is immediately necessary is that stress-relief heat treatment is an understatement of what happens during this process. When a springmaker makes an ordinary compression spring out of hard-drawn carbon steel, such as ASTM A227 wire, it is coiled and then put in an in-line or batch oven at a temperature of about 260°C (500°F). What happens? The outside diameter decreases (by a predictable amount), and so it is imagined that this dimensional change is a manifestation of the reduction in residual stress from the cold-forming process – hence "stress relief."

However, more is happening than this. Without this heat treatment, the dimensions of the as-coiled spring would not be stable. The outside diameter would reduce with time, but after the stress-relief heat treatment, the spring dimensions will be very stable. "Dimensional stabilization" heat treatment would be quite a mouthful as a descriptor of this process, but it is an equally valid way of thinking of it.

But that is not all. A third, and equally important, change is happening during the stress-relief heat treatment. ASTM A227 wire, like many other grades of spring wire, exhibits a type of age hardening called "strain age hardening," and this is also effected during the stress-relief heat treatment. This strain age hardening occurs in A227 wire (and all other grades of carbon spring steel) at any temperature above 200°C (400°F). It has the effect of raising the elastic limit of the wire, which is clearly beneficial, as shown in the simple tensile test diagram in Figure 1, page 00.

So it is now clear that stress-relief heat treatment does three things:

- Reduces (not eliminates) residual stress from forming
- Stabilizes spring dimensions
- Causes age hardening

The second word of caution concerns 302 stainless steel. All three aspects of stress-relief heat treatment are valid for this type of spring material: Forming stresses are relieved, dimensions are stabilized, and strain age hardening occurs. However, springmakers will know that 302 stainless does not behave exactly like carbon steel – the outside diameter of springs increases (by a reasonably predictable amount).

Why is this? One would expect that relief of forming stresses would cause the same direction of movement in the two materials, but it does not. This is because a fourth thing occurs when stress relieving 302 stainless steel springs – namely the transformation of the strained austenite to martensite. Type 302 stainless steel wire or strip is always a mixture of strained austenite and martensite (the martensite giving rise to its magnetism) when received by the springmaker. However, the spring forming strains more of the remaining austenite in the structure and, as this structure transforms to martensite, particularly at the inside surface of a bend, there is a volume expansion. That is what causes springs in this grade to "grow" during stress-relief heat treatment.

The third word of caution relates to the time and temperature advised for stress-relief heat treatment. For this heat treatment, it is the temperature that is more important than the time, unlike tempering where both are very important. The temperature advised for ASTM A227 wire is anywhere in the range of 200°C (400°F) to 370°C (700°F), and the required time is a few seconds up to an hour or two. How can this very wide range of conditions be acceptable? The strain age hardening occurs within a few seconds at these temperatures, and 200°C is sufficient to

relieve almost half of the forming stresses, whereas 370°C will relieve more than 90 percent of the forming stresses without softening the wire appreciably.

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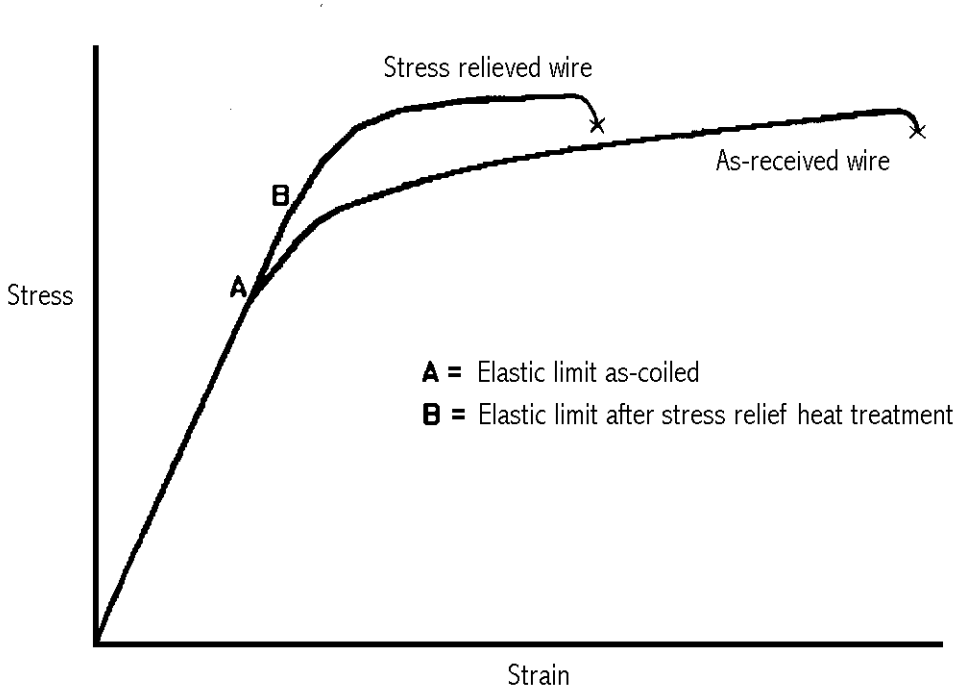

Figure 1: This tensile test diagram shows the benefits of strain age hardening, which raises the elastic limit of the carbon spring steel.