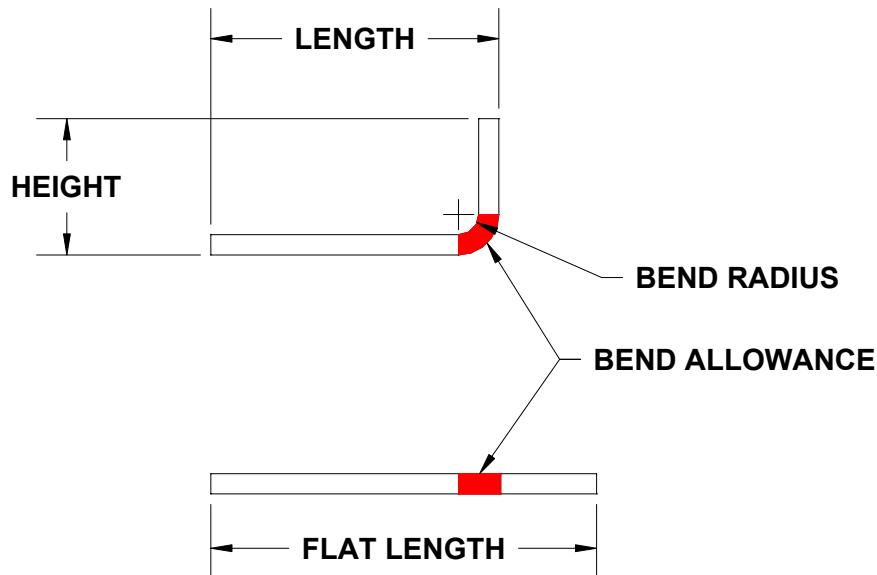


1. Introduction

Bend allowance is a term which describes how much material is needed between two panels to accommodate a given bend. Bend allowance, while being oftentimes tricky to determine for all cases, is fairly easy to predict and calculate for many standard circumstances. Determining bend allowance is commonly referred to as “Bend Development” or simply “Development”.



If in doubt, make a test piece.

Often bend allowances are calculated for a sheet metal part and used to make costly tooling or production parts that require a lot of labor to produce. A scrap tool or production run can be very costly, much more so that a test piece. So if you are ever not sure of your developed flat length, make a test piece (laser, turret or sheared piece) to confirm your development.

One of the easiest ways to make a test piece is to shear a piece to an exact length, and then form it using the exact process that will be used to create the part. After the part is formed, the part is measured and compared to the expected lengths and the bend allowance is adjusted as needed. Often times, when hard tools are produced, laser cut blanks are used to validate the forming tools and part development before the cutting tools are completed.

No rule will apply to every case.

While most bend developments can be predicted with ease and will develop correctly, there is no perfectly scientific method for predicting bend allowance due to the many factors like tooling conditions, actual vs. planned thickness, forming method and the given part tolerance. Many companies will develop their bend allowances based on standard formulas, standard forming practices and historical trial and error.

Bend Allowance Overview

Know the difference between a lazy bend and a bad development.

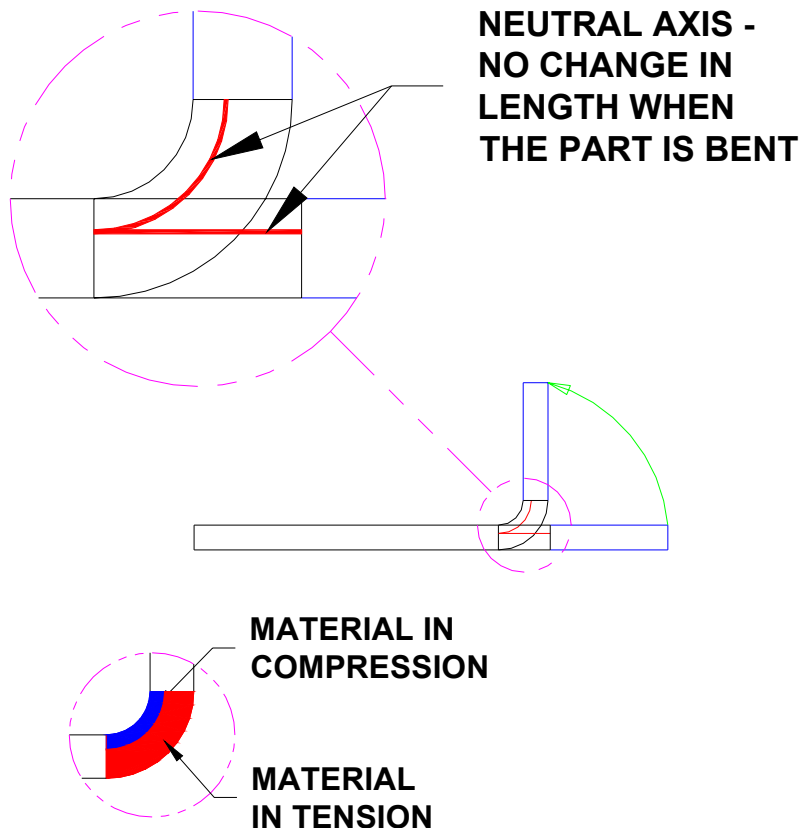
Often times a correctly developed part will be wrong due to poor forming, especially during the first run of the parts. Generally, it takes some time to validate tooling and make sure everything is tuned properly. It is not uncommon for a part with the correct development will have features that “act long” because of “lazy” forming. The most common cause of lazy forming is not bottoming the forming tools adequately.

2. General Principles

The Neutral Axis does not change.

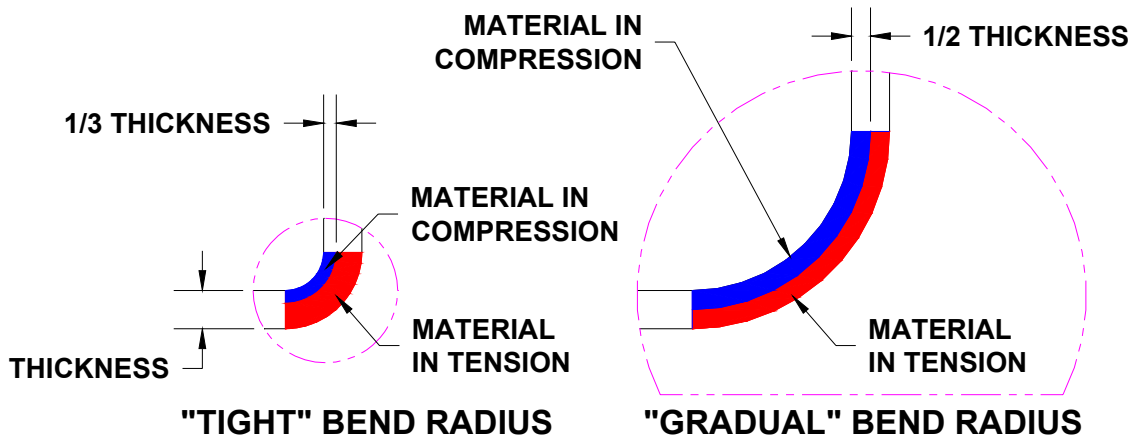
When developing a flat blank length, there is a length of the part that does not change. This length is called the neutral axis. Material on the inside of the neutral axis will compress, while material on the outside will stretch. Based on the material thickness, form radius and forming methods, the ratio of compression to tension in the part will change.

A part that is bent over a very sharp radius, when compared to the thickness, will stretch more on the outside, which means that the neutral axis will lie closer to the inside of the bend. A part that is gradually bent will have less outside stretch, which means that the neutral axis will lie closer to the center of the part.



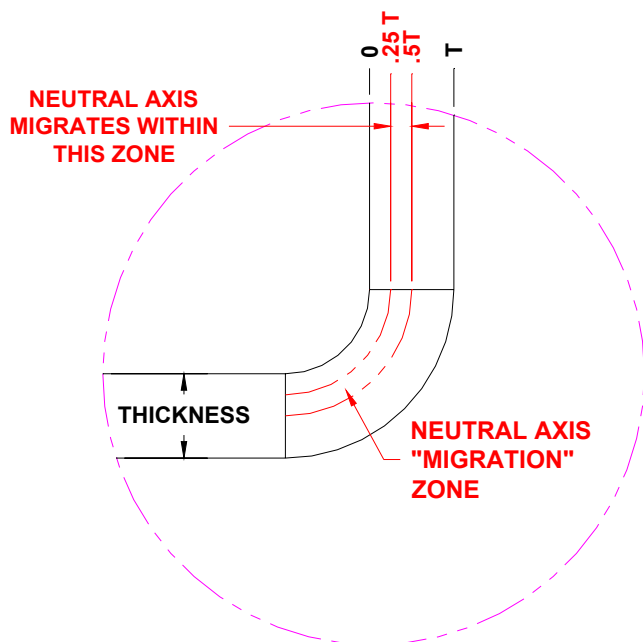
Bend Allowance Overview

Compression/Tension Ratio Depends Mostly On Geometry.



K-factor – Effectively 50%T Max / .25%T Min

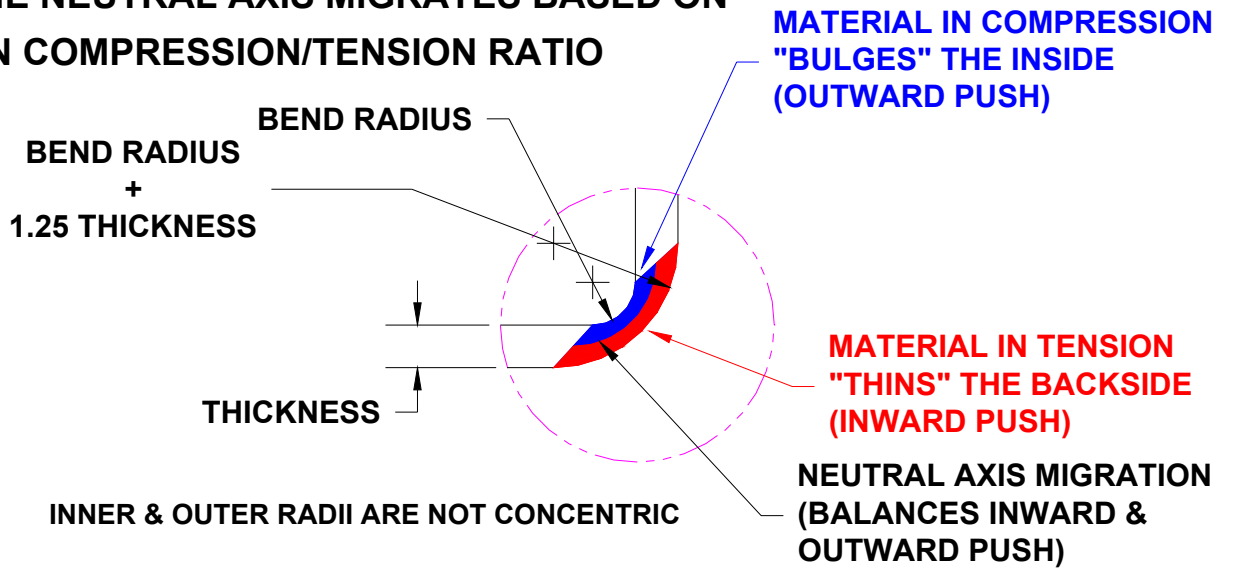
Where the neutral axis is situated in a bend is commonly called the "K-Factor" as it is signified as "K" in the development formulas. Since the inside compression can not exceed the outside tension, the k-factor can never exceed .50 in practical use. This means that the neutral axis cannot migrate past the midpoint of the material (i.e. towards the outside). A reasonable assumption is that the k-factor cannot be less than .25.



Bend Allowance Overview

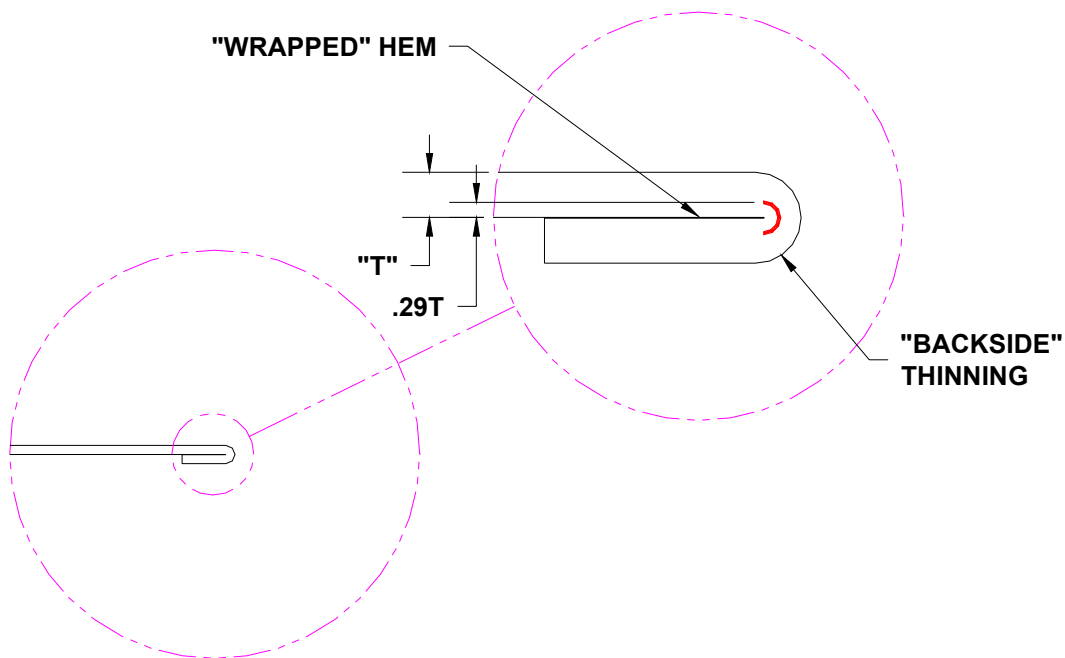
The neutral axis migrates based on the compression to tension relationship of the given bend.

THE NEUTRAL AXIS MIGRATES BASED ON ON COMPRESSION/TENSION RATIO



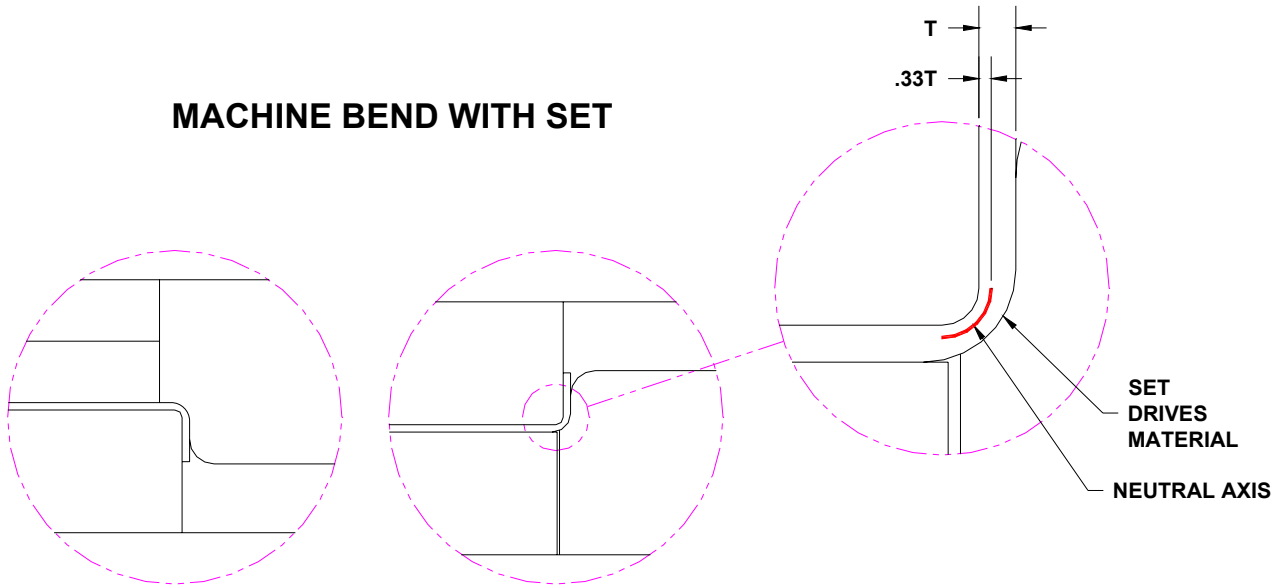
3. Different Bend Types & K-Factors

Wrapped Hem (.29 k factor)

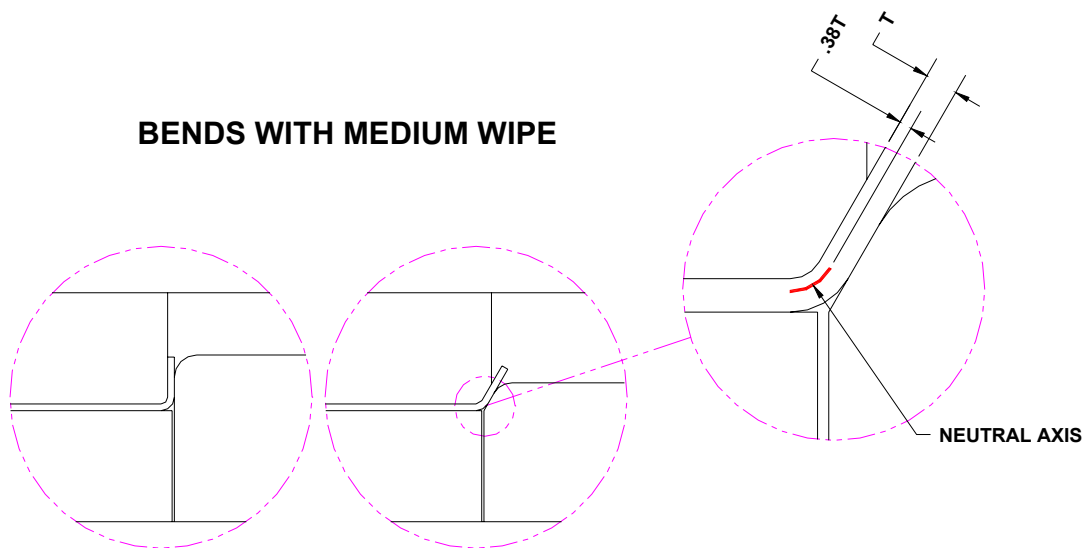


Bend Allowance Overview

Machine Bend with Set (.33 k factor)

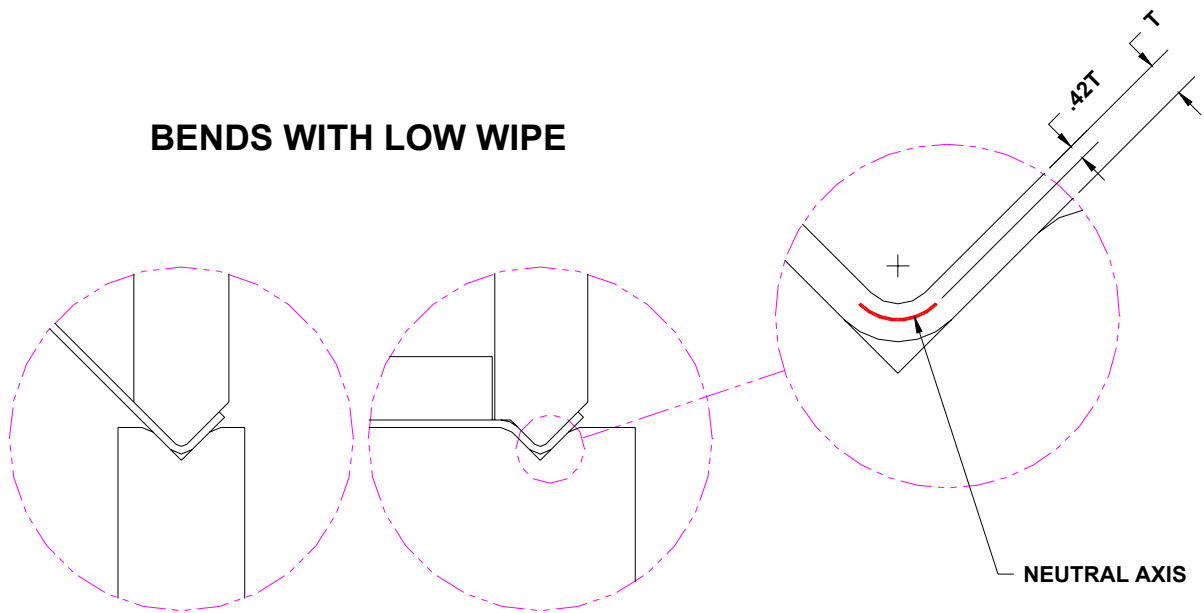


Machine Bend With No Set (.38 k-factor)

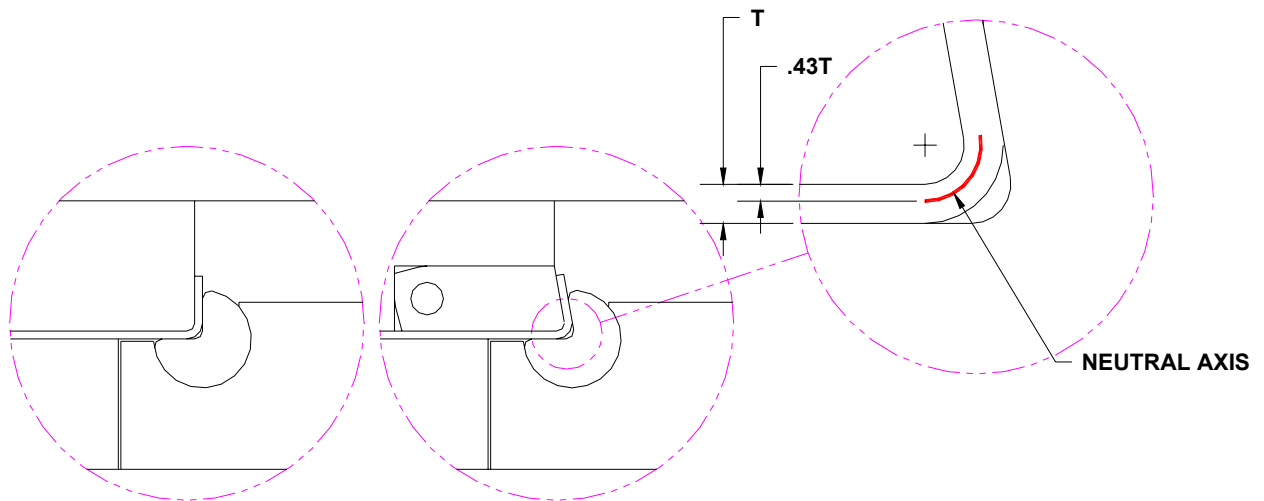


Bend Allowance Overview

V-Bend Or Brake Tool (.42 k-factor)



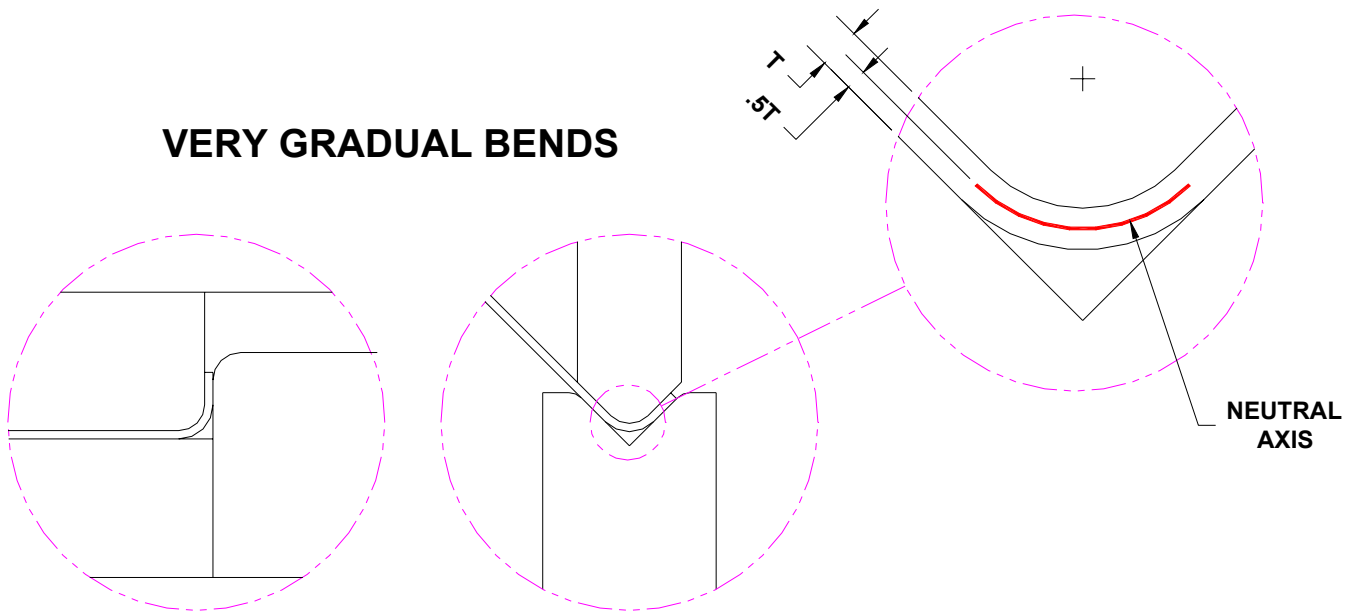
Rotary Benders (.43 k-factor)



Gradual Bends / Large Radii (.50 k-factor)

Bend Allowance Overview

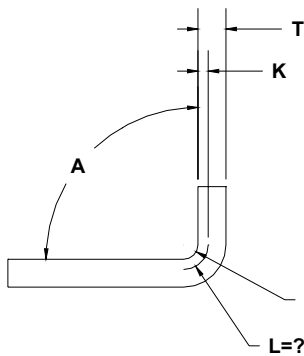
VERY GRADUAL BENDS



4. Related Formulas

Radian Formula

When a developed length is calculated in radians, the equation is extremely simplified because the radian is the actual arc length, so no additional “translation” into angles is needed as in the “standard” formula below. In fact, the “standard” formula is the radian formula plus a “built in” angle conversion from radian measure to (base 360) degrees, shown in the “Common Formula”.



**BEND ALLOWANCE FORMULA
(FOR ANGLE IN RADIANS)**

$$L = A (R + KT)$$

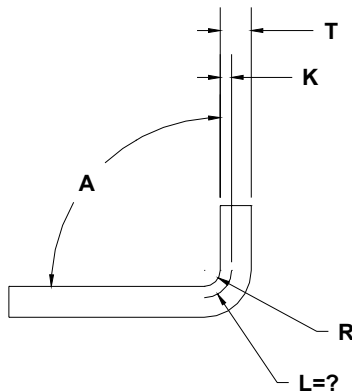
**A = ANGLE (RADIANS)
R = BEND RADIUS
K = NEUTRAL AXIS OFFSET (K-FACTOR)
T = THICKNESS OF MATERIAL
L = LENGTH OF BEND ALLOWANCE**

Common Formula

Since is more common to develop a part based on degrees instead of radians, the bend allowance formula commonly incorporates the degrees to radians conversion.

Recalling that $360 \text{ Degrees} = 2\pi \text{ Radians}$, then $1 \text{ Degree} = 2\pi \text{ Radians} / 360$

To convert the radian formula to work with degrees, we make the substitution $2\pi/360$



$$L = 2 \text{ Pi } A (R + KT) / 360$$

OR

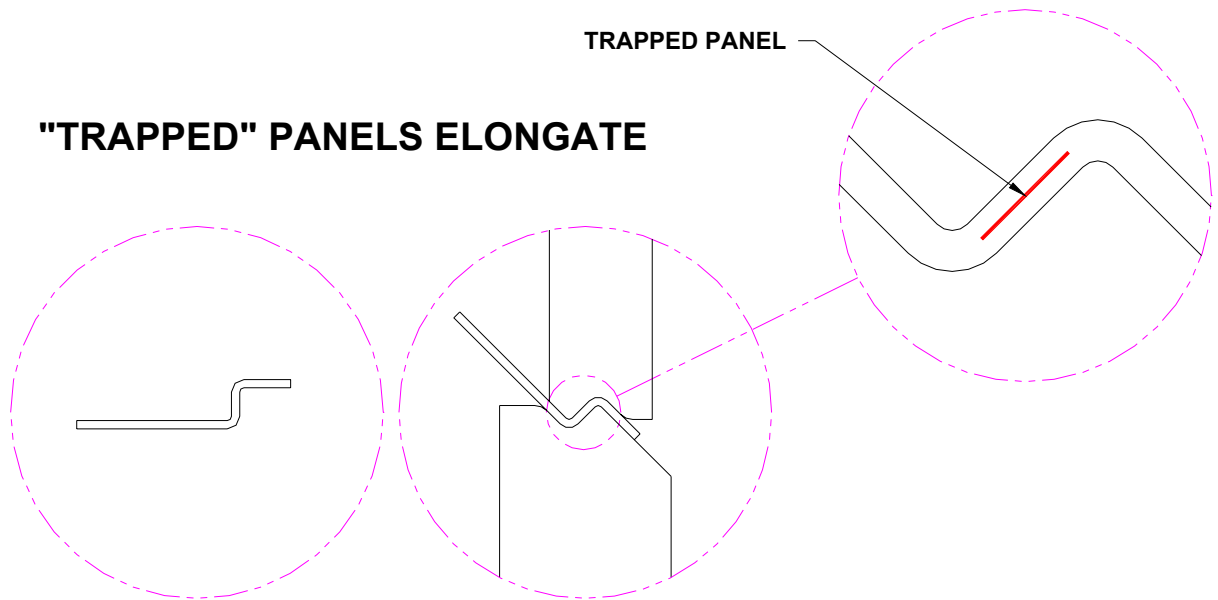
$$L = A (R + KT) / 57.3$$

**A = ANGLE (DEGREES)
R = BEND RADIUS
K = NEUTRAL AXIS OFFSET (K-FACTOR)
T = THICKNESS OF MATERIAL
L = LENGTH OF BEND ALLOWANCE
Pi = 3.14**

5. Special Cases

Single Hit Z-Bend

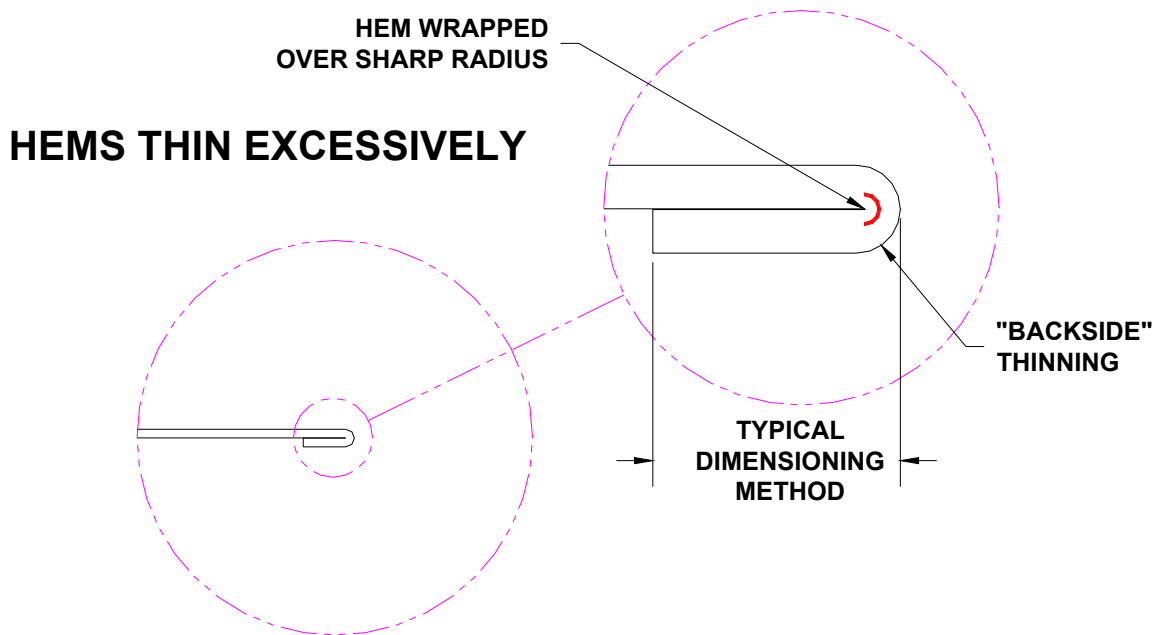
When a z-bend is hit in one hit, the middle panel will stretch more than expected. This is because the middle panel is trapped between two v-forms. A typical example might be on a .312 deep zee bend with .060 material, which might elongate .010”.



Wrapped hems

Wrapped hem developments should be treated with caution. While they will generally develop with a .29 k-factor, they are at minimum made with a two hit process and subject to a bit more variation. If the part has a reasonable tolerance, then the risk is minimized. Often times, a wrapped hem is used as a safety edge or a cosmetic feature.

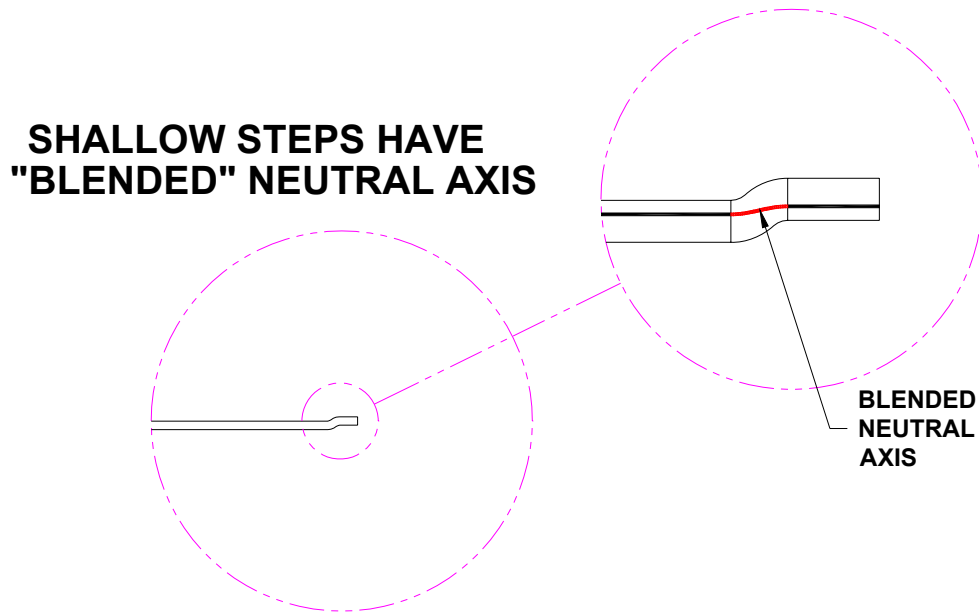
Additionally, a wrapped hem will see significant “backside” thinning which usually influences the leg length. Most parts are designed to a nominal outside thickness and not this backside “thinned out” thickness, so this must be accounted for in the developed length.



Bend Allowance Overview

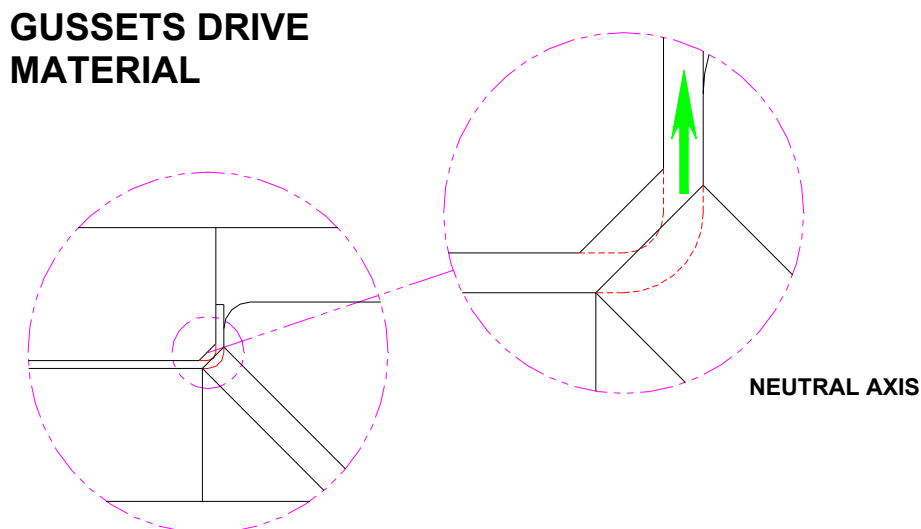
Shallow z-bends

When a shallow bend is used, the neutral axis of one bend blends into another one and does not completely stay within the form arc. This often means that the developed length is only slightly longer than the flat length.



Gusseted Bends

When a part has a gusset in a formed flange, the gusseted area will generally form "high" as the gusset drives material beyond the expected development.



6. PDF Version

A printable PDF version of this information is available [here](#).

7. “Legalese”

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