Cautionary Tale XXXVI Cleanness

There are a few international and company specifications for spring materials that have clauses specifying cleanness or freedom from non-metallic inclusions (sulphides, silicates, aluminas, oxides and titanium carbo-nitrides mostly). When I speak to steel making companies in some parts of the world, they ask me questions about how clean their steel needs to be, especially for suspension springs. My answer surprises most enquirers.

Based upon the premise that I hardly ever diagnose non-metallic particles as having any influence upon spring failures, I assert that cleanness does not matter. There are two notable exceptions to this premise. One is engine valve springs or similar high performance dynamic springs and the other is constant force springs. Engine valve springs do fail by inclusion initiated fatigue, and the inclusion is always 15 microns or greater and is usually between 150-450 microns below the shot peened wire surface.

Engine valve spring wire specifications might be expected to have clauses that limit the maximum size of inclusions near the surface of rod or wire. Commercial specifications do this, but no national or international specifications as yet - I am sure they will soon. Having written this, it was pointed out to me that the American specification for CrSi valve spring wire, ASTM A877, has a cleanness clause. Unfortunately this specification has limits for sulphide, silicate and oxide inclusions, which are most unlikely to affect spring fatigue performance, and permits occasional heavy alumina inclusions, which are the very ones that initiate fatigue failures in engine valve springs. Hence there are not yet any International specifications for valve spring wires that are effective.

Spring steel with very few inclusions near the wire surface, and almost none (absolutely none is as difficult as zero defects to achieve - keep trying but you won't ever succeed) greater than 15 microns is often called superclean. This does not mean that this type of wire has no inclusions - it has silicate inclusions (see Figure 1), which elongate, and are therefore below the critical size at which they might harm spring fatigue life.

The other type of spring that fails from inclusion initiated fatigue is constant force springs that are made from cold rolled pearlitic strip. For reasons that I don't understand, the raw material for this important class of springs is not covered at all in any national or international specifications. If this material were to be described in a specification, then a clause limiting the size and frequency of non-metallic inclusions would be appropriate.

Apart from engine valve and constant force spring specifications, it is my opinion that there is no need for a cleanness clause until such time as someone can demonstrate conclusively that inclusions have significantly influenced the risk of spring failure due to fatigue, corrosion, stress corrosion cracking, embrittlement…. To illustrate this opinion, IST recently tested a batch of 17/7PH springs. Now 17/7PH has more inclusions than any other grade of spring steel, as shown in Figure 2. The fatigue, relaxation and corrosion resistance of these springs was very good indeed.

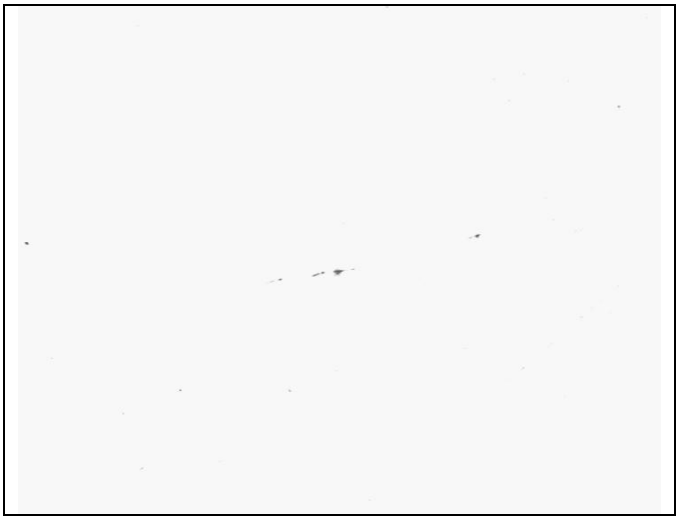

Figure 1 Superclean SiCr

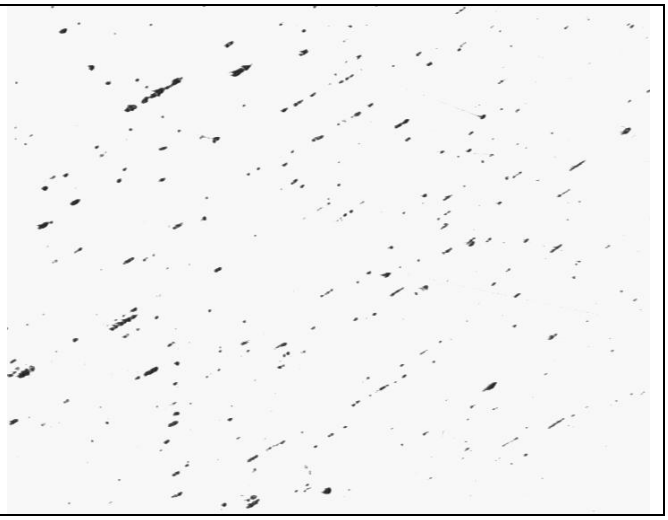

Figure 2 17/7PH

Both wires shown in Figures 1 and 2 meet the criteria of having no inclusions greater than 15 microns and so the springs made from them gave excellent performance.

High strength steels frequently have cleanness specifications in order to enhance fracture toughness and impact strength. In these circumstances cleanness should be specified, but for springs the impact strength does not matter. A correctly designed spring operates only in the elastic range. If it goes plastic it has failed - therefore impact strength of spring steels, which is often extremely low, need not be specified either. The moral of this tale is that cleanness clauses are only needed for springs made from valve quality wire and constant force springs, and then they should be of the type that limit the maximum size of inclusions at positions where the inclusions could do harm – at or just below the strip surface, or within 0.5 mm of the wire surface. And impact strength never needs to be specified.

One final word of caution. Cleanness is the term I have used - it is the correct term, but sometimes it appears as cleanliness - this is incorrect. Cleanliness is something IST test occasionally and it is very important for some applications. It involves washing springs and collecting any particles in filter paper then checking the size of the particles and whether they are magnetic. Cleanliness measures how clean the surface of a spring is, but cleanness measures the non-metallic particles contained within the steel.

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