TECHNICAL TIDBITS
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Stressed Connectors Don't Need a Vacation!
– A discussion on stress relaxation and its effects on connector design

- **Elastic Strain**
- **Plastic Strain**
- **Creep**
- **Stress Relaxation**

The next issue of Technical Tidbits will discuss factors that influence stress relaxation in connectors.

Stress Relaxation and Creep

An electrical connector must maintain good contact force throughout the functional life of the product. Contact force is generated by the deflection of the electrical contacts within the connector (this deflection creates stresses in the metal which then generate the force). In order to remain effective, the contacts must return to their original position when the connector is disengaged (when the connector is unmated). This means that any stress and strain in the metal due to the deflection must be elastic (recoverable). If there is any plastic (unrecoverable) strain, the performance of the connector is diminished.

The key to good contact force is to achieve as high a stress as possible while ensuring that the strain remains elastic. This requires a material with an optimal combination of elastic modulus and yield strength. The relationship between strain and stress is described by the material's stress-strain curve. Figure 1 shows a loading and unloading cycle on a typical stress-strain curve. The permanent set, or plastic strain, is the area (A) on the horizontal axis between the loading and unloading line. However, if a contact is stressed to a certain point on the curve and held there for a long period of time at an elevated temperature, some of the **elastic strain** will convert to **plastic strain**. For example, a computer contact located next to the microprocessor may start to lose force over time. Therefore, even if the stress is well below the elastic limit on the stress-strain curve, some plastic deformation may occur.

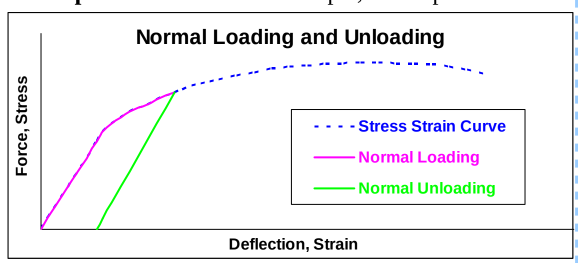

Figure 1. Typical Stress-Strain Curve

There are two similar, yet distinct, mechanisms by which the amount of plastic strain increases over time: creep and stress relaxation. The two terms are sometimes used interchangeably, although they are really different. **Creep** is an increase in plastic strain under constant stress. **Stress relaxation** is a decrease in stress under constant strain. Creep is rarely of importance in electrical contact design, although it can be an issue in the plastic housing into which most connectors are molded. However, creep is much easier to define and understand than stress relaxation. Furthermore, most finite element analysis software requires that stress relaxation be modeled using creep equations. Therefore, creep will be discussed first.

Creep is an increased tendency toward more strain and plastic deformation with no change in stress. Figure 2 shows a the stress-strain curve for a part undergoing creep. The material is stressed with an applied force. Over time, the force and stress do not change, although the shape of the part continuously deforms. When unloaded, there is additional permanent set. Old stained glass windows are thicker at the bottom than at the top. This is an example of creep under the constant force of gravity.

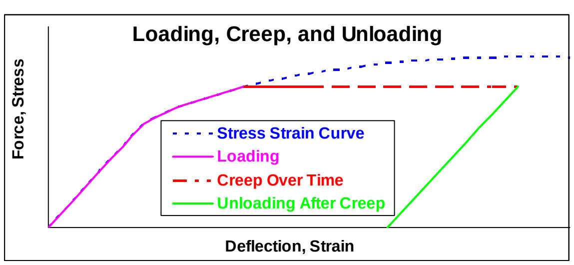

Figure 2. Stress-Strain Curve with Creep

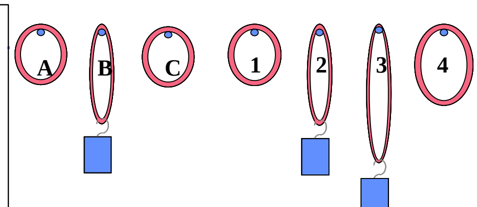

Figure 3. Creep Example

Stress Relaxation and Creep (continued)

A rubber band may be used to illustrate the principles of creep. Figure 3 shows a rubber band hanging from a pin at step A. In step B, a weight (applied force) is hung on the rubber band, creating stress and strain in the rubber band. The weight is removed quickly, and the rubber band returns to its original shape at point C, with no permanent set. The experiment is repeated and shown on the right side of Figure 5. In step 1, the rubber band is at its original position. A weight is applied in step 2, and the system is exposed to an elevated temperature for a long time. At step 3, creep has occurred, and the rubber band has stretched, even though the weight has not changed. The weight is removed at step 4, revealing some permanent deformation.

Stress relaxation is a decreased tendency for the material to return to its original shape when unloaded. Figure 4 shows the stress-strain curve for a material undergoing stress relaxation. Over time, the stress and force decrease, while the strain remains constant. It is important to note the part does not change shape during stress relaxation. When the applied deflection is removed the contact will only partially return to its original position. This means that unlike creep, stress relaxation is invisible, until the load is removed. The performance of the contact will steadily decline, with no visible effects.

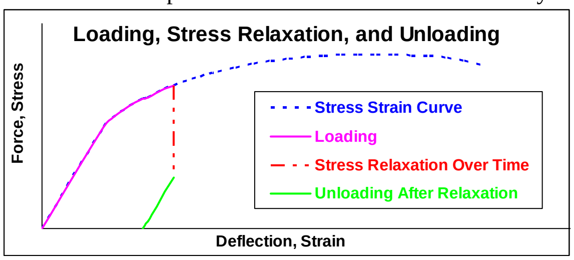

Figure 4. Stress-Strain Curve with Stress Relaxation

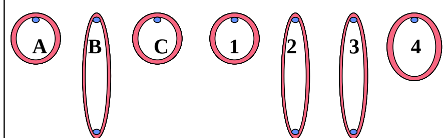

Figure 5. Stress Relaxation Example

Figure 5 shows the rubber band example again, this time used to illustrate the effects of stress relaxation. The rubber band is hung from a pin at step A. It is then stretched out over a second pin (applied deflection and strain) in step B. The second pin is removed quickly, and the band returns to its original shape at step C. The experiment is repeated, and the rubber band is hung at step 1, and stretched out at step 2. It remains stretched, and is exposed to an elevated temperature for a long time. Step 3 shows the rubber band after the exposure. There is no noticeable difference between steps 2 and 3. However, when the pin is removed at step 4, the permanent set becomes visible.

Any good connector design will have to take into account thermal effects on connector performance. This designed contact force must be increased to account for stress relaxation. Electrical connectors can be exposed to heat from automobile engines, computer processors, or even in cell phones left inside a car on a sunny day. Different materials will show different resistances to stress relaxation. In addition, most Finite Element Analysis packages account for creep only, and not for stress relaxation. Therefore, it is left to the connector designer to ensure good contact force through adequate overdesign, or through the use of high performance stress relaxation-resistant alloys like copper beryllium.

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