<u>Cautionary Tale No. 2</u>

<u>Hydrogen Embrittlement</u> <u>~ Might your springs be at risk?</u>

The following quote is necessarily anonymous, but it has many authors from all over the world!

"I've been making this spring the same way for twenty years without any problems, but now you tell me that a few springs from the most recent batch I supplied have failed due to hydrogen embrittlement. How can this be when I haven't changed anything and nor has my plater?"

Hydrogen embrittlement is the most mis-understood failure mechanism in springs. There is a risk, often very small, that some springs will be susceptible to it. Despite this, *IST* purvey the philosophy that "if a spring manufacturing process route works well, then don't fix it", unless the small risk of failure is unacceptable to the end user, or you seek to achieve a continuous improvement in the quality of your products.

Hydrogen can arise due to the reaction of a strong acid with spring hard steel, or due to an electrolytic process. Examples used in the spring manufacturing industry include:

Cleaning in acid – hydrogen evolution is certain, but the risk is small if the acid is dilute and inhibited. Cleaning in an alkali or by a mechanical method are viable alternatives that give rise to zero risk.

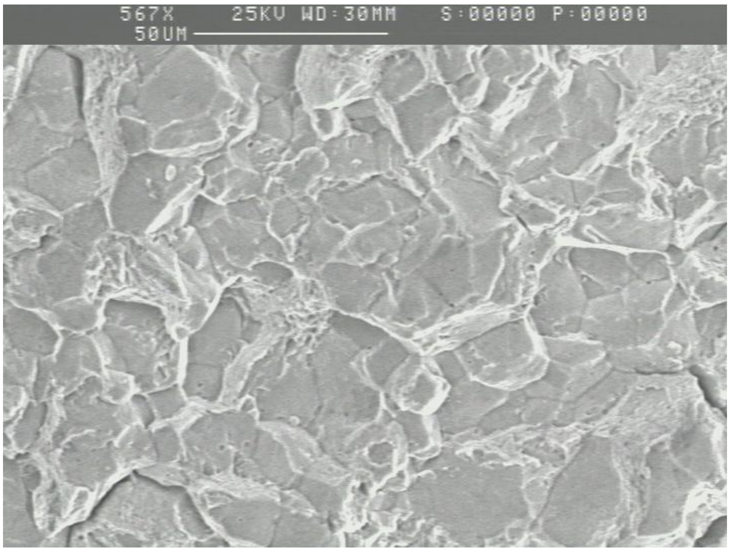
Phosphating – hydrogen evolution is certain, but the risk of embrittlement is small because a phosphate coating is porous to hydrogen. De-embrittlement heat treatment according to ISO9717 and/or avoidance of loading a spring soon after phosphating reduce the risk.

Electroplating and de-embrittlement – hydrogen evolution in electroplating is certain, but if de-embrittlement is carried out according to the rules given in ISO 9588, then the risk of embrittlement is small. Note that springs with a pearlitic microstructure (drawn carbon steel) or a bainitic structure (austempered) are at a much lower risk than steels with a tempered martensite structure. Electroplating silicon chromium steel, which has a tempered martensite microstructure, gives rise to such a high risk of hydrogen embrittlement that whatever the de-embrittlement treatment, *IST* have never seen a plated silicon chromium spring in one piece!

Corrosion of springs will only give a risk of hydrogen embrittlement if the corrosion occurs in acid conditions with limited access of oxygen (air).

It is certain that many springmakers will manufacture products that have a small risk of hydrogen embrittlement. Apply de-embrittlement rules carefully – if 4 hours de-embrittlement has been OK, but the rules say 18 hours, change to 18 hours and reduce your risk. Don't use a dip in 50% hydrochloric acid as the final stage of cleaning. Alkali or mechanically cleaned springs before coating in preference to acid cleaning, remember deembrittlement treatments do not drive away all your hydrogen – these treatments reduce the risk significantly, but the standards tell you clearly that they don't eliminate the risk.

Finally, some metallurgical labs will tell you that hydrogen embrittlement cannot be diagnosed for certain in failed springs or other components. In 98% of investigations, *IST* can give a clear diagnosis of hydrogen embrittlement. However, be aware that for every instance where *IST* are asked to confirm that hydrogen was the problem, almost half of the failures are shown to be fundamentally due to some other cause.



Scanning electron photograph showing an intergranular fracture due to hydrogen embrittlement – in this instance initiated by corrosion. Note the small proportion of ductile microvoid coalescence – the proportion of this ductile fracture mechanism usually increases as one moves away from the fracture origin in a hydrogen embrittlement failure. Note also the evidence of grain separation, another typical feature of this failure mechanism.