**Cautionary Tale: Stainless Steel Heat Treatment**

During a recent training course given by the author on behalf of IST, a delegate asked many questions about the changing properties of 302 stainless steel spring wire during spring production at his factory. In particular, he wanted to know why stainless steel behaved differently from music wire. For instance, he knew that the outside diameter of music wire springs got smaller when heat treated, but stainless steel springs got larger. He had also been told to utilise a different value for the torsional modulus, G, for stainless steel after heat treatment, but the value of G was the same before and after heat treatment for music wire. He had been well informed, but wanted to know the reason why.

In another training course, several delegates were convinced that both their music wire and SiCr springs would have a different microstructure after heat treatment, and were keen to know how this change could be recognised. One of their automotive customers was requesting utilisation of CQI-9 quality procedure, which covers the stress relieving of springs, and demands that the metallographic structure produced be examined. Their company had the facilities to examine microstructures, which most spring manufacturers do not. However, they were surprised to hear that by means of optical metallography, the microstructure of music wire, SiCr and 302 stainless steel would be exactly the same before and after heat treatment. For this simple reason, it is IST's opinion that CQI-9 quality procedure should not be applied to stress relieving, but it is appropriate for spring manufacturers who carry out harden and temper or austemper heat treatments.

Returning to the subject of stress relief heat treatment of stainless steel springs, if the microstructure does not visibly alter, how can it be that the value of G changes? The value certainly does change, and there is very good guidance about the expected change in the European specification for stainless steel spring wire, EN10270-3. However, the values published in the appendix to this specification are approximate, and depend upon a number of factors. Despite being approximate, IST strongly recommend use of the values in this standard, as the best available, and good enough for spring design purposes.

When stainless steel spring wire is drawn, the microstructure starts off as austenite, but in every die a little of the austenite transforms to martensite. After several reductions in area, the wire will acquire the tensile strength required for springs, and the microstructure will be a mixture of austenite and martensite – the latter being the part that makes the wire magnetic. The spring manufacturer will coil this wire, and thereby impart a residual stress at the inside surface of the spring. When the spring is heat treated, some more of the austenite will transform to martensite, and this will occur most at the position where the residual stress is a maximum. There is a volume expansion associated with this transformation, which causes the spring diameter to become larger, but it might be expected that the microstructural change would be visible on optical metallography but IST's experience is that it is not. The percentage of austenite and martensite would be detectably by X-ray methods, but no-one knows what percentage would be satisfactory for spring performance, so there is no point in using these X-ray methods, which would be expensive.

It is also this change in the percentage of martensite in the structure that causes the moduli, E and G, to increase, for the stiffness of martensite is greater than that of austenite. This explains why 316 stainless steel spring wire has a lower modulus than 302, which itself is lower than 17/7PH – the last having the greatest percentage martensite, but all have a structure referred to austenitic. If the springmaker has made springs with a small coiling ratio (index), then there will be more residual stress, and consequently more transformation during heat treatment. The result will be that small index spring will have a higher modulus than similar springs, made from the same wire, with larger index.

The moral of this cautionary tale is that observations made by spring manufacturers about the behaviour of spring materials can nearly always be fully explained by the leading experts in this field of technology.

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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 - e-mail* m.hayes@springexpert.co.uk