

**Return to Bender!** – A discussion on how materials tend to springback after being formed.

- **Elastic Springback**
- **Springback Ratio**

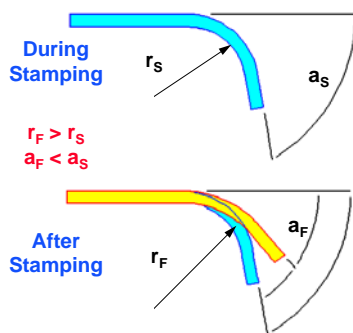
## Elastic Springback

When an electronic connector is formed, the base metal must be transformed from flat strip into a complicated, three dimensional part. This requires permanent deformation of the base metal. However, most connector materials are chosen due to their resistance to permanent deformation. Naturally, this tends to complicate the fabrication process. This conflict between manufacturability and required performance can best be seen in **elastic springback**.

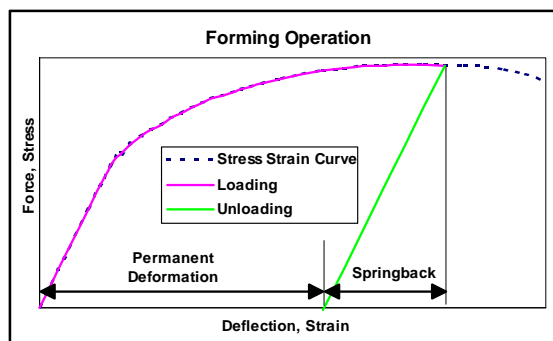
When a component is formed, the stamping tool bends the metal into a certain angle with a given bend radius. Once the tool is removed, the metal will spring back, widening the angle and increasing the radius. The **springback ratio** is defined as the final angle after springback divided by the initial stamping angle (Figure 1).

In order to understand springback, it is necessary to look at a material's stress-strain curve. When a bend is being formed, the material is deliberately over-stressed beyond the yield strength in order to induce a permanent deformation. When the load is removed, the stress will return to zero along a path parallel to the elastic modulus (Figure 2). Therefore, with some exceptions, the permanent deformation will usually be less than the designer-intended deformation of the strip. The springback will be equal to the amount of elastic strain recovered when the die is removed.

It is also important to note that the stress is highest at the top and bottom surfaces of the strip and falls to zero at the neutral axis of the bend, roughly in the middle of the strip. Therefore, most of the stress in the interior of the strip is elastic and only the outer surfaces undergo yielding. The interior of the strip would like to straighten out the bend when the load is removed while the outer edges tend to resist straightening. The bend will not return to a zero stress state, but instead will spring back to an equilibrium point where all internal stresses balance. This is why forming operations induce residual stress in the material.



**Figure 1.** Elastic Springback



**Figure 2.** Stress and Strain Response During Forming Operations

Several variables influence the amount of springback that is seen in a bend. A material with a higher yield strength will have a greater ratio of elastic to plastic strain, and will exhibit more springback than a material with a lower yield strength. On the other hand, a material with a higher elastic modulus will show less springback than a material with a lower elastic modulus. Figure 2 shows that the unloading stress-strain curve would be shifted toward less springback if it had a higher slope. In addition, the R/t ratio of the bend will come into play. A sharp bend will concentrate the stress more than a gradual bend, resulting in more plastic strain. Therefore, smaller R/t ratios will result in less springback.

*The next issue of Technical Tidbits will include an informative discussion on stress relaxation.*

**Elastic Springback (continued)**

There are several methods to deal with springback. The first is to experimentally determine how much tighter the forming bend must be made in order to allow the material to springback to the desired bend angle. Another mechanical solution is to coin the outside of the bend in order to introduce compressive stress on the outer fibers, which balance out the tensile stresses created during forming operations. At very small R/t ratios, this may even result in negative springback, where the final angle will be tighter than the stamped angle. However, this is a very severe forming operation, which may make the strip more likely to fracture during forming.

The four variables that affect springback can also be used in an effort to control it. For instance, a material with a high modulus may be used to reduce springback. This will also result in increased contact force. A lower yield strength material may be used, but will result in a lower performance connector, since the lower yield strength limits the amount of stress that the connector can withstand. Strip thickness may be adjusted. However, bear in mind that in this age of miniaturization, most connectors are progressing towards the use of thinner strip, which will result in more springback. A smaller bend radius can be used to reduce springback. This requires a material with better formability.

For any given application, springback must be experimentally determined. The following example may serve as a guide. The four variables which govern springback can be combined into a single, non-dimensional variable as shown in Figure 3. During a series of 90° V-block formability tests, the springback angle was measured for a number of common connector materials. The springback ratio of each test was plotted against the non-dimensional variable. For every spring connector alloy tested, the results all fell on the same curve. This means once the springback is calculated for several materials and R/t ratios, springback behavior can be extrapolated for any other connector alloy. A curve-fit regression equation for that curve is shown in Figure 3. Note: the equation shown is valid only for 90° V-block plane strain bend testing, and will not be representative of actual bends in the field.

Springback will occur in virtually every bend formed on a connector. It cannot be eliminated or predicted without experiment, but can be mitigated by careful material selection. For a new part configuration, trial and error is still necessary to determine how much springback will occur. If the bend is outside the specified tolerance, either the tool configuration or the material must be changed to bring the connector back in spec.

Increases Springback	Decreases Springback
Lower Modulus	Higher Modulus
Higher Strength	Lower Strength
Thinner Strip	Thicker Strip
Larger Bend Radius	Smaller Bend Radius

$$K = \frac{\alpha_{final}}{\alpha_{initial}} = -25.54 \cdot X^3 + 17.91 \cdot X^2 - 5.85 \cdot X + 1.08$$

$$\text{where } X = \left( \frac{\text{Yield Strength}}{\text{Elastic Modulus}} \right) \cdot \left( \frac{\text{Inside Bend Radius}}{\text{Strip Thickness}} \right)$$

**Table 1.** Variables Affecting Springback

**Figure 3.** 90°V-Bend Springback Prediction

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**Reference:**

Harkness, John C.  
“Prediction of Elastic Springback in Forming of Heat Treatable and Mill Hardened Tempers of Beryllium Copper Strip.”  
Proceedings of the 1989 ICIT Conference

Please contact your local sales representative for further information on springback or other questions pertaining to Brush Wellman or our products.

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