Bending Sheetmetal in My Brake, Version 1.2

By R. G. Sparber

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Overview

This article is based on notes taken while watching this informative video: https://www.youtube.com/watch?v=HemwD3NpKXk

I will present the steps needed to make one bend or two. Don't run screaming from the room, but the theory will follow. A tolerance analysis is performed next, which is essential to the design process. I close with a comparison with the numbers given in the video.

Contents

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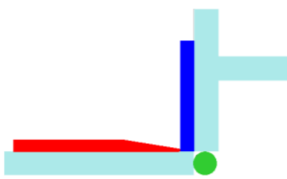
The Bend Process

Preparing to Bend

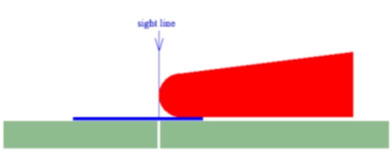
1. You will need at least three and at most twelve sample strips of the material you plan to bend.
2. Measure the **material thickness** (MT) using a micrometer or a caliper able to display at least to the nearest 0.001-inches.



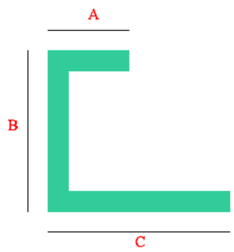
3. Set the fingers (in red), so when the apron is set vertically, the material to be bent (in dark blue) is a tight fit against the end of the finger.

4. Cut strips of the material about ½-inch wide and about 3-inches long. The sides must be parallel and the corners at 90°. The overall accuracy of your bends will depend on how well you prepare this sample. Deburr.

5. Blue the surface. Using a light touch with a scribe, draw a line across the strip about 1-inch from the end. Repeat on the other end. Do not cut into the metal with the scribe. The line's exact location is not important, but it must be perpendicular to the side.
6. Lay the strip on a flat surface and use your caliper to measure its length. Call this number the Over All Length (OAL).



7. Slide the short end of the strip under the finger of the brake such that the line barely shows. Clamp the finger and bend 90°. Repeat on the other end so that a "U" is formed.



8. Measure the length of one side of the U. Call this value “A.” Repeat for the other two sides and call them “B” and “C.”
9. Calculate *k:*

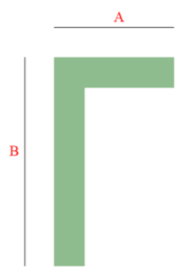
$$k = \frac{(A+B+C)-OAL}{2} \qquad (1)$$

where OAL is the Over All Length of the sample before bending.

10. Repeat the process at least twice[2] more to get a minimum and maximum *k*. This will tell you how much you can expect *k* to vary given this material and this brake. The more *k* values you collect, the more accurate will be its characterization.

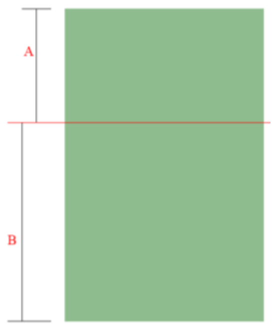
[2] It would be best if you ran 12 test strips, threw away the largest and smallest values of *k*, and then calculated the average, min and max.

A Single Bend



Look at a 90° bend from the side. The outside corner is called the **mold point**.

There are distances A and B from the mold point to the ends of the stock.

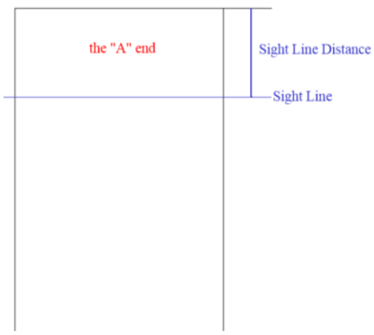


When viewed from the front, we see that the mold point is on the **mold point line**.

The needed **Over All Length** (OAL) of the stock is:

$$OAL_{needed} = A + B - k \quad (2)$$

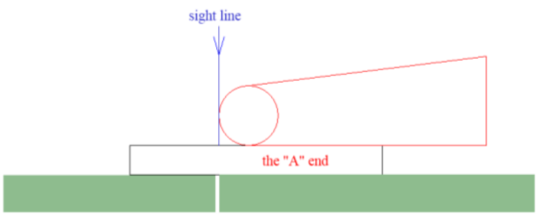
Where k is the average value measured with the process on page 2.



Assuming the "A" end will go under the brake's fingers,

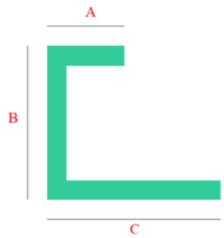
$$\textbf{Sight Line Distance} = A - material\ thickness \quad (3)$$

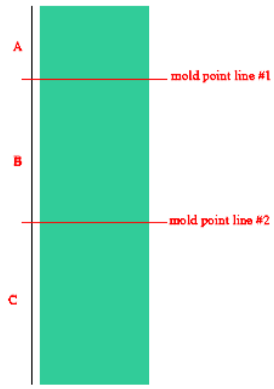
Blue the area and mark the **sight line** on the stock using a light touch with a scribe. Do not cut into the material because that can change how it bends.



Slide the "A" end of the stock under the fingers. Sight straight down at the end of the finger and adjust the stock, so the sight line is just visible. Clamp down the fingers and make the bend.

Two Bends



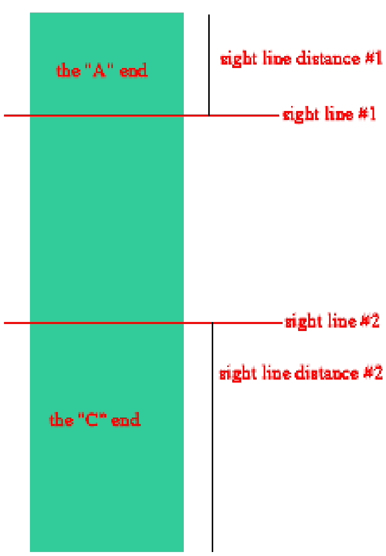


With two bends, there are three distances, A, B, and C, to the two mold point lines.

The needed Over All Length is:

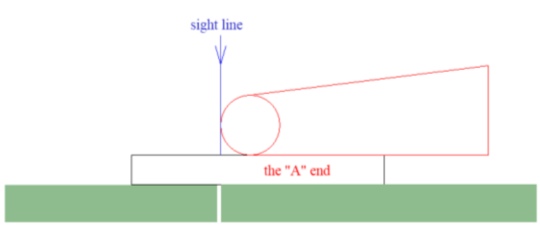
$$OAL_{needed} = A + B + C - 2k \quad (4)$$

Where k is the average value measured with the process on page 2.

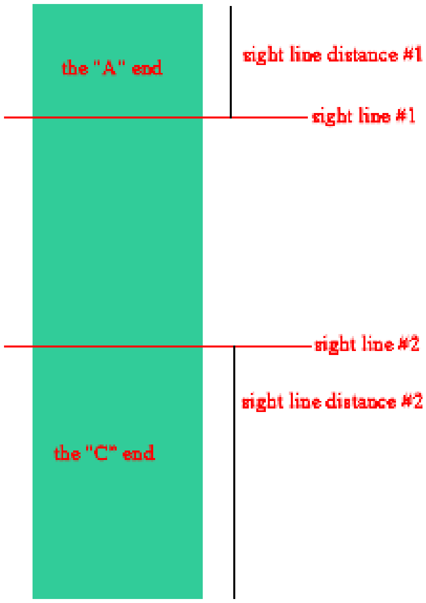


Assuming the "A" end will go under the brake's fingers first,

$$\text{sight line distance \#1} = A - material\ thickness \quad (5)$$



Slide the "A" end of the stock under the fingers. Sight straight down at the end of the finger and adjust the stock, so the sight line is just visible. Clamp down the fingers and make the bend.

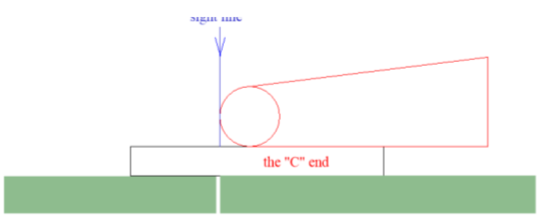


To form the second bend, define sight line distance #2:

The “C” end will go under the brake’s fingers.

$$\text{sight line distance \#2} = C - material\ thickness \quad (6)$$

Mark the sight line on the stock.

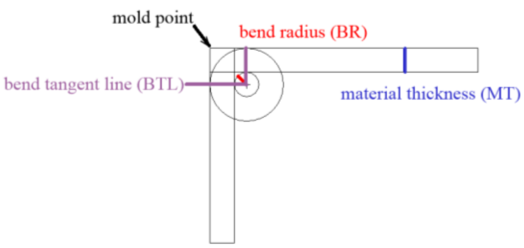


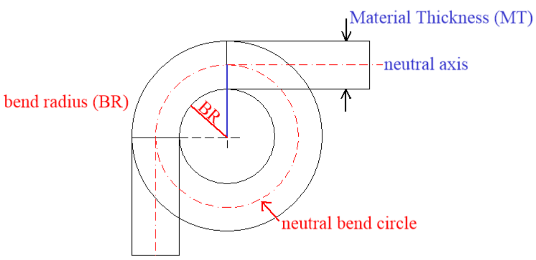
Slide the “C” end of the stock under the fingers. Sight straight down at the end of the fingers and adjust the stock, so sight line #2 is aligned. Clamp down the fingers and make the bend.

If you want to know why this works, read on.

The Theory
You can successfully bend sheet metal without knowing why it works. Understanding the logic behind the process will enable you to design parts.

Definition Of Terms





- Mold point – the ideal outside corner of the bend.
- Bend radius (BR) – the actual radius of the inside of the bend (that red line).
- Bend tangent line (BTL) – a horizontal or vertical line that terminates at the center of the bend radius.
- Material thickness (MT)
- Bend allowance (BA) – the material used to make the bend. It takes less material to make the actual bend than the idea, square, bend.
- Setback = bend radius + material thickness
- neutral axis – the line that does does not distort[3] through the bend (not exactly the centerline)
- Neutral bend circle – the circle aligned with the neutral axis

[3] The material stretches on the outside of the bend and compresses on the inside of the bend.

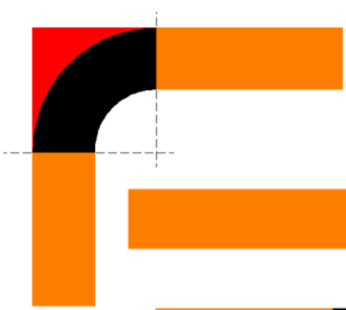
Bend Allowance

If you could make a sharp 90° bend, no material would be used in the bend.

The pre-bent material would have nothing between the tan and black areas.

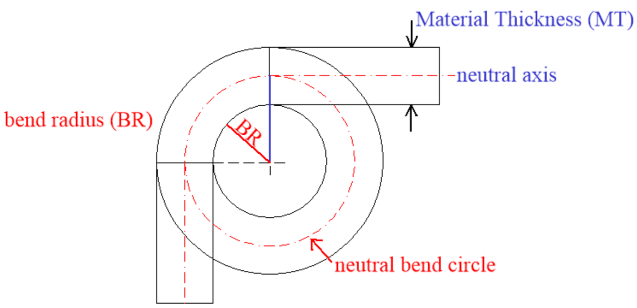
A practical bend includes a radius. If you tried to make a sharp 90° bend, the metal would likely crack.

The pre-bent material would have this black area which is formed into the bend. This black area is our bend allowance.

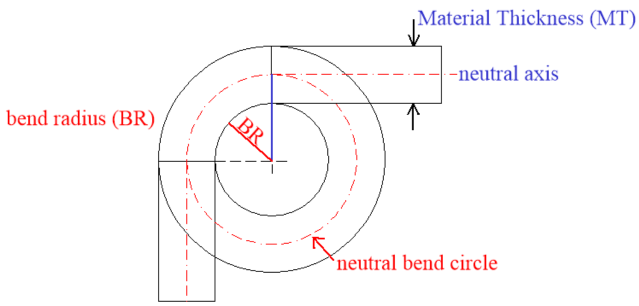


A sharp 90° bend means that the material must go all the way to the corner while the radius bend “cheats” the corner. Therefore, we use less material in the radiused bend than in the sharp corner.

The length of the pre-bent material, as defined by the mold point, must be reduced as we convert this sharp bend to a radius.



In the bend, the outside surface is stretched while the inside surface is compressed. Only along the neutral axis and the neutral bend circle is there no distortion.



The bend allowance (BA) is ¼ of the circumference of the neutral bend circle. If the neutral axis was at the centerline (i.e., ½ of the material thickness), the circumference (C) would be:

$$C = 2\pi(r)$$
$$C = 2\pi\left(BR + \frac{1}{2}MT\right)$$

Then, bend allowance, BA, is

$$BA = \frac{C}{4}$$

so

$$BA = \frac{2\pi}{4}\left(BR + \frac{1}{2}MT\right) \quad (7)$$

$$BA = \frac{2\pi}{4}\left(BR + \frac{1}{2}MT\right) \quad (7) \quad \textit{repeated}$$

$$BA = \frac{2\pi}{4}(BR + 0.5MT)$$

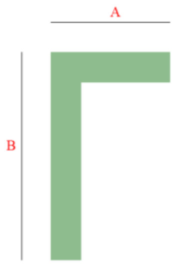
According to the Machinery's Handbook, the average neutral axis is 0.447 times the material thickness rather than 0.5, so we get

$$BA = \frac{2\pi}{4}(BR + 0.447MT)$$

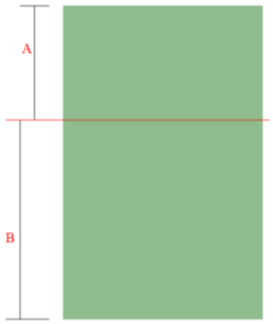
$$BA = 1.571BR + 0.702MT \quad (8)$$

This means that for each bend, we must reduce the overall length of the material as defined by the mold points by BA, as shown in (8).

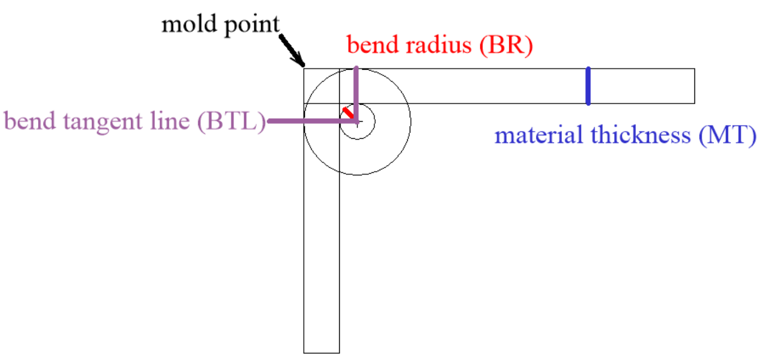
A Single Bend



The distance from the one end of the stock to the mold point is A, and the distance from the mold point to the other end is B.

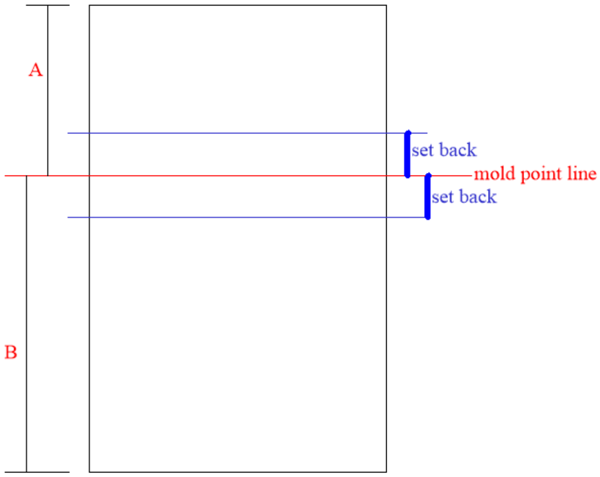


This is drawn on the flat stock.



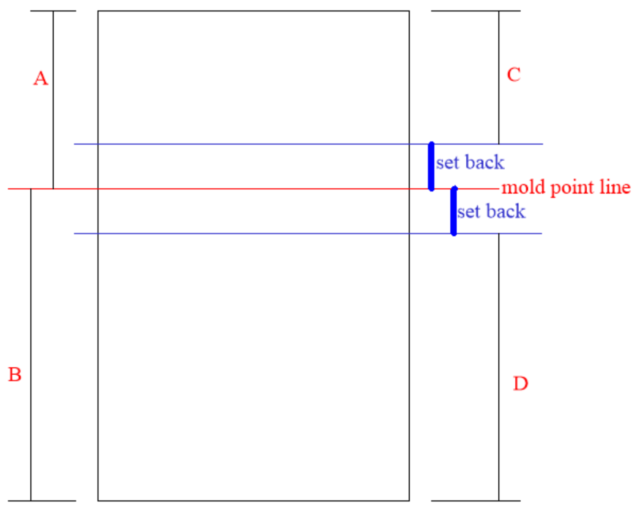
The set back (SB) is the distance from the mold point to the start of the bend, the bend tangent line (BTL).

$$SB = BR + MT \qquad (9)$$



Set back lines are marked on the stock.

$$SB = BR + MT \quad (9) \ \ repeated$$



Dimensions A and B are reduced by the set back to produce C and D.

C = A – SB (10)

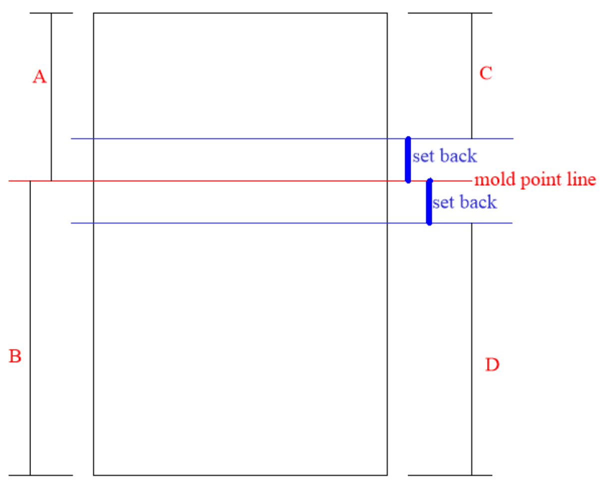
D = B – SB (11)

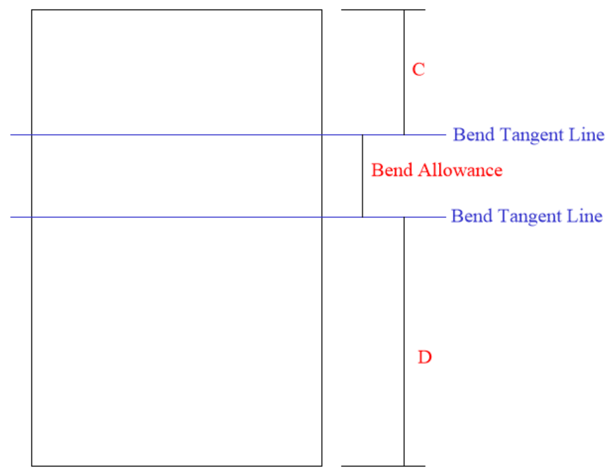
Plugging in (9) into (10), we get

C = A – (BR + MT) (12)

Similarly, (9) into (11) yields

D = B – (BR + MT) (13)





With C and D established, we replace the set back and mold point lines with the Bend Allowance. Call the lines above and below the bend allowance **bend tangent lines**.

From page 9 we have

$$BA = 1.571BR + 0.702MT \quad (8)$$

The needed overall length (OAL) of the stock is then

$$OAL_{needed} = C + BA + D \quad (14)$$

Substituting for C, BA, and D we get

$$OAL_{needed} = \{A - (BR + MT)\} + \{1.571BR + 0.702MT\} + \{B - (BR + MT)\}$$

$$OAL_{needed} = A - 0.429BR - 1.298MT + B$$

Therefore, for a single bend, the needed Over All Length is:

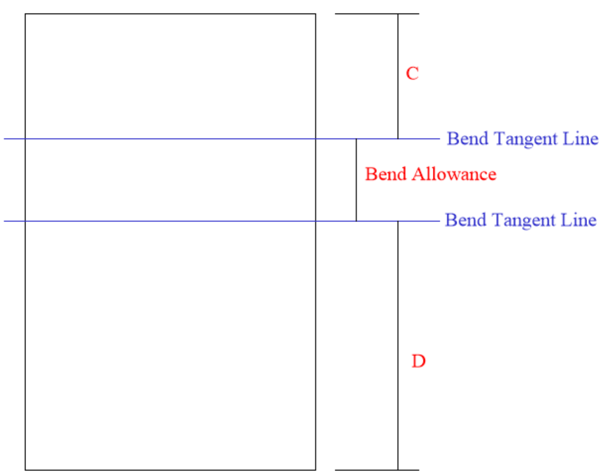
$$OAL_{needed} = A + B - k \quad (15)$$

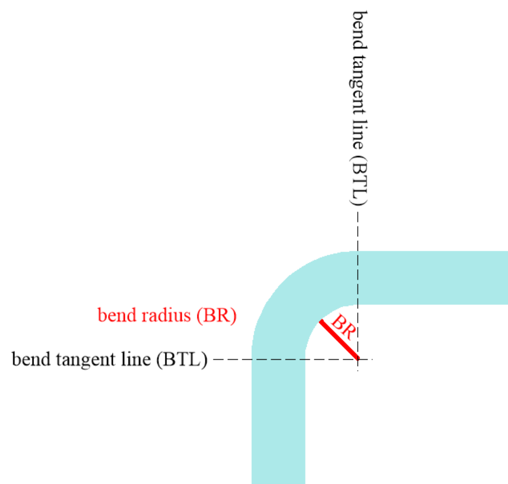
where

$$k = 0.429BR + 1.298MT \quad (16)$$

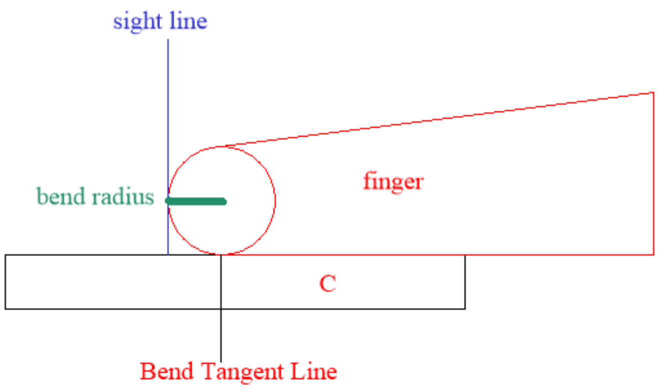
BR is the bend radius, and MT is the material thickness.

Next up is making the bend.

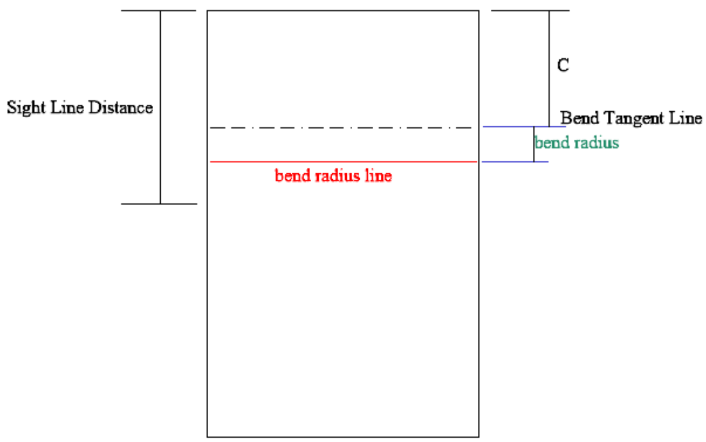




The material used in the bend is bounded by the bend tangent lines (BTL).



With the C area under the finger, I want to form the bending radius, which starts at its bend tangent line. That's nice, but I can't see the BTL since it is under the finger.

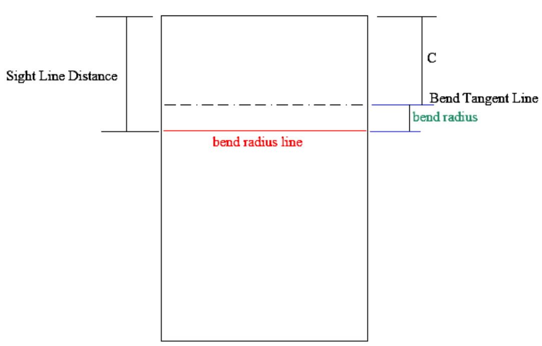


I can make a new line that is offset by the bend radius. Call this the **bend radius line**.

I will know that the BTL is aligned with the center of the bend circle when I can stand over the finger, sight down on the radius, and see the bend radius line.

Given that section C is under the finger, the sight line distance (SLD) is:

$$SLD = C + BR \quad (17)$$



Recall

C = A – (BR + MT) (12)

Plug (12) into (17) and we get

$$SLD = \{A - (BR + MT)\} + BR$$

Which, surprisingly, boils down to

$$\text{Sight Line Distance } = A - material\ thickness \quad (18)$$

Two Bends

Recall that for a single bend, the needed Over All Length is:

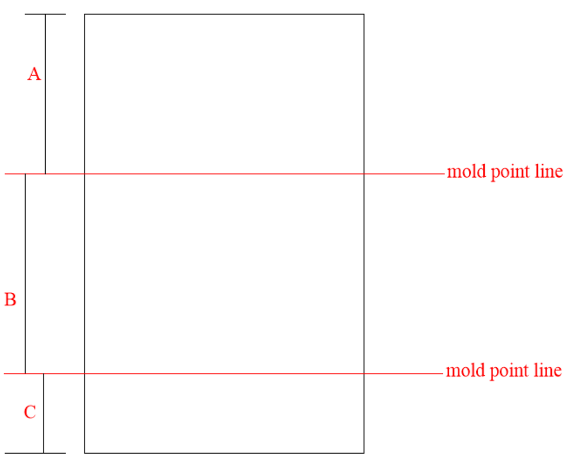
$$OAL_{needed} = A + B - k \quad (15)$$

where

$$k = 0.429BR + 1.298MT \quad (16)$$

BR is the bend radius, and MT is the material thickness.

(15) is saying that our needed OAL equals the ideal length shrunk by k for our single bend.



When we add the second bend between sections B and C, our OAL is increased by C and decreased by another k. We, therefore, have, for two bends:

$$OAL_{needed} = A + B + C - 2k \quad (19)$$

where

$$k = 0.429BR + 1.298MT \quad (16)$$

BR is the bend radius, and MT is the material thickness.

The sight line distance discussed on page 13 still applies when we put section C under the fingers.

Measuring Bend Radius? *k* is More Useful!

A commercial-grade brake has a well-controlled bending radius. My homemade brake isn't that solid. My bend radius is unknown plus varies with material thickness because the finger bends slightly when under pressure.

At first, I tried making a test bend and then using a drill bit to gage the BR. That wasn't accurate enough. Then I turned to the equations and realized that the answer was there.

$$OAL_{needed} = A + B + C - 2k \quad (19)$$

where

$$k = 0.429BR + 1.298MT \quad (16)$$

If I measured the OAL, A, B, and C, I could use (19) to calculate k. To my surprise, the BR isn't involved.

$$k = \frac{(A+B+C)-OAL}{2} \qquad (1)$$

Tolerance Analysis

I have found that sheet metal is devilishly hard to cut accurately with the tools I have on hand. I can follow a precisely scribed line with my hand sheers ± 0.03-inches. My best effort is with my bandsaw, using fixtures. Then I can get within ±0.010-inches.

It is a fact that we can measure with more accuracy than we can cut. This is why I call for measuring test strips back on page 2 rather than cutting them to a specific length.

Consider the two central equations:

$$OAL_{needed} = A + B + C - 2k \quad (19)$$

A, B, and C are specified in the design, so they have no error. Our constant, *k*, depends on measuring four dimensions:

$$k = \frac{(A+B+C) - OAL}{2} \qquad (1)$$

Not as evident in this equation is that *k* will vary depending on how tight and ridged your brake is. Run enough test strips, and you will learn the average value for *k* plus how much it varies. My brake has a *k* of 0.051±0.004 when bending 26 gauge galvanized steel sheet.

The hardest part to get right is cutting the Over All Length.

Calculating the sight line distance is the most accurate part of the process because A, or C, is from the design, so it is exact. Material thickness is easily measured with a caliper or mic.

$$\text{Sight Line Distance } = A - material\ thickness \quad (18)$$

The hardest part is to scribe the line and then to position it accurately under the finger.

$$OAL_{needed} = A + B + C - 2k \quad (19)$$

$$\text{Sight Line Distance } = A - material\ thickness \quad (18)$$

My design process uses the average value for *k*, so its error will be centered.

I plug in my chosen values of A, B, and C and get out the OAL.

The challenge is to bracket what I will measure when done with the bending. To do this, I built an Excel spreadsheet. The user specifies their expected SLD tolerance plus OAL tolerance. Then the spreadsheet calculates the worst-case minimum and maximum anticipated B values.

Design Equations with average k and SLD			
needed A	1.000	average BR=	0.059
needed B	1.000	average k =	0.051
needed C	1.000	min . K =	0.047
needed OAL =	2.898	max. K =	0.055
set SLD1 =	0.980	SLD tolerance =	0.0200
set SLD2 =	0.980	OAL tolerance =	0.0200

Estimate max OAL, A & C; min B		Estimate min OAL, A & C; max B	
OAL =	2.878	OAL =	2.918
SLD1 =	1.000	SLD1 =	0.960
SLD2 =	1.000	SLD2 =	0.960
est A =	1.020	est A =	0.980
est C =	1.020	est C =	0.980
est B =	0.931	est B =	1.067

In this example, I want to bend up a U that is 1-inch on a side. The material is 0.020-inches thick. Based on experience, I set my SLD and OAL tolerance to be ±0.02-inches.

The result is that I should be able to cut the OAL to between 2.878 and 2.918-inches.

A and C should be between 0.980 and 1.020-inches. B is between 0.931 and 1.027-inches.

Bench Test

Using the above data, I tried to cut a strip of sheet metal 2.898-inches long. I got an OAL of 2.8825-inches. After bending, I measured A at 1.0145-inches, and C came in a 1.014-inches. B measured 0.956-inches. All of these values are within the predicted range.

If I could achieve a SLD and OAL tolerance of 0.005-inches, I can expect to be within 0.005-inches of the desired values for A and C and within 0.024-inches for B. To get tighter, I would need to reduce the variation in *k*.

You can find the spreadsheet at https//Rick.Sparber.org/BendingEquations.xlsx.

Compare My Equations to the Video

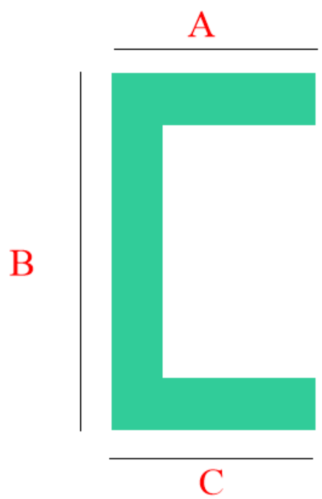
https://www.youtube.com/watch?v=HemwD3NpKXk

The presenter uses a bend radius of 0.125-inches and a material thickness of 0.040-inches.

$$OAL_{needed} = A + B + C - 2k \quad (19)$$

Where $k = (0.429 \times bend\ radius) + (1.298\ \times material\ thickness)$ (16)

$$k = (0.429 \times 0.125) + (1.298\ \times 0.040)$$
$$k = 0.106$$



A and C are equal to 1.5. B equals 4.5

$$OAL_{needed} = A + B + C - 2k \quad (19)$$
$$OAL_{needed} = 1.5 + 4.5 + 1.5 - (2\ x\ 0.106)$$
$OAL_{needed} = 5.789$, which is what the presenter calculated.

Acknowledgment
Thanks to Douglas Ripka for his insights, encouragement, and editorial assistance.

I welcome your comments and questions.

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