Roll Forming – General overview
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Design in the world of Engineering is a mental process of creativity when we layout our vision of functionality and arrangement of elements or details in a product.

Roll Forming Definition

Forming a flat strip of sheet metal through pairs of rolls gradually without changing the thickness.

Roll Forming is a progressive motion process of forming flat strip of cold metal through several stages of forming or bending.
Henry Court has introduced forming steel using the technology of rolling in 1783. His first rolling mill had grooved rollers to produced iron bars more quickly and economically than the old methods of hammering.

The idea has been developed through the centuries and today’s modern roll mills are used to form continuous flat sheet metal in almost any desirable shape.
The technology of Roll Forming is justified when:
- Great volume of parts is required to be produced (i.e. 1,000,000 feet per year)
- Ability to produce variety of shapes in the same Roll Mill
- Ability to produce parts at variable length
- Ability to produce parts of similar shape with the same Roll Tooling
- Smooth surface on the finished product
- Forming parts with different thickness - 0.006” – 0.750”
- Integration of additional operations in line such as notching, piercing welding, embossing etc.
- Sufficient cost reduction 15% to 25% in great volume compare with press brake forming
Designing parts for the technology of Roll Forming

Good Roll Formed Product requires proper Product design. Product features the designer must be aware of:

1. **Cross section depth**
   - The depth of the part determines Roll’s Diameter
   - As deeper is the cross section, as bigger is the Roll’s diameter and controlling the shape of the part is more difficult.
   - Deeper cross section will require more passes for smooth run. It is even more complicated if the part is not symmetrical.
   - Deeper cross section will require sufficient distance – vertical (bottom to top shaft) and horizontal (pass to pass).
   - The cost for the Roll Tooling is higher (if it can be accommodated to an existing Roll Mill. Otherwise a new Roll Mill will be required with a configuration to meet the part’s design requirements).

2. **Web length or flat area**

When the part is designed for Roll Forming should be considered the following:
   - Length of the flat area
   - Wide flat cross sections will cause wrinkled surface

   - If having a wide flat cross section is absolutely necessary - consider flattening Rolls (i.e. after roll forming the part is additionally bent and cut through a progressive Die in 2 or 4 pieces),
   - If the desired wide flat area is not of importance for assembly purposes - consider adding grooves (arcs, triangle or rectangular shape) for stiffening. Too many grooves as well may cause cross bowing. One or two grooves are desired in the middle of the part.
3. Cross section and elements

For the purpose of the Roll Tooling design is important to be determined all arcs and straights elements. Arcs reflect the bending angle (what is the most appropriate angle of bending without stretching the straight elements at the end) and radius of the neutral axes. Straight elements reflects to the elongation of the material – stretching or compressing when the material moves from pass to pass, trapping (locking) the part between the Rolls. The length of each straight element is important.

4. Piercing, notching, holes pattern

In Roll Forming strain is the worst enemy and having openings in the material often create unpredictable side effects.

In product design should be considered the following when holes piercing or edge notching is required:

- Holes should be away at least 3 – 4 times material thickness from the line of bending
- Holes should be at sufficient distance from the cut edge
- Holes close to the part edges will cause wavy edges
- Holes at the line of bending will be distorted into an oval.
- Having edge notching is considered forming a precut material. The continuity of the strip strength is disturbed and is required more passes – up to 1/3 more passes.

5. Minimum Radius of bending

Generally is considered minimum inside radius of bending = material thickness.

6. Air bending

Some products are having for example “T” shape sections where so-called air bending is required. The meaning is that the Rolls are not in contact with the material when forming it. In that case side roll passes are required or push blocks.

Forming a part like:

is mostly air bending.
7. **Symmetrical Cross section**

When the left hand side and the right hand side of the part are the same, side effects are not expected.

8. **Non Symmetrical Cross section**

Side effects are expected for non-symmetrical parts such as:

- Longitudinal bow
- Camber (sweep)
- Twist
- Flare – edges at both end will be opened or closed
- Cross bow – the bottom (web) of the part will deviate from straight to round

Cause of the above effects can be as a result of not only because of non symmetrical part but:

- Tight tolerances
- Not appropriate bending radiuses with a respect of material thickness and material properties
- Not sufficient roll tool design
- Holes are too closed to the edges in pre-notching and pre-punching stage
- Stress concentration in the material
- Your roll mill is too old and you have difficulties maintaining shafts parallel in horizontal and vertical direction.
- Your roll mill is not set up properly

Solutions for such effects:

- Evaluate the product with all tolerances, holes location, thickness, mechanical properties etc. before offering Roll Forming technology
- Require good roll tool design (to avoid re-cutting)
- Good Roll Mill condition and efficient set up
- Evaluate the work done by each pair of rolls for each pass
- Require side roll passes
- Require strengtheners

9. **Part dimensioning**

It is considered the correct method of dimensioning when the part is measured inside not outside. All deviation in material thickness is considered to be accommodate outside
10. **Tolerances**
For the purpose of high volume of production (meaning of high speed) acceptable tolerances are required in order to justify the technology of Roll Forming. Depends on the application the Roll formed products can have:
- Loose - +/- .030”-.040”
- Medium - +/- .015”-.025”
- Tight - +/- .005”
Tolerances. It is a thin line between production volume, line speed and reasonable tolerances. Loose tolerances allow high speed roll forming. Tight tolerances will require more Roll Mill passes and low line speed. All Roll Formed products must have reasonable dimension variables without to affect the function of assembly.

11. **Material mechanical properties**
It is important for the purpose of roll forming to be understood the **yield strength** of the material. When bending, the material must be stressed beyond the **yield point**, otherwise it will spring back. Permanent deformation of the material is happening after the yield point. **Ultimate strength** or so-called **Tensile strength** is the maximum stress value obtained on a stress - strain curve.
**Theory of Bending**

**Bending and changing the radius of neutral axis**

Forming a flat strip of cold metal is a process that is a progression motion through several stages of forming or bending. In any cross section you can define straight and curved elements. It is assumed that the straight elements do not change their length. For the curved elements the neutral axis is changing position and the location depends on:

- Material thickness
- Radius of bending
- Material’s mechanical properties

Let’s look at a curved element and isolate a single fiber or visualize it as a rod (see Fig No1) between sections: 1-1 and 2-2 in an angle $d\psi$.

O1-O2 fiber axe before bending, C1-C2 after bending – neutral axe

The normal stresses ($\sigma$) on both sections 1-1 and 2-2 are creating a pair and the line between the section 2-2 and actual line of action will change with ($\delta d\psi$)

To define the normal stresses ($\sigma$) between points A1 and A2 in a distance Z from the neutral axe will accept the positive Z direction (of the coordinate system) as and extension of section 2-2.

The fiber A1A2 will elongate A2D2 and the respective stress is:

$$\sigma = \varepsilon E$$

Where $\varepsilon$ - the relative fiber elongation A1A2.

$$\varepsilon = \frac{A1D2}{A1A2}$$

$\rho$ – radius (A1A2 fiber)

Therefore:

$$A2D2 = z \delta d\psi$$

$$A1A2 = \rho d\psi$$

$$\varepsilon = \frac{z \delta d\psi}{\rho d\psi}$$

$$\sigma = \left(\frac{z \delta d\psi}{\rho d\psi}\right)E \quad (1)$$
Formula (1) based on Huck’s Law gives the normal stress distribution in height in relation of bending moment.

As \((\delta \frac{d\psi}{d\psi})\) and \(E\) are constant, the normal stress \(\sigma\) is changing and depends on variables: \(z\) and \(\rho\)

In straight beams the stress has linear distribution.

In curves the stress has hyperbolic distribution (Fig.2). It can be seen that the stress in positive direction (+)Z is increasing slower than those in (-) Z direction.

Thus in a curve section the stress is bigger in inner side than in outer side of the element.
If we solve the static equation:

\[ \sum X = 0; \quad \int_{F} \sigma \, dF = 0; \quad (2) \]

And

\[ \sum M_y = 0; \quad M - \int_{F} \sigma \, dF z = 0; \quad (3) \]

\[ \int_{F} \sigma \, dF = \int_{F} E (z/\rho) \, d\psi \, d\psi \, dF = 0 \]

As we solve it:

\[ \int_{F} (z/\rho) \, dF = 0 \quad (4) \]

This equation allows us to find the position of the neutral axis. As we exchange

\[ z = \rho - r \quad \text{(Fig. No1)} \]

\[ r = \frac{F}{\int_{F} dF/\rho} \]

It is essential to understand the bending and stress distribution in the process of Roll forming, where bending is happening in each stage of forming the strip, the mechanical properties of the material and the minimum radius of neutral axes.

All that refers to Roll’s tool designers, who need to foresee the behavior of the material in each stage of forming and properly design the tooling. There are few roll tooling design software in the market with sophisticated features as FEA calculations that predict side
effects but still there are many unknowns in this area and only the designer’s experience is the key in tooling design.

**Bending allowance—Recommended bend radius**

Recommended bend radii can be found in standard steel specifications (ASTM, DIN) or by the steel supplier.

As a rule of thumb:
- For CRS 30-50kpsi yield bending allowance is 35-40% inside radius
- For stronger materials – 80kpsi it should be considered close to 50%

**Roll Tooling Design – general overview**

**Design procedure**

1. Draw the part
2. Count all arcs and straight elements of the part
3. Determine the pass line
4. Determine the center line
5. Determine the most convenient layout of the part for roll forming
6. Flower development

Using one of the programs on the market for Roll Tooling design configure:
- Passes required for forming the part
- Strip width calculations
- Roll Mill required shaft diameter
- Roll Tooling Diameter
- Roll’s Progression from pass to pass
- Vertical distance
- Horizontal distance
- Bottom to Top shaft ratio
- Roll space required in the Roll Mill
- Bending allowance based on the mechanical properties of the material
- Any side roll passes for Air bending or shape control
- Straightening mechanism
- When developing the flower start unfolding the part from finished shape to flat strip
- Based on the material thickness and mechanical properties evaluate all bending angles. Smooth bending is required. Choose the most appropriate angles for each straight element bending.
- Smooth run from pass to pass is required. If the angle of attacking the bend is too big it may cause edge waviness

For more instructions on flower development see [RH95 Simply Roll Design Software tips](#).
7. **Design the Roll Tooling around the flower.** All Roll Tooling Software develops the Rolls around the flower automatically. **It is designer’s responsibility to decide:**

- Where to trap the part
- Use both ends of the Rolls as gagging – for set-up purposes
- Clearance at the corners – Female’s rolls
- Where to release the rolls in order to avoid or reduce material scuffing or using top Rolls as idlers
- Where to split the Rolls for the purpose of CNC machining.
- What type of steel material to use for Rolls. The most recommended tool material for Roll Tooling in today’s market is: 52M, L6, O1, D2.
Roll Forming Machine Configurations

The Roll Forming Machine is defined by:

- Quantity of Passes
- Shaft Diameter
- Roll’s space
- Bottom to Top shaft Ratio
- Vertical distance – Top to Bottom shaft
- Horizontal distance – Pass to Pass
- Type of Roll Forming machine
- Required Horse Power
- Line speed

The engineering methods of calculating the shaft’s diameter and Horse Power are complicated and most Roll Forming Machinery builders are configuring the machine based on their experience.
Roll Forming Machines – types and applications

1. Dedicated

   Featured:
   a. Inboard stands with bottom to top gears driven,
   b. Top to Bottom shaft Ratio - fixed
   c. Worm gear reducers connection – Bottom shaft driven
   d. Outboard Stand – removable
   e. Heavy Duty Base

   Applications: This type of Roll Mills is build for dedicated product/products

2. Continuous gear reducer box

   Featured:
   a. Inboard continuous Gear Reducer
   b. Outboard Stand – removable
   c. Heavy Duty base

   Applications: Build for dedicated product/products (can be used for few products with same Roll Tooling Diameter). It is a less expensive version of dedicated Roll Mill. The gears are hardened teeth. It is convenient for mounting side roll passes.

3. Cantilevered

   Featured:
   a. Continuous Gear box reducer
   b. Shafts cantilevered length – 5-6”
   c. Easy Roll tooling change, service and alignment
   d. Heavy Duty Base
**Applications:** When often Roll Tooling change is required, alignment and roll tooling set up is easy and quick.

4. **Section**
   Featured:
   a. Inboard Stands with quick disconnect coupling
   b. Outboard stand – standard design
   c. Section plate – one section consist of 4 passes (standard)
   d. Worm gear reducers continuous driven
   e. Heavy-duty base with location pins for the sections mounting. The base is build to accommodate different quantity Sections – depends on the profile’s passes requirements.

**Application:** The Sectioned Roll Mills are developed in order to save time and money for Roll Tooling change, Tooling set up, alignments etc. The roll tooling for certain profile is aligned and setup in one set of sections (2, 3, 4 sections). With quick disconnect couplings changing set of sections from one profile to another is easy

5. **Gear Head**
   Featured:
   a. Ability to accommodate different size of Roll Tooling (Diameters) and bottom to top shaft ratio – 1:1, 1:1.5, 1:2 (or any custom ratio)
   b. Inboard stand – gear head warm gear reducer with linkages
   c. Outboard Stand – standard configuration
**Application:** Designed and build mostly as an universal Roll Mill with ability to be used for forming different profiles – when different Rolls Diameters and ratio is required.

6. **Duplex**
   a/ Duplex Roll Mill with cantilevered shafts:
   - Heads adjustable towards the center line

   **Application:** When both sides of the profile are symmetrical including any piercing towards the centerline. The centerline of the Roll Forming line is Datum. Opening or Closing the heads accommodates profiles with variable width. Continuous strip applications
   - One head – stationary, other – adjustable with drive shaft through.

   **Application:** When the technology is using precut sheet metal. Alignment of the sheet is towards the stationary Roll Mill Head. The Datum line is the Stationary Head’s shaft alignment. Opening or Closing the heads accommodates profiles with variable width up to 48”. Applicable for door panel lines.

   b/ Duplex Roll Mill with slides shafts.
   One head – stationary, other head – adjustable with drive shaft and Roll’s shafts sliding through.
**Application:** Using Duplex Roll Mills with Top and Bottom shafts sliding through is applicable when the Cantilevered shafts Roll Mills are not capable of voiding shafts deflection. This type of design, features firm shaft support at any profile width without causing shaft deflection – when the bending line of the formed profile is too far away from the shaft’s bearing.

7. **Double Duplex**

Double duplex Roll Mill is an accommodation of 2 Duplex, Cantilevered shafts, continuous gear head Roll Mills with adjustability towards the centerline.

**Application:** Stud Roll Forming Line. Stud requirements: Lip – $\frac{1}{2}”$, Leg 1.5” to 4” and Web 4”-12”. The First Duplex Mill forms the lip of the stud. The second Duplex Mill is forming the Leg.

Construction applications, cable tray application etc.

8. **Double deck Roll Mill**

Two Roll Mills are accommodated in one common base elevated in different height.
- Common base
- Common Drive
- Different height Pass Line

**Application:** Two similar Profiles are Roll formed simultaneously – i.e. Corrugated metals.
9. **Ultra thin Roll Mill**

Features:
- 5/8 to 3/4” Shaft Diameter
- Ultra fine system for shaft elevation
- Continuous gear transmission

The above covers the most general type of Roll Forming Machines, but there are many other types of Roll Forming Machines on the Market – custom designed for custom metal processing technologies.

**Roll Forming Lines Configuration**
See Roll Forming Line for general layout in our web site.

**PRODUCTS**

Varity of shapes can be roll formed if we have:

- The right product design
- The right material
- The right equipment
- The right tooling

Material of the product can be: cold rolled steel, hot rolled steel, galvanized, stainless steel, aluminum etc.

Applications: Roof and wall panels, residential framing, channels, structural frames etc.

**Reference**

1. Soprotivlenie materialov – P.A. Stepin
2. Machinery’s Handbook

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