Springback / Springforward

Springback is defined as, the material angularly trying to return to its original shape after being bent; so, why does this happen? There are three basic reasons why Springback occurs in metal, plastic, etc. The first reason, displacement of molecules within the material and the second is stress and the third strain, where we begin.

Stress and Strain

As the material is bent, the inner region of the bend is compressed while the outer region is stretched. This means that the molecular density is greater on the inside of the bend than on the outer surface. This means that pressure will permanently deform the outer areas of the bend before it deforms the inner areas.

The diagram in Figure 2 shows the stress-strain properties and how those stresses and strains are affected by the different three different bending methods: Air forming, Bottom Bending and Coining

The Elastic zone is defined as: the material is moved, but not bent. When the Stress is released, the material will return to its original shape without any permanent deformation.

When enough force/penetration is applied, the material reaches its “Yield point” and permanent deformation of the metal begins to occur.

The Air Forming Zone shows that when the pressure from the press is exerted on the sheet, the metal begins to bend. In air forming, this region will “springback” slightly when released. Attempting to return back to its original shape. The amount of springback the material returns is a property of the metal and radius.

In common materials when the material thickness and the inside radius are equal, the spring back is usually 2° or less.

However, springback does increase dramatically as the inside radius of the bend increases in relationship to the material thickness.

During the “Bottom Bending Zone” process, the material contacts the bottom of the die, angularly over-bending an amount equal to the springback and then experiencing a brief stage of Negative Springback, also known as “Springforward” as the pressure is increased.

As the force continues to increase, the material enters the area known as the “Coining Zone” where for a brief moment it experience a second brief moment of over-bend before Springforward again occurs. Ultimately the SpringBack/Forward forces average out becoming the process we know as Coining.

With this process, the final product has no Springback remaining. A “coined” sheet metal part is one in which the...
punch tip penetrates the neutral axis while thinning the material at the point of bend and realigning the molecular structure of the material.

**Compensating For Springback**

While **Coining** is one way of compensating for Springback, it is typically not the best option and rarely used anymore.

**Bottom Bending** can be a viable option, offering a higher degree of control over the bend angle, but even this can prove a challenge due to the tonnage requirements.

**Air forming** when combined with a modern **CNC** press brake can offer a reasonably stable process. Still differences within sheets can still contribute to fluctuations in bent angles:

**Thickness, Grain Direction, Tensile, etc.**

To achieve a perfect bend it may be necessary to use some type of “Angle compensation” feedback mechanism. These systems use mechanical sensors, cameras or lasers to track Springback at the workpiece and then adjust the bend in real time for each piece.

Generally the best way to conquer springback, even in difficult materials such as stainless steel and some aluminums, is to calibrate the machines and/or each setup.

**Calculating Springback**

The springback factor, referred to here as “Sf”, is the relation between the beginning and ending angles. A springback factor of Sf=1 means there is no Springback and a value of 0 is the total Springback.

\[
Sf = \frac{\text{Beginning angle}}{\text{ending angle}}
\]

If you are looking for a 90° bend angle and you achieve 90° you have no springback; but if you are looking for a 90° bend and you achieve an 88° bend, you achieve 2° of springback.

\[
90° / 88° = \text{a springback factor of 1.022}
\]

When calculating the springback factor it is important to understand that the bend radius also has an effect.

As the inside radius increases in its relationship to the sheet thickness, springback also increases.

It should be noted the radius of the bend will also spring open a small amount in the same manner as the angle does.

This means the formed or forced radius will be slightly smaller than the final radius, coining excluded. These are the relationships used to determine a springback factor.

“Ir” equals the Inside bend radius

“Mt” the Material thickness

“Ar” the Actual radius
Springback Factor = \[ \frac{1}{2} \times \frac{2 \times Ir / Mt + 1}{2 \times Ar / Mt + 1} \]

You can take it much further by incorporating the yield stress and elastic modulus into your calculations. Basically, the higher “yield stress”, the greater Springback.

**slowed bottom**

**Designing with Springback**

It is important to understand the difference between the “bending angle” and the “bent angle” when discussing sheet metal. For example, when fabricating on the Press Brake, an operator will bend to the “bending angle”. Bending angularly past the required bend angle, compensating for the springback. Allowing the desired angle or “bend angle” to be attained when the part is released from pressure.

**Practical Springback**

The amount of springback differs depending on several factors:

- The harder a material is, the greater the springback will be. This is also known as the tensile strength.
- The sharper the punch is, the less springback there will be.
- The larger the die width is in air forming, the greater the number of degrees of springback because of the larger radius.
- The greater the bend radius is in relationship to the material, the greater the springback will be.

Using a one-to-one relationship between the material thickness and inside radius will yield a springback consistent with the natural springback of the material being formed. In which case, the following is basically true:

Stainless steel 2 to 3 degrees  
Mild aluminum 1.5 to 2 degrees  
Cold rolled steel .75 to 1.0 degree  
Hot rolled steel .50 to 1.0 degree  
Copper and brass .00 to .5 degree

The tensile strength of the material, type of tooling, and the type of bending greatly influence the amount of springback.

The yield strength of the material has a tremendous influence on the amount of springback that occurs during bending. The higher the yield strength is, the greater the amount of springback. Also notice how the amount of springback increases in proportion to an increase of bend radius, figure 5. This increase in springback is also directly proportional to a increased inside radius.

This should be taken into account every time there is a need to vary from the geometrically correct optimum V-die width. If air forming, the radius changes with the die opening.

Figure 6 demonstrates how bend angle affects the amount of springback across a range of material of the same thickness. Regardless of material type or strength, it will experience an increase of springback as the bend angle increases.

**Profound Radius and Springback**
As the inside bend radius increases to the point of becoming a **Profound radius** radius bend, a bend where the inside radius is equal to or greater than eight times the material thickness, you will see the springback start to increase at an ever increasing rate as the “radius bend” increases, figure 5.

Take the following example:

1. Mild steel with a thickness of .031 with a one-to-one relationship of radius to material thickness would have a springback of 1/2 to 1° of springback.

2. Mild steel with a thickness of .031 with a bend radius of 2.375 the springback increases to 30°.

Springback is a semi-predictable factor when working with sheet metal. Knowing how to predict sheet metal springback will allow you to make better tooling selections, especially in the area of the profound radius bends where this increase can and does exceed 40°.

The calculations, however, work rather well, whether a radius, or profound bend.

Cold rolled steel = 1/2 to 1 degree of springback
Cold rolled steel = .500 to 1 degree of springback
Mt. = .031 CRS
Rp. = .030 Actual calculated springback = .460
Degree of bend angle = 90°

As you can see .460 is not quite .500 (1/2 a degree) but it’s real close. You might want to refer back to the decimal degree conversion tables.

The springback for a bend radius of 20mm (.787 decimal) in a material thickness of 1.0mm (.039 decimal) would be 9°.

The formula is based on mild cold rolled steel, which has a factor of 1.0 and should work regardless of material thickness. Factors for other materials and circumstances allow this formula to work in almost all cases.

The degrees of springback can then be defined as: \[ D° = \frac{Rp}{Mt \times 2.1} \]

For example:

Mt. = .8
Rp. = 20
D = 90°

Degrees of springback = 20 / (.8 * 2.1 )
Degrees of springback = 20 / 1.68
Degrees of springback = 11.904
This means that there is 11.9° of springback in this material to bend radius relationship. There are still more factors that will need to be taken into consideration when you are trying to predict springback. Both the tensile strength of the material will greatly influence the final amount of springback. Some Aluminums could have 1.5 times as much springback as that of the cold rolled steel we just calculated.

Softer and annealed metals such as brass or copper can have as little as 25% of springback from our sample.

Both the chart and the formulas are based on the air forming of cold rolled steel. If you are bottom bending, coining, or using a urethane, you need still to compensated for the springback.

By multiplying the calculated springback values from the formula presented above, by the following factors for material type, you will increase the accuracy when calculating the springback value.

To summarize these factors:

2.0 for stainless steel.
2.0 for a urethane or spring load backup.
.5 for aluminum.
1.0 for cold rolled steel.
.75 for hot rolled steel.
.50 for brass or copper (1/2 hard)

Rework the previous example using aluminum instead. Starting with the material thickness (Mt) of 1.0 mm (.039 imperial) and a bend radius of 20 mm (.787 decimal) and the formula would then read:

The degrees of Springback $D° = \frac{Rp}{(Mt + 2.1) \times 1.5} = 13.5°$
The degrees of Springback $D° = \frac{Rp}{(Mt + 2.1) \times 1.5} \times .667 = 9°$
The degrees of Springback (aluminum) $D° = 13.5°$
The degrees of Springback (aluminum with backup) $D° = 9°$