Electronics Materials-Elastic, viscous and viscoelastic materials

An elastic material obeys Hooke's law which states, in its simplest form, that the extension or change in length of a piece of material is equal to the force applied multiplied by the elastic (or Young's) modulus. We have all done experiments with a spring to investigate Hooke's law; more and more weights are hung from the spring and if the weight is doubled then we find that the change in length has also doubled. However, the change in length is maintained only as long as the weights continue to hang from the spring and provide a force. When the weights are removed the spring oscillates for a while and then settles down again at its original length. A spring is a very good mental model of an elastic material in 1-dimension because the important thing about the response to stresses (or forces) by an elastic material is that the stress is maintained while the material is deformed. However, if the force applied to an elastic material is too great then the material will stretch beyond its elastic limit and will 'yield'. After yielding, the material will deform permanently - this is known as plastic deformation and is usually associated with breakage.

Some materials are viscous rather than elastic. When a force is applied to a viscous material the material does not stretch, it flows like a liquid. Most materials used in electronics don't flow as easily as water but at high temperatures can be a bit like extremely 'thick' (or viscous to give it a scientific name) syrup. The important thing about a viscous material is that when the force is removed it does not return to its original shape because the force has been 'used up' in the fluid flow. A good mental model of a viscous material is a dash-pot, in which a plunger is pushed through a liquid.

Many materials show viscoelastic behaviour. Figure 1 illustrates a mental model of 'series viscoelastic' behaviour; it is a series combination of a dashpot and a spring; the spring has elasticity, G, and the dash-pot has viscosity, η. When a force is applied across the combination, at first, the spring stretches. Later, however, the dash-pot will start to flow and the spring will gradually return to its original length. It takes some time for the material to respond fully to the force and, once it has responded fully, if the force is removed the material does not necessarily return to its original dimensions, since flow has occurred.

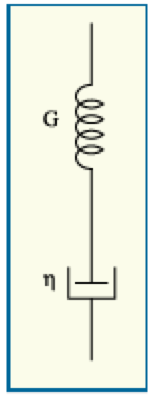

Figure 1: Series combination of dash-pot and spring – the series viscoelastic model

Figure 2 illustrates a second common mental model of a visco-elastic material. This is a parallel combination of a dash-pot and a spring. Again, the perfectly elastic spring has elasticity, G, and the dash-pot has viscosity η. When a force is applied across the material the spring stretches but, at the same time, the dash-pot flows. As the material flows and its length increases, its movement is impeded by the spring which provides an ever increasing restoring force to prevent flow. If the force is removed when the material has fully responded, the material will return to its original length. However, the return process will also be slowed down by the dashpot.

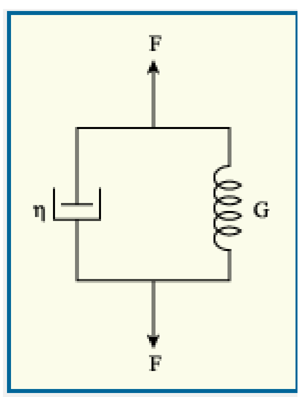

Figure 2: The parallel viscoelastic model

The series and parallel models are the 'building blocks' of descriptions of how materials respond to forces or stresses. However, many materials exhibit more complex behaviour which needs a large number of dash-pots and springs to describe it adequately. Elasticities and viscosities can also be temperature-dependent and sometimes vary with time and moisture content. For polymer materials elasticity and viscosity vary with precise composition.

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Source:
http://www.ami.ac.uk/courses/topics/0198_evvm/index.html