Sheet Metal Bending

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1.1 Overview

In the sheet metal processing industry, even more complex parts can be manufactured by cold forming. The sheet metal to be processed are not only edged in one direction, for complicated components such as casings, covers, etc, the edges must run in different directions.

The component receives its spatial form through various bending of an initially flat sheet metal mill bar. The design of the sheet metal part is determined by the command that is to fill the part. The prepared part is then transferred to the output product, the flat sheet metal mill bar (developed view).

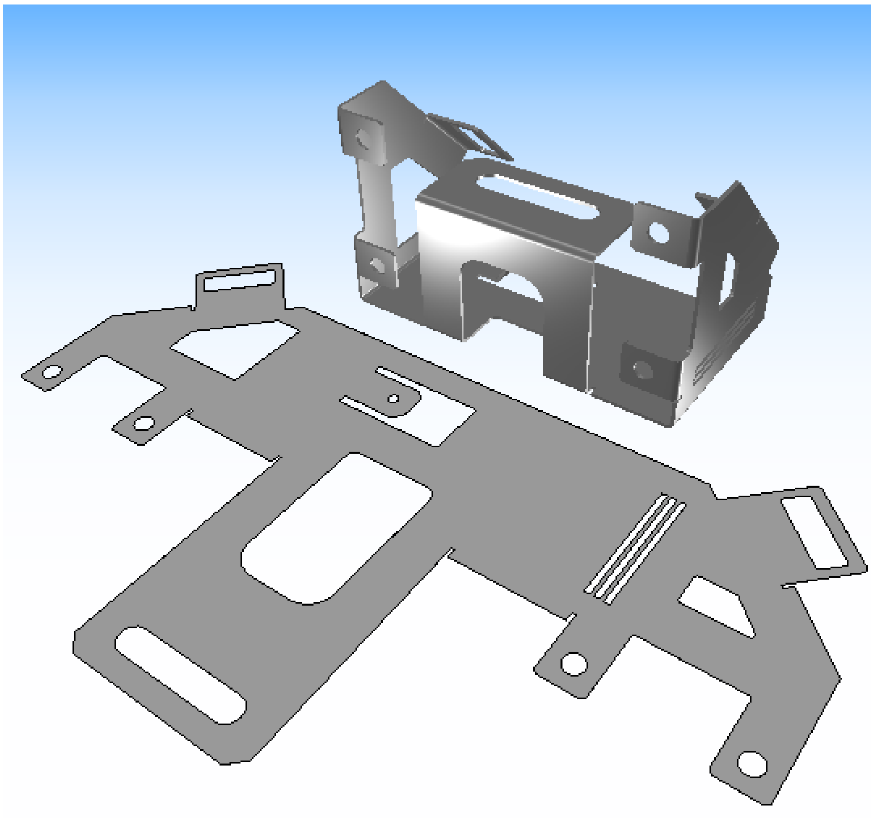


Illustration of sheet metal part (solid) and its developed view.

When bending, it is not only dealing with a pure geometric procedure, but the material properties of the material from which the part is to be folded must also be taken into account. The modifications resulting from the folding are considered with additional values with the calculation of the length in the unfolded state.

Sheet metal bending has many advantages with the help of a CAD system. The time consuming searching to determine folding additions in tables which can easily lead to errors, is no longer necessary. Therefore, work is completed much faster and the time won can be used for example, to optimise the mill bar cutting so that there is less waste material. Additionally, after certain preparation, the determined waste material can be taken over by a NC-program to be punched out automatically. Therefore, the product becomes reality, from design to production.

1.2 General information concerning folding

Folding is one of the more frequently used cold forming in the industry. By disregarding edge deformation it is limited to a two dimensional way of viewing.
It is permitted for a relation of sheet metal width to sheet metal thickness that is larger than 5, which is mostly applicable for folding cases.

With folding, the material on the outer radius – i.e. on the outer fibre – is stretched and compressed on the inner radius – i.e. on the inner fibre. As a rule, this leads to a sectional reduction.

The actual run and therefore the length of the neutral fibre (location, at which tensile stress and compressive strain are level), cannot be determined geometrically and therefore cannot be used for the calculation of the stretched length of a sheet metal part. So empirical factors are necessary as to how they are found in the DIN standard 6935.

The folding procedure consequently has a material displacement in the folding zone. In the inner of the folding, the material is exchanged by the compressive stress and the material layers become thicker. From the tensile stress in the outer area, the material is lengthened and the layers become respectively thinner.

The fibre that has the same length again after the folding procedure as it did before folding, is known as a neutral fibre. The reason that the non-lengthened fibre does not fall together with the middle fibre is due to the modification of the sheet metal thickness in the folding area. Generally, for a material, yield stress and abrasive flow curves are not the same and the influence of the lateral strain also plays a role. The thicker the sheet metal and the smaller the folding radius, the more the position of the neutral fibre deviate from the middle fibre in the direction of the inner radius.

The neutral fibre is taken into consideration when making modifications to the folding area. The position of the neutral fibre in the folded state determines the bending of this fold using the dimensions. This fibre in an unfolded state, has the length of the folding part.

The length of the neutral fibre and therefore the part in an unfolded state, becomes smaller, the larger the distance of the neutral fibre is from the centre line in the direction of the folding midpoint.

For various materials, in order to calculate the length in an unfolded state, compensation or aggregate values, that are dependent on the sheet metal thickness and folding radius, are available in tables and diagrams. These values have been generated in tests for various materials. In order to determine the length in an unfolded state, the material, folding radius and sheet metal thickness respective aggregate values are added to the arc length.

2 Sheet metal bending

2.1 Requirements for bendable solid

In order to carry out sheet metal bending, the solid generated in the 3D view window must fulfil the following requirements:

- The folding zones must exist as cylinder or cone face.
- The folding zones must project tangentially in the bordered faces.
- The outer radius of a folding zone should always amount to the inner radius + sheet metal thickness.
  If this requirement is not fulfilled, calculating the developed view with the option “Sheet metal thickness from workpiece“ will result in an error message (“Error in model“).
  In this case, the sheet metal part can only be bent with an entered sheet metal thickness.

2.2 General procedure

In order to load *sheet metal bending*, proceed as follows:

1. Select the menu command *Extras, Sheet Metal Bending*.
2. A dialog box then opens.
   In this dialog box, determine the settings for the calculation of the cutting.
3. Confirm the command button *Cutting*.
4. Identify a flat, bendable solid face whose bend is to be calculated.
   A dialog box then appears which contains the calculated developed view.
5. Use the key combination *Ctrl Tab* to change to the 2D drawing window.
6. Position the developed view.

With this command, 2D line objects and dimension text are generated. They are included and drawn in the model structure in the following way:

Drawing, partial drawing
All objects in a developed view are saved in the active partial drawing of the currently selected drawing.

Group
When positioning a developed view, a group is set up under the current group with the description **UNFOLD**. The generated objects are saved in this group.

The group relationship can later be modified using the menu command *Define, Group*.

Colour, line type, width
All objects in a developed view are linked with specific layers which therefore determine the colour, line type and width:

Sheet metal contour	Current drawing layer
Fold lines	Centre line layer
Fold zone	Invisible lines layer
Text (as dimension text)	Dimension text layer

The link with a layer as well as colour, line type and width can be modified for each object using the menu command *Edit, Object Display*.

Protocol file

The protocol file with the extension DAT entered in the dialog box for parameter definition, can be opened with any ASCII editor.

2.3 Define settings for bend

After loading the menu command *Extras, Sheet Metal Bending*, a dialog box appears which can be used to define the settings for the developed view.

thickness

Generally, there are 2 different options for the definition of the sheet metal thickness:

from part

If this setting is active, the current sheet metal thickness of the workpiece is taken as the basic calculation for the developed view.
If, at the same time, the setting *double sided bend* is active under *Other*, the inner as well as the outer face of the workpiece is bent. Both of these bends can vary, e.g. with oblique holes by the position of the breakthrough.

defined

If this setting is active, the value defined as the sheet metal thickness is used for the calculation.
It is insignificant which sheet metal thickness the workpiece actually has.
The program calculates the bend as if the workpiece has the set sheet metal thickness everywhere, starting from the selected bending plane.
The cutting for the outer or inner face of a workpiece can be calculated for various sheet metal thickness (depending on which dimensions are to be kept), without the complete workpiece having to be redesigned.

Please note:

For the bend calculation, the inner radius is always decisive. With an outer face (in reference to the bending plane), this is calculated as the outer radius minus the sheet metal thickness ($R_i = R_a$ - BD).

Therefore with the option *defined* you must check that, with the definition of a too large sheet metal thickness, the inner radius is smaller or equal to zero at any place (outer face).

Method of calculation

DIN

This determines the calculation type for the definition of the stretched length by DIN 6935. Information concerning this can be found in the *Calculation types, Calculate according to DIN standard 6935* chapter.

Machine data

This determines the calculation type for the definition of the stretched length by machine data. **Other file:** this command button can be used to select the file required for the machine data.
A description of the file format can be found in the *Calculation types, Calculate with machine data* chapter.

Neutral fibre

This determines the calculation type for the definition of the stretched length by a defined neutral fibre position. . Information concerning this can be found in the *Calculation type, Calculate with empirical values*.

Options

Protocol file

The name of the protocol file (without extension) can be entered here. The bend results are saved in this file.
When saving, the file is allocated the extension DAT.

Bend double sided

If the current sheet metal thickness of the workpiece is used as the basic calculation of the bend (setting *from workpiece*), you can determine whether both sides of the bend should be drawn (inner and outer sides of sheet metal).

Generate contour for bearer solid

With oblique breakthroughs, the breakthrough contours have a different position on both sides of the bend (inner and outer sides of the sheet metal). If this switch is active, a maximum breakthrough solid is calculated from both breakthrough contours and the contours drawn in both bends.

deltaL for exact contour

This value influences the calculation exactness of three dimensional curves in 3D space (e.g. with a hole by a folding zone). The smaller the value, the more exact the calculation of the breakthrough contour.

Method to reduce polygon points:

In order to retain the most exact representation of the bend, the calculated contour polylines consist of many individual control points. If a lower number of control points are advantageous for NC programming, this can be minimised. This results in the drawing not being so exact.

None
: No minimisation. All calculated control points are drawn.

Linear
: The number of control points is minimised according to the tolerated deviation. The new control points are connected by lines.

Arcs
: The number of control points is minimised according to the tolerated deviation. The new control points are connected by arcs.

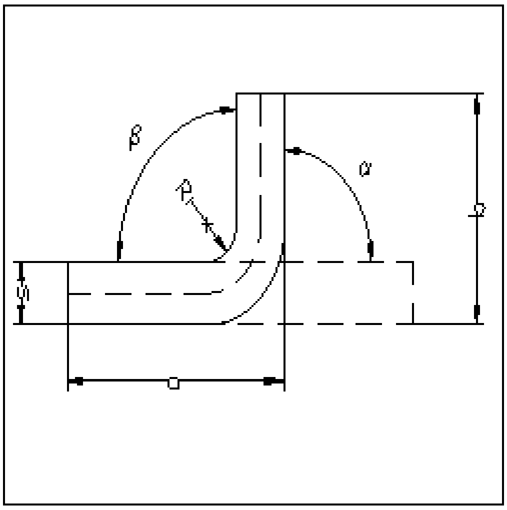
Tangent arcs
: The number of control points is minimised according to the tolerated deviation. The new control points are connected by arcs with tangent projections.

Max. deviation
: The smaller the deviation of this “non exact“ polyline is from the calculated polyline, the more control points are drawn.

3 Calculation types

3.1 Calculate according to DIN standard 6935

This standard for the cold fold of flat rolled steel is valid for applications in steel construction and in general Mechanical Design.



Description according to DIN 6935

r	Inner radius
α	Fold angle
β	Opening angle
a, b	Side lengths
s	Sheet metal thickness

The correction factor k takes into account the deviation of the neutral fibre to the middle fibre (s/2), and therefore the length modification resulting from the folding procedure.
k can only accept values in the range between 0 to 1 and the folding angle can lie between 0 and 180 degrees.

The **correction factor k** is calculated from:

$$k = 0{,}65 + \tfrac{1}{2} \log (r/s) \qquad \text{for } r/s \leq 5$$

$$k = 1 \qquad \text{for } r/s > 5$$

The **stretched length L** is calculated from the following equation:

$L = a + b + v$

The **compensating value v** is calculated by the following equations according to the value of the opening angle ß:

0° $\leq \beta \leq$ **90°**:

$$v = \pi \cdot \left(\frac{180° - \beta}{180°}\right) \cdot \left(r + \frac{s}{2} \cdot k\right) - 2 \cdot (r + s)$$

90° $\leq \beta \leq$ **165°**:

$$v = \pi \cdot \left(\frac{180° - \beta}{180°}\right) \cdot \left(r + \frac{s}{2} \cdot k\right) - 2 \cdot (r + s) \cdot \tan\left(\frac{180° - \beta}{2}\right)$$

165° $\leq \beta \leq$ **180°**:

v = 0

in practice usually sufficient for the exactness since the values for v are invariably small.

3.2 Calculate with machine data

With this calculation type, the deduction values of the folding zone are taken from a user defined machine data table which are dependent on the sheet metal thickness, folding radius and opening angle.
Any intermediate values are interpolated linear. If they cannot be interpolated because one of the two neighbouring values is not defined, *CADdy++ Mechanical Design Sheet Metal Bending* prompts for user input.

The **stretched length L** is calculated (similar to DIN standard 6935) with the following equation:

L = a + b - x   with x: = deduction value

Example file MACHINE.TBL

Use this file that is included in the delivery as an example file since this is overwritten if an update is carried out.
Therefore, copy this file, allocate a different name e.g. according to the material, and enter the required values in this copy.

```
;-------------------------------------------------------------------
; N O  V A L I D  V A L U E S !!
; N O  V A L I D  V A L U E S !!
; N O  V A L I D  V A L U E S !!
;
; E X A M P L E
; E X A M P L E  for machine data table
; E X A M P L E
;
; N O  V A L I D  V A L U E S !!
; N O  V A L I D  V A L U E S !!
; N O  V A L I D  V A L U E S !!
;
; Use an ASCII file editor to customize the values to your specific
; conditions.
;-------------------------------------------------------------------
;  Notations used in tables:
;  ";" = remark character
;  "*" = start of a new table
;
;  "/" = special character
;      S = sheet thickness
;      R = bending radii
;      A = opening angle
;      T1 = Tolerance (+/-) for sheet thickness, S (valid for the
;           whole file)
;      T2 = tolerance for equal min and max bending radius, R
;           The T2 tolerance is only utilized at the minimum and
;           maximum bending radii, R, in the tables.
;           For model bend radii that fall between two values existing
;           in the table, the resultant correction value, x, is
;           determined by linear interpolation using the appropriate x
;           values in the table.
;      T3 = tolerance for equal min and max opening angle, A
;           The T3 tolerance is only utilized at the minimum and
;           maximum opening angles, A, in the tables.
;           For model opening angles that fall between two values
;           existing in the table, the resultant correction value, x,
;           is determined by linear interpolation using the
;           appropriate x values in the table.
;------------------------------------------------------------------
;  The correction value, x, is applied as follows:
;  L = A + B - x
```

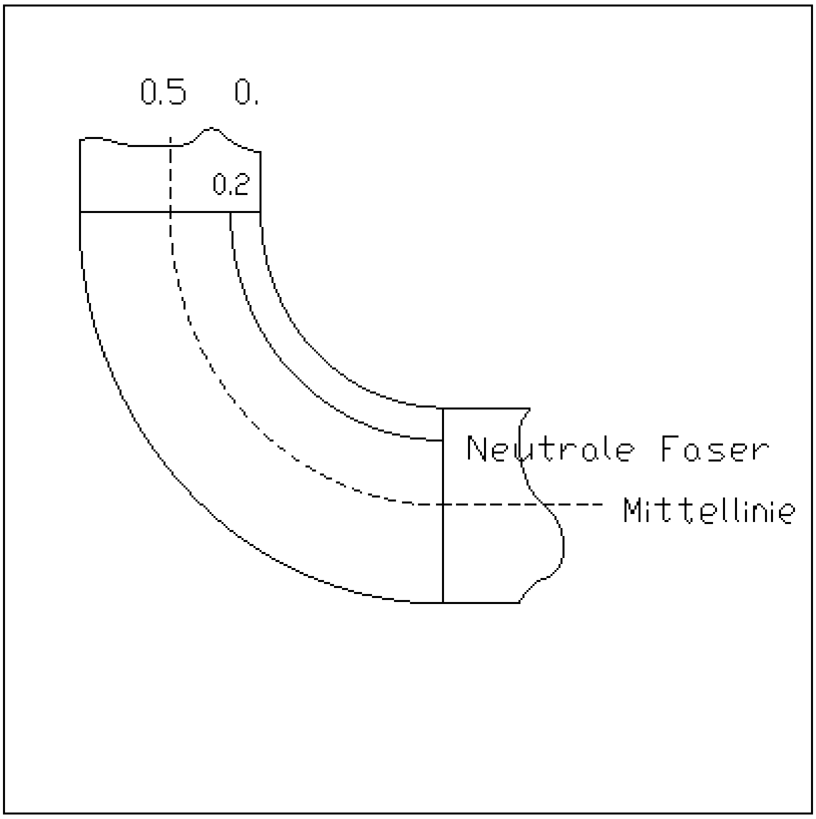
```
;  (L = unfolded length in flat pattern)
;  (A = length of side A (outside measurement of bendingzone))
;  (B = length of side B (outside measurement of bendingzone))
;---------------------------------------------------------------------
; Angle, A, expressed in degrees.
;---------------------------------------------------------------------
;TOLERANCES valid for the whole file
/T1 0.0001
/T2 0.01
/T3 0.01
;
*** TABLE 1
;sheet thickness
/S 0.5
;
;bending radii
/R            0.500  1.000  1.500  2.000  2.500  3.000  3.500  4.000
;opening angle: ---------------------- correction value x ----------
/A   60.      0.000  0.100  0.200  0.300  0.400  0.500  0.600  0.700
/A   70.      1.000  1.100  1.200  1.300  1.400  1.500  1.600  1.700
/A   80.      2.000  2.100  2.200  2.300  2.400  2.500  2.600  2.700
/A   90.      3.000  3.100  3.200  3.300  3.400  3.500  3.600  3.700
/A  100.      4.000  4.100  4.200  4.300  4.400  4.500  4.600  4.700
/A  110.      5.000  5.100  5.200  5.300  5.400  5.500  5.600  5.700
/A  120.      6.000  6.100  6.200  6.300  6.400  6.500  6.600  6.700
/A  130.      7.000  7.100  7.200  7.300  7.400  7.500  7.600  7.700
/A  140.      8.000  8.100  8.200  8.300  8.400  8.500  8.600  8.700
/A  150.      9.000  9.100  9.200  9.300  9.400  9.500  9.600  9.700
;
*** TABLE 2
;sheet thickness
/S 3.0
;
;bending radii
/R            0.500  1.000  1.500  2.000  2.500  3.000  3.500  4.000
;opening angle: ---------------------- correction value x ----------
/A   60.      0.000  0.100  0.200  0.300  0.400  0.500  0.600  0.700
/A   70.      1.000  1.100  1.200  1.300  1.400  1.500  1.600  1.700
/A   80.      2.000  2.100  2.200  2.300  2.400  2.500  2.600  2.700
/A   90.      3.000  3.100  3.200  3.300  3.400  3.500  3.600  3.700
/A  100.      4.000  4.100  4.200  4.300  4.400  4.500  4.600  4.700
/A  110.      5.000  5.100  5.200  5.300  5.400  5.500  5.600  5.700
/A  120.      6.000  6.100  6.200  6.300  6.400  6.500  6.600  6.700
```

```
/A  130.      7.000  7.100  7.200  7.300  7.400  7.500  7.600  7.700
/A  140.      8.000  8.100  8.200  8.300  8.400  8.500  8.600  8.700
/A  150.      9.000  9.100  9.200  9.300  9.400  9.500  9.600  9.700
;
; end of file
```

3.3 Calculate with neutral fibre

This calculation type allows the user to use empirical values:
The shortening of the folding zone can be determined manually by entering the position of the neutral fibre.

Values between 0 (corresponds to inner radius) and 1 (corresponds to outer radius) are possible. The length of the neutral fibre defined like this determines the actual folding zone length in cutting.



Calculate with position of neutral fibre

If the calculation type "*neutral fibre*" is set in the "*Settings*" dialog box, each folding zone is calculated with the values entered there for the actual position of the neutral fibre.

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