Cautionary Tale: Prestressing

By Mark Hayes

Prestressing is a process used by the spring industry that brings significant benefits to spring performance. Few other industries use the process. For this reason, it is a process that is not always fully understood.

Many springmakers may know that the process improves the available elastic deflection of the springs they make, but do not understand fully the mechanism behind this improvement. Springmaker's customers often understand even less, and question whether it is an essential process. The purpose of this cautionary tale is to explain some of the theory behind prestressing of compression springs, which will help springmakers and their customers understand the process and the benefits it brings.

Prestressing of compression springs is a process that involves loading the spring to a length that causes the free length to be reduced. After prestressing, the benefits accrued are

a) The elastic deflection range available is increased. Hence, the spring may be designed to a lower weight, usually by selecting smaller diameter wire.
b) The fatigue life will be improved.
c) The relaxation performance will also be improved.

Prestressing brings these benefits to compression springs by raising the torsional elastic limit of the wire and imparting a residual torsional stress into the surface of active coils. This torsional stress is in the opposite direction to the applied torsional stress when the spring is loaded.

How does it work? It is just the surface of the active coils that are improved – the core of the wire remains elastic and is unaffected. Recent European research (in which IST participated) has shown that the residual stresses can be measured accurately using X-ray methods. The magnitude of these residual compressive stresses at the inside surface are about 25 –30 percent of those resulting from shot peening.

Now we have enough information to explain the benefits, which are illustrated by the two Goodman diagrams below.

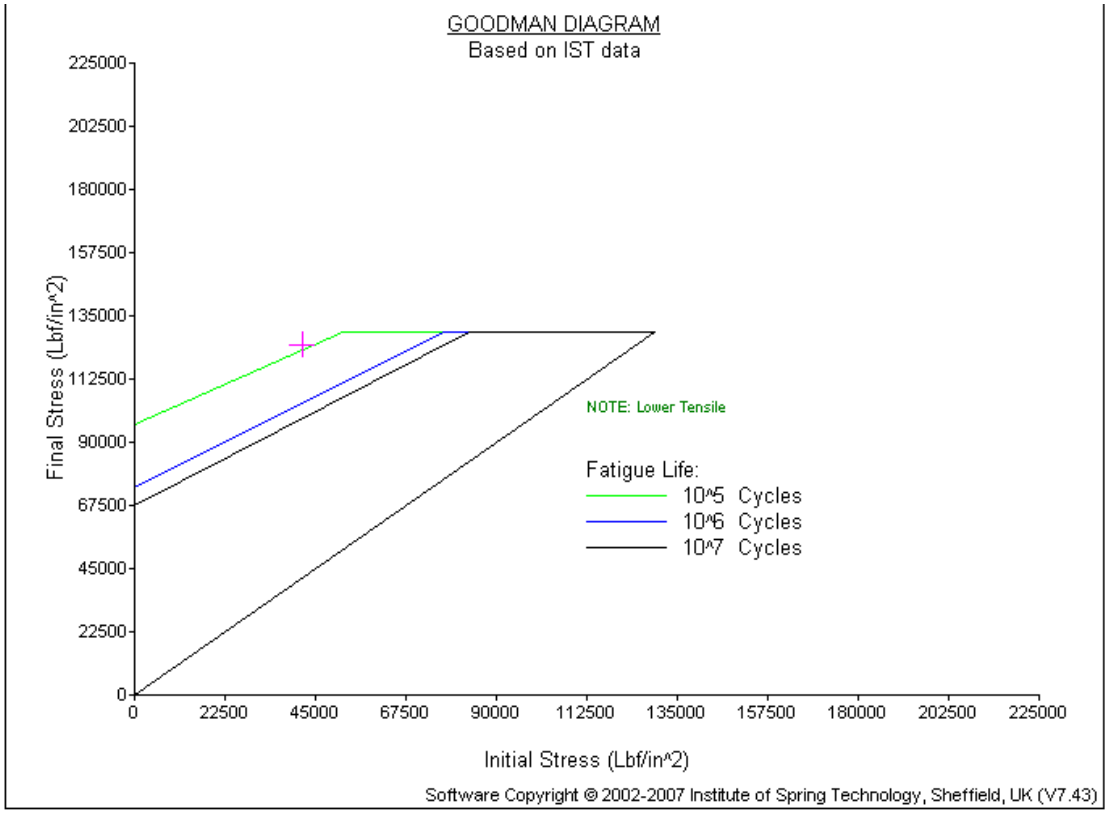

Diagram 1: Without prestressing the spring made from ASTM A228 music wire is at risk of fatigue failure after one hundred thousand cycles, and has a usable maximum stress of about 130ksi.

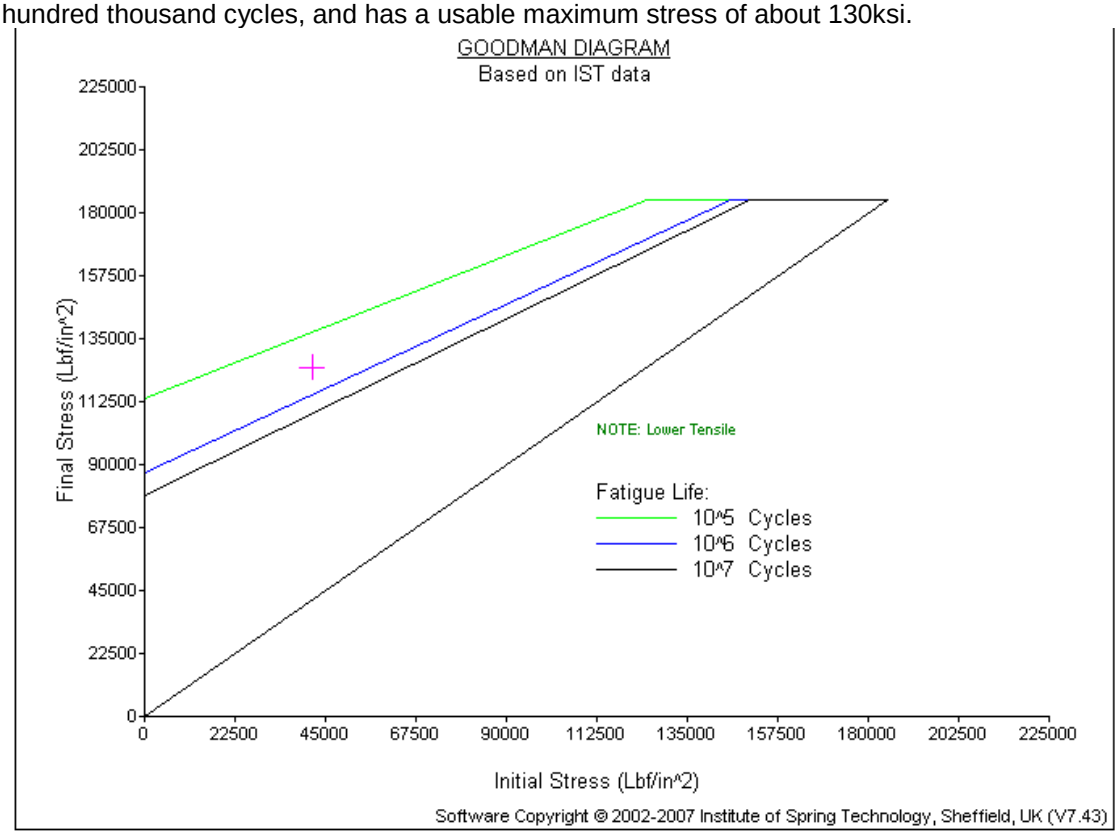

Diagram 2: With prestressing the same spring will be at risk of fatigue failure after a few hundred thousand cycles, and has a usable maximum stress of about 185ksi.

The relaxation performance estimated for these springs, stored at a stress of 85ksi and 100°C for one year, would be 5.5% without prestress and 4.25% with prestress. If the prestressing were done warm the relaxation predicted would be as little as 1.5%.

After this compelling argument in favor of prestressing, a word of caution is required. The smaller the spring, the more difficult and expensive it is to undertake the prestressing process. In addition, springs that buckle are difficult to prestress and are always a little “bent” afterwards.

Note that torsion bars, leaf springs and torsion springs can all be improved by prestressing.

Mark Hayes is the senior metallurgist at the Institute of Spring Technology (IST) in Sheffield, England. He manages IST's spring failure analysis service, and all metallurgical aspects of advice given by the Institute. He also gives the spring training courses that the Institute offers globally.

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. Contact Hayes at (011) 44 114 252 7984, fax (011) 44 114 2527997, or e-mail m.hayes@ist.org.uk.