Positive spring back! In bending operation, the surface layers of the sheet in the bend area suffer maximum stresses. The outer layers of the bend region suffer tensile stress and inner layers suffer compressive stresses. The surface layers are first to reach the plastic state. However, even in severe bends, the layers very near to neutral section of sheet may remain elastic. On unloading the elastic deformation tries to recover, thus unbending the sheet by a small angle. This unbending is called as spring back.

Here $d_i > d_f$
and $R_i < R_f$

Bend allowance $(R_i + \frac{t}{2})d_i = (R_f + \frac{t}{2})d_f$

Thus springback factor

$$K_s = \frac{d_f}{d_i} = \frac{R_i + \frac{t}{2}}{R_f + \frac{t}{2}}$$

$$K_s = \left(\frac{R_i}{t} + 1\right) \left(\frac{R_f}{t} + 1\right)^{-1/2}$$

If $K_s = 0$, complete recovery
$K_s = 1$, no springback
Factors affecting the spring back

- Angle & bend
- Thickness of sheet
- Type of tooling
- Work-hardening characteristics of material

Minimization of spring back

1. By overbending the sheet so that on unloading the sheet recovers to the desired angle & bend.

2. By setting (compression) the material at the bend region so that the recovery is minimum.
Flange length

Outside setback = OR + thickness of sheet

Leg

Apex

Outside radius (OR)

Neutral Axis

Inside radius (IR)

Inside setback

Bend angle (B)

Offset of neutral axis to
When the sheet metal is put through the process of bending, the metal around the bend is deformed and stretched. As this happens, the part gains a small amount of total length.

The bend allowance is the arc length of bend as measured along the neutral axis.

\[
\text{Bend allowance} = \frac{\pi}{180} \times B \times (IR \times K \times t)
\]

where:
- \( B \) = Bend angle in degrees
- \( IR \) = Inside radius of bend
- \( t \) = Material thickness
- \( t_o \) = Neutral axis offset

\( K = K \text{ factor} = \frac{t_o}{t} \) can be selected from the table

\[0.3 \leq K \leq 0.5\]

\[
\text{Bend deduction} = 2 \times \text{Outside setback} - \text{Bend allowance}
\]
Bend Radius or IR (Inside Radius) → May be given or we may be free to select.
If we are free to select, then following points must be considered:
- The geometry of fit
- Tool (punch and die for bending)
- Minimum safe bending

By minimum safe bending chart

Minimum bend radius (IR)

IR = 2t to 5t for plain carbon steel
= t for stainless steel
= 2t to 3.5t for Ti alloys
= 0.3t to 0.15t for brass
= 0.35t for Al alloys
## K factor values

<table>
<thead>
<tr>
<th>Sheet material</th>
<th>K values when IR &lt; 2t</th>
<th>K values when IR ≥ 2t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mild steel</td>
<td>0.2t</td>
<td>0.33t</td>
</tr>
<tr>
<td>a) Edge bending</td>
<td>0.33t</td>
<td>0.5t</td>
</tr>
<tr>
<td>b) V, U bending</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Soft copper, soft brass, soft and hard steel, half hard Aluminum</td>
<td>0.33t</td>
<td>0.5t</td>
</tr>
<tr>
<td>3. Hard copper, hard brass, hard steel and spring steel</td>
<td>0.5t</td>
<td>0.5t</td>
</tr>
<tr>
<td>4. Half hard copper, half hard brass, half hard steel, hard Al</td>
<td>0.4t</td>
<td>0.5t</td>
</tr>
</tbody>
</table>
BENDING FORCE (F)

For air bending

\[ F = \frac{RLST^2}{W} \]  
(R is die opening factor)

where, \( R = \)
- 1.33 when die opening \( \approx 8t \)
- 1.20 when die opening \( \approx 16t \)

\( L = \) Length of bent part (mm) (or width of the part)

\( S = \) Ultimate tensile strength of sheet metal (N/mm²)

\( t = \) Sheet thickness (mm)

\( W = \) Width between contact points on die

\[ W = R_1 + R_2 + C \]

= Punch corner radius (i.e. \( R_1 \)) + die corner radius (i.e. \( R_2 \))

+ clearance i.e. \( C \)

\( R = 0.67 \) for U or channel bending

\( R = 0.33 \) for single wiping bend
Determine the bending force for the sheet product as shown in figure. Assume \( S = 340 \text{ N/mm}^2 \). The bent length is 100 mm.

Setback 1 = 15 + 4 = 19 mm
Setback 2 = 19 mm + 8.9256 mm
Setback 3 = 8.9256 mm

Setback 2 = 80

\[
\text{leg}_1 = 50 - 19 = 31 \text{ mm}
\]
\[
\text{leg}_2 = 80 - 19 - 8.9256 = 52.0744 \text{ mm}
\]
\[
\text{leg}_3 = 45 - 8.9256 = 36.0744 \text{ mm}
\]

Bend allowance for bend 1
\[
BA_1 = \frac{\pi}{180} \times 2 \times (IR \times \pi \times K \times t)
\]
\[
= \frac{\pi}{2} (15 + 0.33 \times 4)
\]
\[
= 25.6354 \text{ mm}
\]

Bend allowance for bend 2
\[
BA_2 = \frac{\pi}{180} \times 45 \times (12 + 0.33 \times 4)
\]
\[
= 20.9224 \text{ mm}
\]

Length of the blank for the product = \( \text{leg}_1 + BA_1 + \text{leg}_2 + BA_2 + \text{leg}_3 \)
\[
= 31 + 25.6354 + 52.0744 + 20.9224 + 36.0744
\]
\[
= 167.7066 \text{ mm}
\]
Bending force calculation

\[ F = \frac{RLSt^2}{W} \]

Assuming due opening of 16t, hence \(R + 2\)

\[ R = 0.33 \]
\[ L = 180 \text{ mm} \]
\[ S = 340 \text{ mm}^2 \]
\[ t = 4 \text{ mm} \]

\[ W = R_1 + R_2 + c \]

for bend 1 \( W = 15 + 15 + 4 = 34 \text{ mm} \)

for bend 2 \( W = 12 + 12 + 4 = 28 \text{ mm} \)

Bending force = Bending force for bend 1 + Bending force for bend 2

\[ = \frac{0.33 \times 180 \times 340 \times 4^2}{34} + \frac{0.33 \times 100 \times 240 \times 4^2}{28} \]

\[ = 5280 + 6411 \]

\[ \approx 11691.42 \text{ N} \]

\[ \approx 11.69 \text{ kN} \]