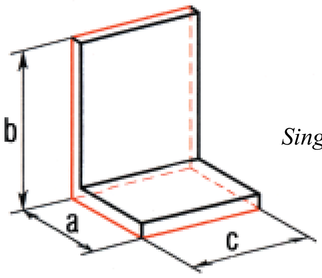
Calculating the unfold dimensions

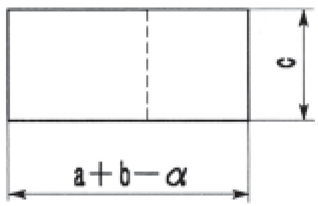
Chapter 1 Outer dimension summation method

1.1 Calculating the unfold length

There are a number of ways to calculate the unfold length. Because the outer dimension summation method is easy to understand and highly accurate, it is often used in actual practice.



Single view drawing



Unfold drawing

In the drawings above, a, b, and c are the dimensions of the outer edge of the plate.
They are called the outside dimensions (shown in red).
The dimension α is called the bend allowance.
To find α, calculate the difference between the unfold length before machining and the outside dimension after machining (a + b). For example, if the unfold length before bending is 90 mm, and if the length of a (outside dimension) after bending is 31.08 mm and b is 61.08 mm, the bend allowance is 31.08 + 61.08 - 90 = 2.16 mm.
The bend allowance varies depending on the material, plate thickness, and machining conditions such as the width of the "V" of the die. Most factories have data based on actual machined examples. Bend allowance tables calculated for the varying conditions are provided on the following page. The tables are for the machining method called "bottoming" (a popular bending method).
The table below provides recommended V-width values for various plate thicknesses, for your reference.

t	0.5-2.6	3.0-8	9-10	12 or more
v	6t	8t	10t	12t

The bend allowance also varies depending on factors such as the wear on the die shoulder or the tip of the punch, variations in the plate thickness or material (variations among different steel manufacturers and variations among lots from the same steel manufacturer), and whether the direction of the bend is perpendicular or parallel to the rolling direction. Where a highly accurate unfold is required, it is necessary to create a bend allowance table using the company's bending machine and each of the various materials.

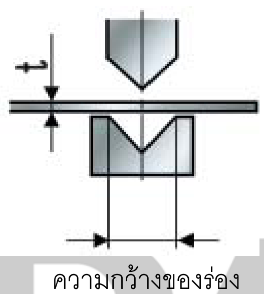
Bend allowance tables **(90° Bend)**

SPCC

t \ v	4	6	8	10	12	14	16	18	20
0.5	0.92	1.04							
0.6	1.10	1.22	1.36						
0.8	1.38	1.52	1.70						
1.0	1.58	1.72	1.90						
1.2		1.98	2.16	2.28					
1.6			2.58	2.65	2.84				
2.0				3.25	3.42	3.60			
2.3				3.55	3.80	4.02			
3.2							5.45	5.60	5.85

SECC

t \ v	4	6	8	10	12	14
1.0	1.46	1.75	1.92			
1.2		2.02	2.16	2.35		
1.6			2.62	2.70	2.80	
2.0				3.40	3.50	3.62



SUS

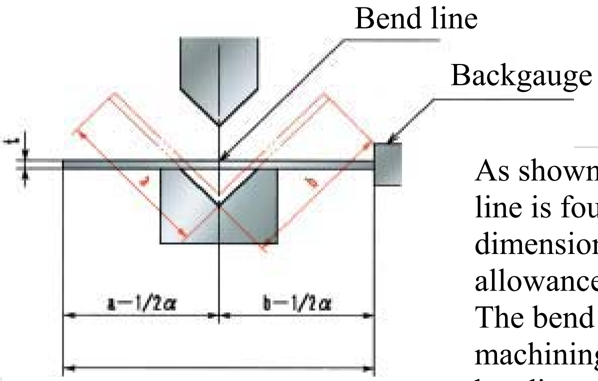
t \ v	4	6	8	10	12	14
0.5	1.02	1.18				
0.6	1.10	1.16	1.36			
0.8	1.38	1.54	1.72			
1.0	1.52	1.81	2.00			
1.5			2.60	2.84	2.96	
2.0				3.44	3.68	3.82

The bend allowances above were obtained using 90° bottoming for test machining at Amada School. Use these as reference values, keeping in mind that the bend allowance varies with the material, die set and bending conditions.

A5052P

t \ v	4	6	8	10	12	14
0.5	0.94	0.94				
1.0	1.56	1.56	1.56			
1.5			2.34	2.34	2.34	
2.0				3.24	3.24	3.26

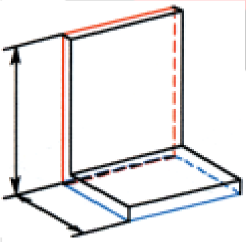
1.2 Calculating bend lines



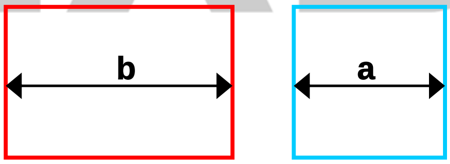
As shown in the diagram above, the position of the bend line is found by subtracting 1/2α from each of the dimensions a and b (1/2α is called the one-side bend allowance).
The bend line is generally not required for outline machining, but it shows the position of the punch for bending.
When creating unfold drawings, it is sometimes necessary to calculate the position of the bend line. The calculation method is explained later in this document

1.3 Surface composition

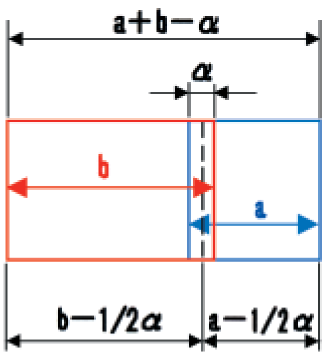
Surface composition is a method that makes the creation of unfold drawings easier. In surface composition, the outside surfaces (shown in red and blue) of a 3-dimensional part are considered as independent surfaces (ignoring the plate thickness). These surfaces are overlapped with the bend allowance (creating a margin) and combined.



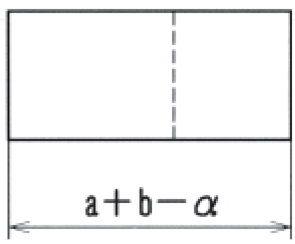
Two surfaces (red and blue) are taken as separate surfaces.



When they are combined, the result is as shown below.



The unfold drawing that results is as shown below.

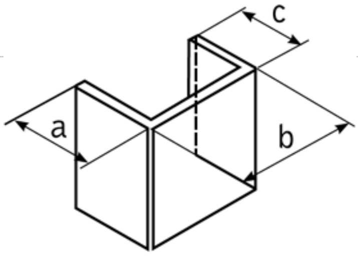


Unfold length

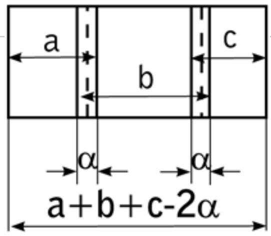
1.4 Calculating the unfold length for parallel bends

Let us use the method explained in the previous section for calculating the outside dimensions to calculate the unfold length for a typical shape.

1) U-shape bending



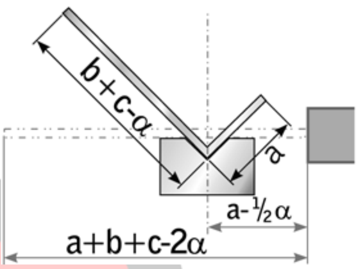
Surface composition method



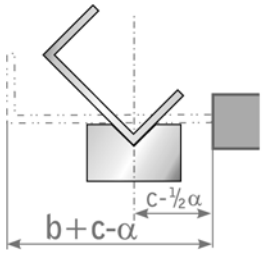
(unfold length)

Backguage setting

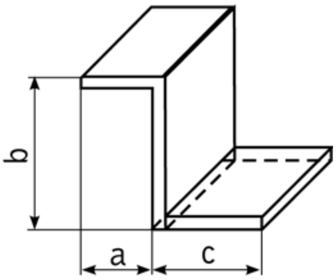
<u>Step1</u>



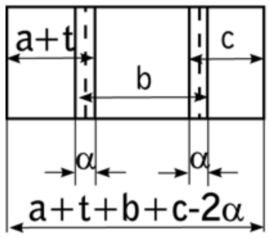
<u>Step 2</u>



2) Z-shape bending



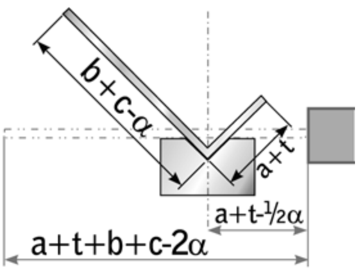
Surface composition method



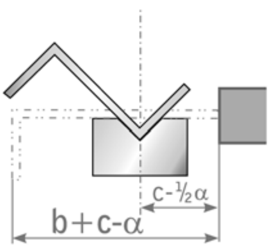
(unfold length)

Backguage setting

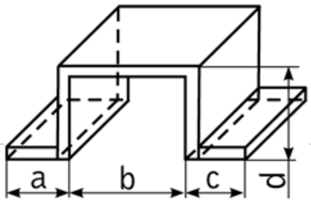
<u>Step1</u>



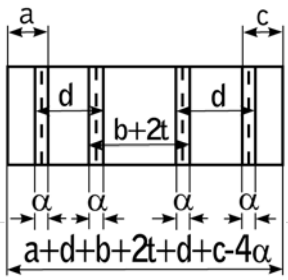
<u>Step 2</u>



3) **Hat bending**



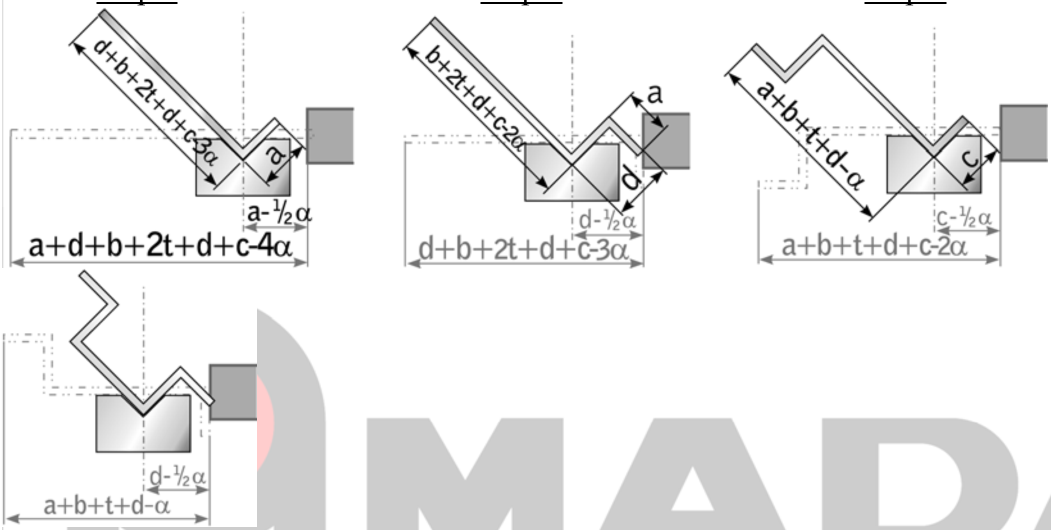
Surface composition method



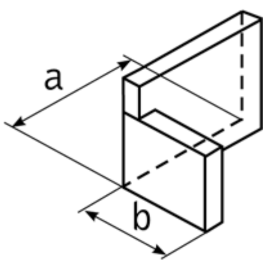
(unfold length)

Backguage setting

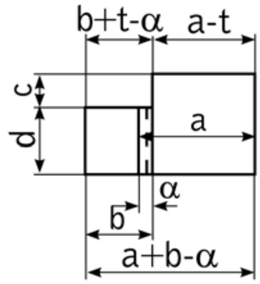
Step 1 Step 2 Step 3 Step 4



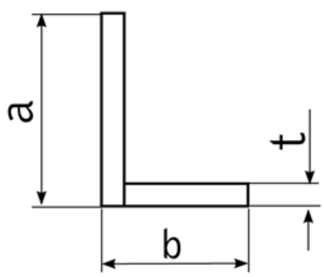
4) **Calculating a notch dimension - 1**

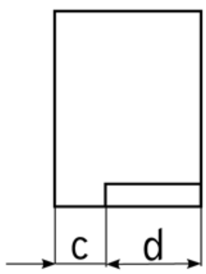


Surface composition method

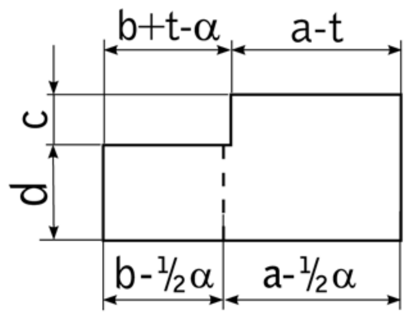


Third angle projection

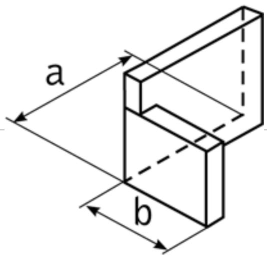




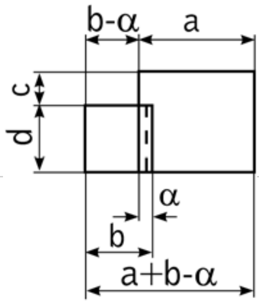
Unfold drawing



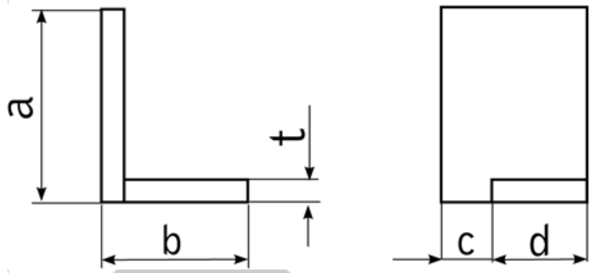
5) Calculating a notch dimension - 2



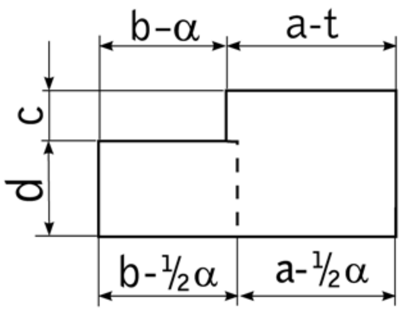
Surface composition method



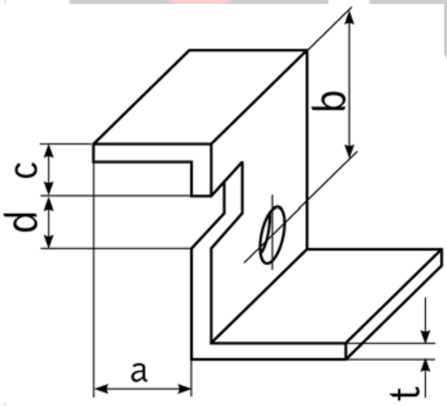
Third angle projection



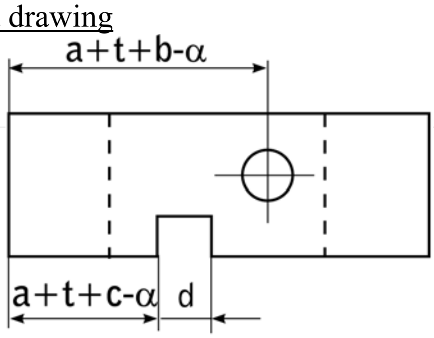
Unfold drawing



6) Where there are holes and slits

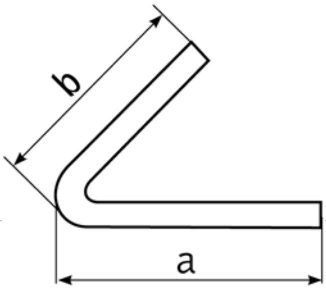


Unfold drawing

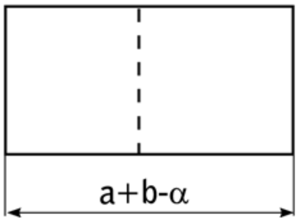


7) **Acute angle bending**

It is common to obtain the outside dimensions from the external radius R.

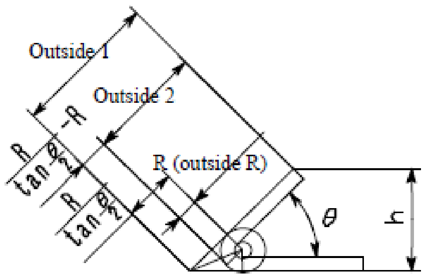


<u>Unfold drawing</u>



(unfold length)

Converting the dimension from the point of the angle (outside dimension 1 below) to the dimension from the external radius R (outside dimension 2).



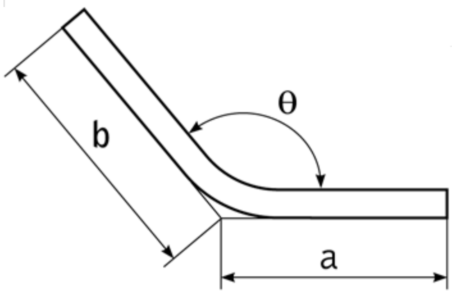
- Converting outside dimension 1 to outside dimension 2

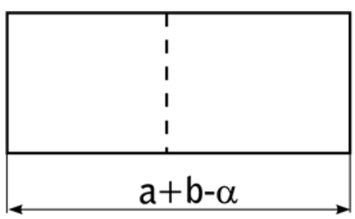
$$\text{Outside dimension 2} = \text{outside dimension 1} - \left[\frac{R}{\tan\theta/2} - R\right]$$

- Converting h to outside dimension 2.

$$\text{Outside dimension 2} = \frac{h}{\sin\theta} - \left[\frac{R}{\tan\theta/2} - R\right]$$

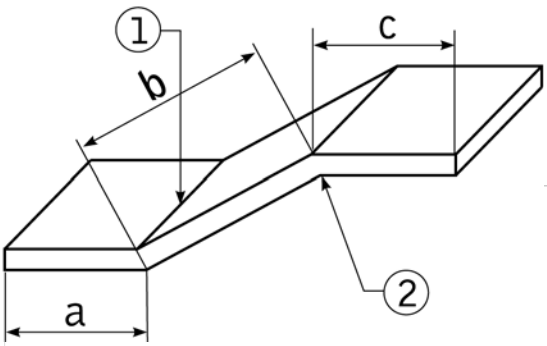
8) **Obtuse angle bending**



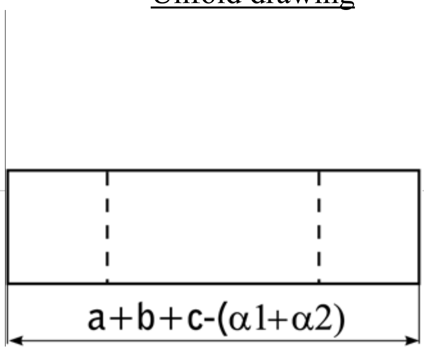


(unfold length)

9) **Obtuse angle bending (joggle)**



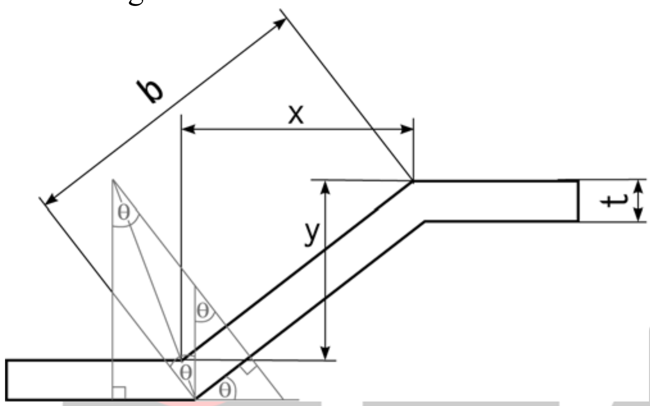
Unfold drawing



α 1 : Bend allowance of 1

α 2 : Bend allowance of 2

Calculating outside dimensions a and b and the formula for the unfold length.



$$b = \sqrt{x^2 + y^2} + t \times \tan\frac{\theta}{2}$$

Bend allowance table for acute and obtuse angle bends (SPCC)

t \ θ	45°	60°	120°	135°
1.0(V=6)	0.66	1.01	0.86	0.56
1.2(V=8)	0.80	1.26	0.94	0.68
1.6(V=10)	1.04	1.54	1.38	0.88
2.3(V=16)	1.54	2.40	2.02	1.30
3.2(V=25)	2.24	2.48	2.94	1.90

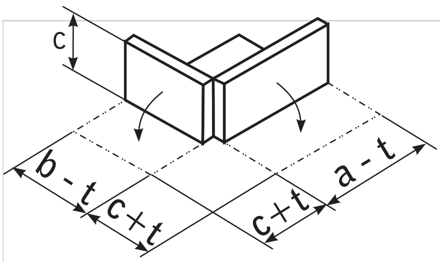
The bend allowances above were obtained from test machining at Amada School. Use these as reference values, keeping in mind that the bend allowance varies with the material, die set and bending conditions.

1.5 Calculating the unfold length of boxes

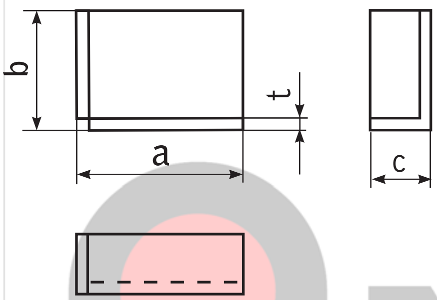
In cases of parallel bends only, there are no butts, which occur in bending for boxes. There are a number of butt patterns used in actual practice.

Some common butt patterns are shown below.

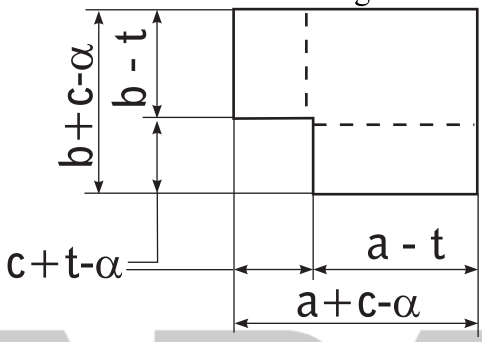
1) Box shape type 1 (no overlapping, no setback)



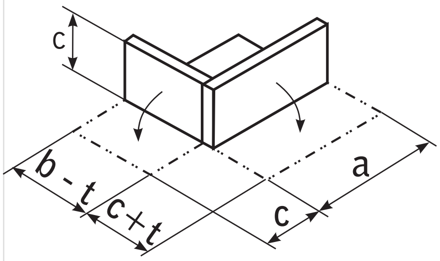
Third angle projection



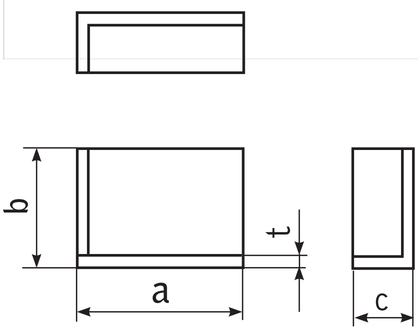
Unfold drawing



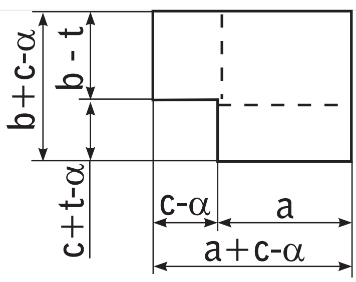
2) Box shape type 2 (overlapping, setback)



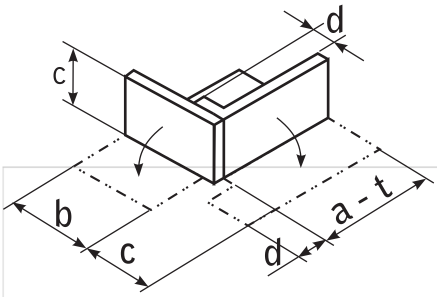
Third angle projection



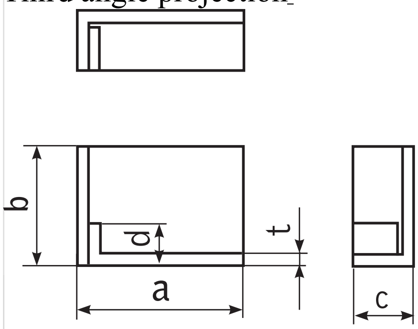
Unfold drawing



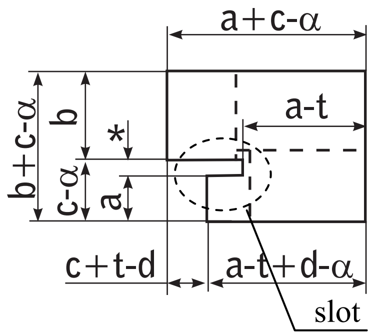
3) Box shape type 3 (folding inside)



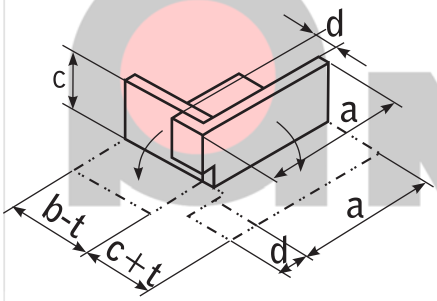
Third angle projection



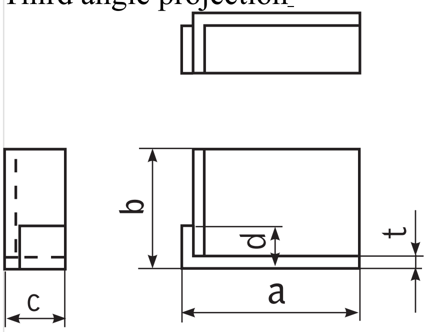
Unfold drawing



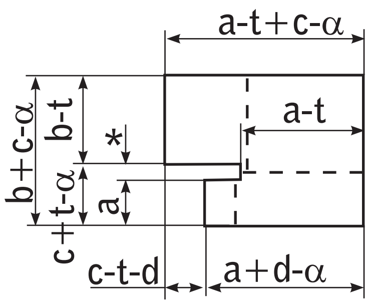
4) Box shape type 4 (folding outside)



Third angle projection



Unfold drawing

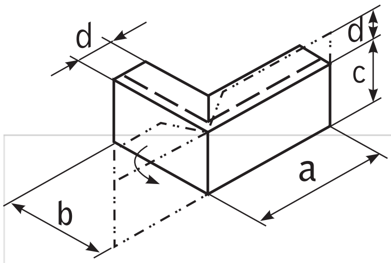


Note: The slit width indicated by the asterisk (*) is as follows:

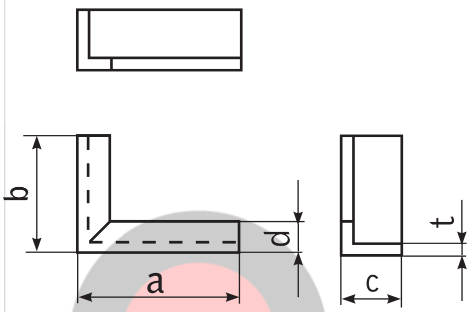
Punching : about 3 mm
Laser machining : about 0.2 mm
Therefore, the dimension of the A part is not c - t.

If the width of the slit marked by the asterisk (*) is 0.2 mm, caution is required as the tip will interfere with the internal radius R of the top plate.

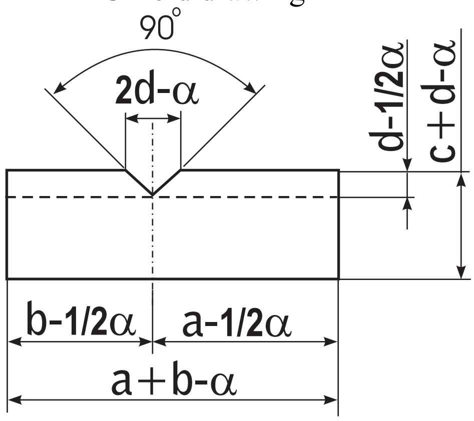
5) V-notch



Third angle projection

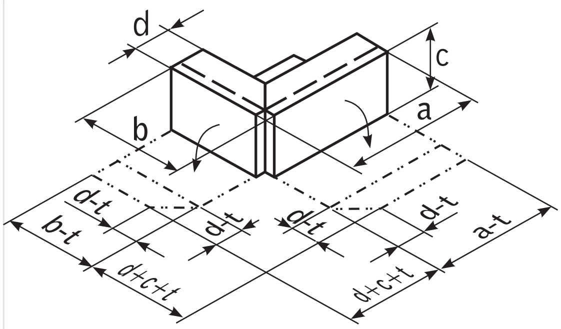


Unfold drawing

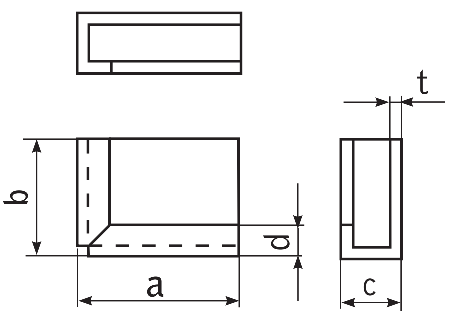


Θ Because the center of the notch is bent, it is possible to calculate the center of the notch from the dimension of the bend line.

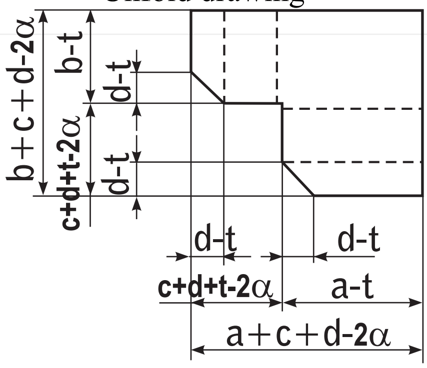
6) Overlapping (diagonal)



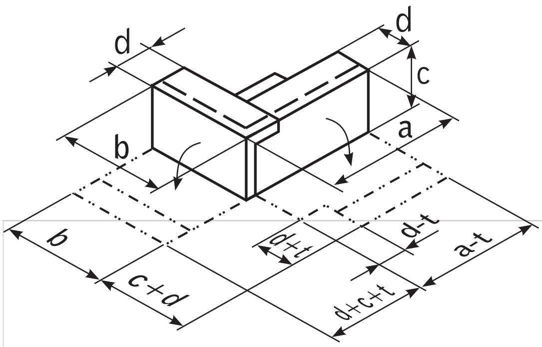
Third angle projection



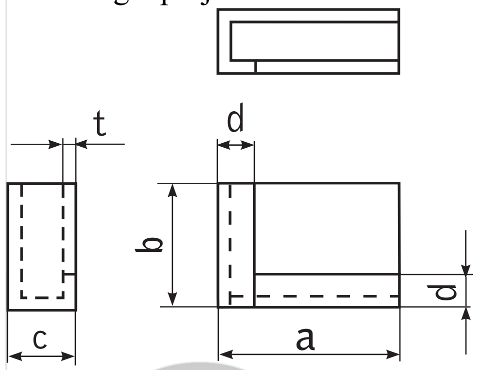
Unfold drawing



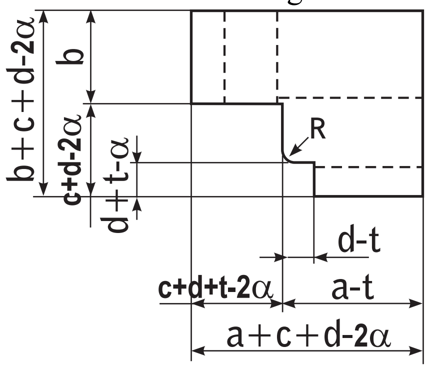
7) Overlapping (parallel)



Third angle projection

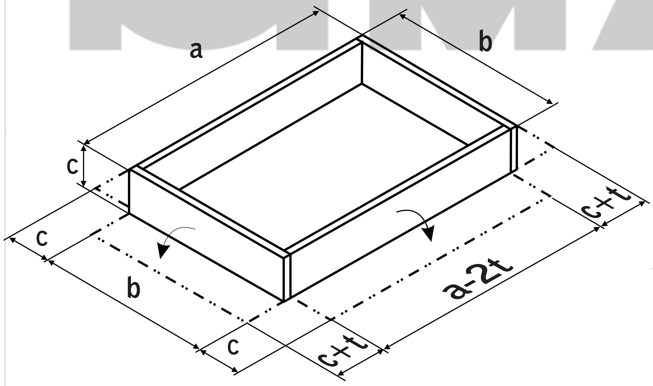


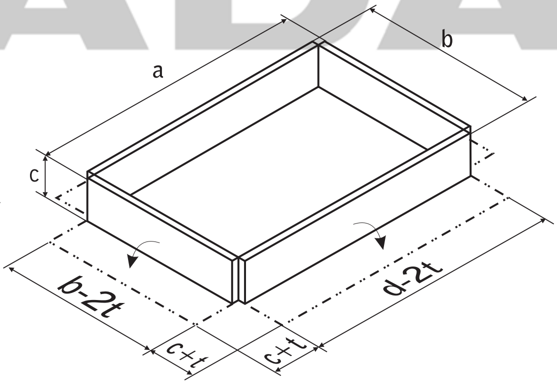
Unfold drawing



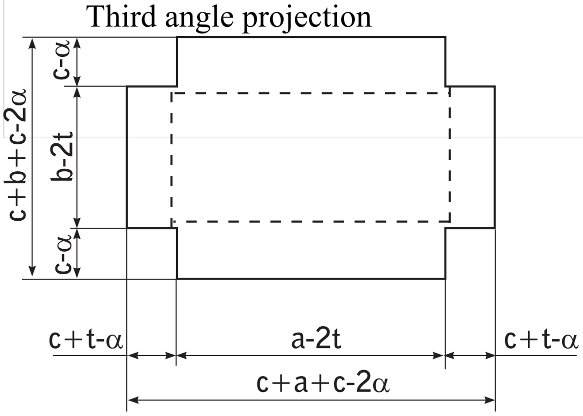
R: approximate plate thickness R

1.6 Example for standard box unfold

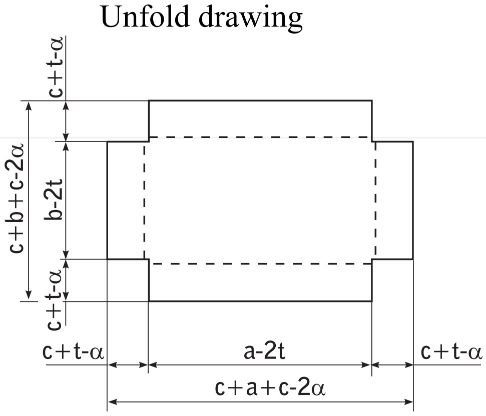




Third angle projection

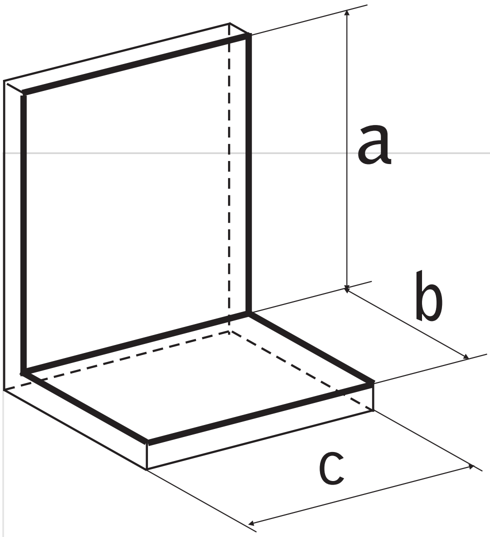


Unfold drawing

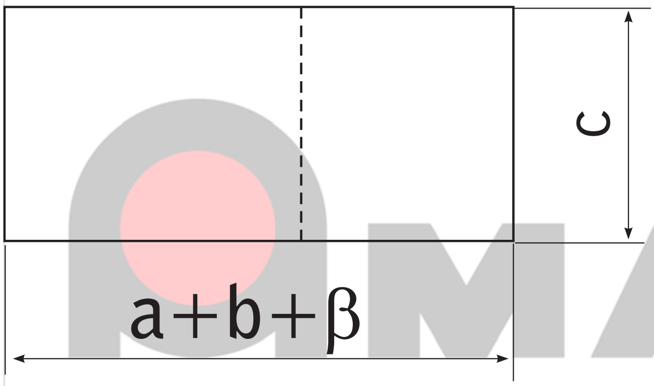


Chapter 2 Inner dimension summation method

The concept for the inner dimension summation method is the same as the outer dimension summation method, except that the inner rather than the outer dimensions are used in the calculation.



Single view drawing



Unfold drawing

(unfold length)

Unfold length = a + b + β

The dimensions a, b, and c are called the inner dimensions of the plate.
β is called the shrinkage allowance (inner bend allowance), and it is calculated by subtracting the post-machining inner dimension (a + b) from the pre-machining unfold length.

As was the case with the outer dimension summation method, most factories have data for β based on actual machined examples.

Note that β is related to the bend allowance (α) for the outer dimension summation method as shown in the equation below:

90° bend

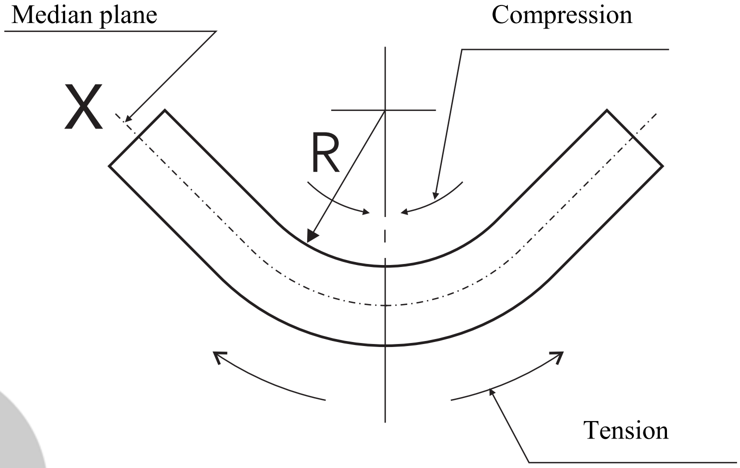
$$\beta = 2t - \alpha$$

Obtuse angle bend

$$\beta = 2t \times \frac{1}{\tan\frac{\theta}{2}} - \alpha$$

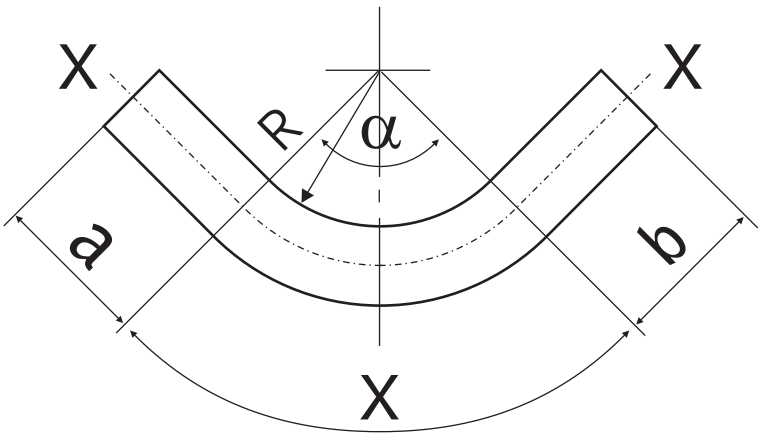
Chapter 3 Median plane standard method

When a punch and die are used to change the shape of a workpiece, in the case of a V-shape, compressive strain occurs on the inside of the V (punch side), while tensile strain occurs on the outside of the V (die side).
The extent of this strain is greatest at the surface of the plate, and toward the core of the plate, it is reduced. Near the center, a plane can be imagined that is affected by neither compressive nor tensile strain. This plane is called the median plane (this is a plane in 3D terms, or a line in a cross-section of the plate) and it is expressed by the line X – X as shown in the figure below. Finding the unfold dimension based on calculating the length of this line is called the median plane standard method. This is a desktop calculation method that only gives you an approximate value. Where high accuracy is required, the outer dimension summation method should be used.



3.1 Median plan standard method - 1 (where bend R ≥ 5t)

Where the radius of the bend is 5 times or more the thickness of the plate, there is no change in the plate thickness at the bend, and there is almost no stretch. In other words, this calculation method is appropriate for cases where the median plan lies on the center line of the plate thickness t.



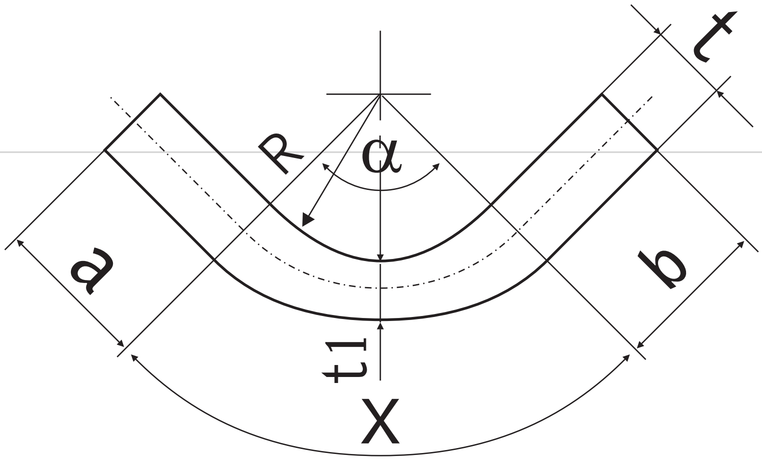
In the figure above, the equation is as follows, where L is the unfold length.

$$L = a + x + b \quad x = (\alpha/360) \bullet 2\pi (R + t/2)$$

Here, where $\alpha = 90°$, the result is $L = a + 1.57 (R + t/2) + b$

3.2 Median plane standard method = 2 (where bend R < 5t)

If the bend radius is small compared to the plate thickness, the plate material is stretched as shown in the figure below, becoming thinner, and the median plane is closer to the inside.



The rate of reduction in the plate thickness (t1/t) varies with the size of the value (R/t), and is grouped as shown below.

Group	R/t	t1/t
A	0.5 or less	Approximately 0.4
B	0.5 - 1.5	0.6
C	1.5 - 3.0	0.66
D	3.0 - 5.0	0.8
E	5.0 -	1.0

As can be understood from the table above, for Group A (R/t is 0.5 or less), the thickness of the plate after bending (t1) is 40% of the original plate thickness.

For Group E (R/t is 1 or greater), there is no change in the plate thickness.

For example, if a 1.2 mm thick plate is bent to a 1.5 mm bend radius, R/t is 1.25 or Group B. Therefore, t1/t becomes 0.6.

This means that, as the result of bending, the original 1.2 mm plate is reduced in thickness to only 0.72 mm (1.2 x0.6 = 0.72 mm), which means that the median plan is 0.36 mm from the inside surface.

The length of the median plane is the unfold length, which can be obtained by the following formula:

$L = a + x + b$ $\qquad$ $x = (\alpha/360) \blacklozenge 2\pi (R + t1 \times 1/2)$

Here, where $\alpha = 90°$, the result is $L = a + 1.57 (R + t1 \times 1/2) + b$