Cautionary Tales Part XX

Wear

The problem of end coil fatigue failure was discussed in the last cautionary tale, but before fatigue occurs there is wear, if the failure occurs at the position where the end tip touches the first active coil. Wear will also occur whenever a spring is in moving contact with an adjacent component, such as in buckling compression springs that contact their guide rod (or tube), and in torsion springs that operate on a mandrel. Wear of a spring in service is unlikely to lead directly to a risk of failure, but it will affect the load/ deflection characteristic, and when it becomes severe, may cause abnormal stresses to be set up that lead to fatigue crack initiation.

There are three types of wear that may occur in springs, namely abrasive, fretting and adhesive wear, and the purpose of this article is to clarify the differences between these mechanisms, and to draw attention to circumstances when it might be significant to the end user, the spring manufacturer's customer.

Abrasive wear is the most common type and occurs when two surfaces contact with low to moderate applied forces, and some relative movement. The softer of the two materials in contact will generally wear more due to a rubbing action, but the harder material, usually the spring, will also wear to produce a flat abraded surface such as those shown in figures 1 and 2. A spring, made from round wire, will often be in line contact with a curved surface, and the wire from which the spring is made will wear quite quickly initially, but the wear rate will reduce as the contact area increases. This will cause a change in the frictional contact that a torsion spring makes with its mandrel for instance. The main risk associated with this type of wear is uneven loading of the coils of the spring leading to part of the spring having higher operating stresses than calculated, and loss of section in part of the spring, again leading to abnormally high stresses local to the wear. Thus wear can lead to fatigue failure, corrosion fatigue, or stress corrosion cracking (if a corrosion protective coating had been worn or abraded away).

Fretting can also be a type of abrasive wear, but when the product of the wear process is an oxide, and this gets trapped between the two wearing surfaces, the oxide acts as an abrasive powder and accelerates the rate of wear. For carbon steel, low alloy steel and stainless steel springs the oxide has a distinctive red-brown colouration, and is often mistaken for rust. For titanium alloys the oxide is particularly abrasive. The main risk associated with this type of wear, additional to that described under abrasive wear, is the fretting can lead to the build up of significant residual stresses close to the wear zone and these stresses are additive to the applied stresses and can result in fatigue failure.

Adhesive wear occurs after an abrasive wear zone has been created, and involves adhesion between the two wear surfaces. If the adhesive bond between the two surfaces is strong enough, then the wear process may lead to particles being ripped from the wear surface, a typical surface being as shown in figure 3. It is easy to imagine how this type of wear will be potentially more severe in its effect upon spring performance than abrasive or fretting wear.

The moral of this cautionary tale is that, to reduce the risk of all types of wear, lubrication is very beneficial, but oil will not stop the wear process altogether. Fretting and adhesive wear have been known to cause failure of springs at high lives in designs that would normally be considered to have very high safety margins, particularly in springs made from wire sections in the size range 4 – 10mm diameter.

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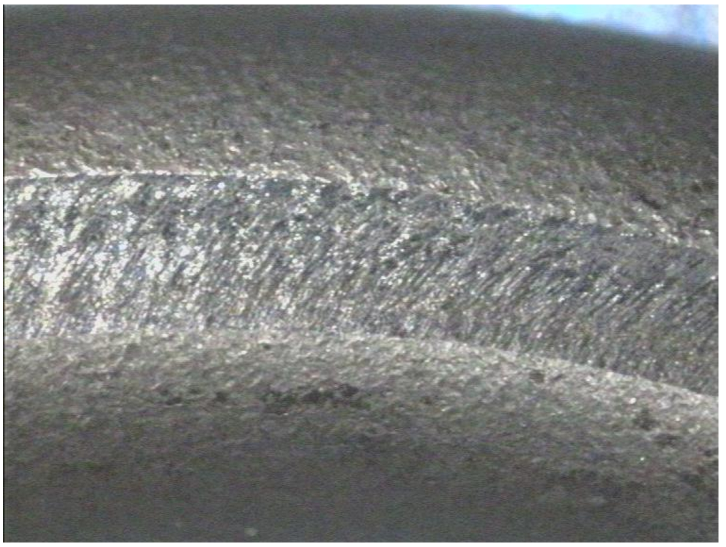

Figure 1 Abrasive wear between the first active coil and end coil. The abrasion is transverse at an angle of about 60° to the wire axis indicating that the end coil is moving in a lateral direction while in contact with the first active coil. The wear zone is smooth in topography.

Figure 2 Abrasive wear at the inside surface of a painted torsion spring where it had made contact with its mandrel. There is little red-brown discolouration in the wear, which is fretting oxide, which has formed despite the excellent lubrication of this spring, which failed due to an ordinary fatigue mechanism after 140 thousand cycles.

Figure 3 Severe adhesive wear that occurred between the end coil and first active coil of a spring made from 5mm diameter 17/7PH after two years of almost continuous service in a diesel engine. Note the rough topography and lumps that have been ripped from the wear surface and the cracks at the top of the photograph, which form prior to the ripping out.