Rolling sheet & plate

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Rolling is similar to forming sheet metal with press brake; it can be a “black art” or maybe magic, but in reality it is neither.

It comes down to understanding the properties of the material and how pressure from the rolls can affect those properties. A good example is the result of forming in the press brake when each material piece is different; each will form, or roll, differently than the last piece. But, with knowledge and understanding, the black art of rolling or forming can become a workable skill.

Operating Parameters of the Machine

Begin with selecting the correct machine to roll the part on. Modern rolling machines are usually cambered (crowned) at 50% of the full-rated value of the machine. Therefore, a 1-inch machine is cambered to roll 1/2-inch plate. All machines are really designed to function best when used to half their working value.

Problems arise when the upper limits of any machine are approached, be it roll former or press brake. That means that even a small increase in thickness can make a difference in the way the rolls will perform. For example, if a .625-inch plate is rolled through a 1.000-inch rated machine, a small degree of barreling will likely occur.

Rolling Diameters

Part of taking roll forming out of the realm of “black magic” is selecting the right sized roller for the job. A good “rule of thumb” for three and four roll machines is that you can roll sheet or plate at 1 1/2 times the upper roll diameter, but that is not the case for the two roll urethane roller. If the top roll has a 10-inch-diameter, the minimum best practice “rollable” inside diameter will be 15 inches. Almost all machines achieve precise measurements working at 50% of the full-rated value of the roll.

Machines that incorporate planetary guides keep roughly 50% more area under bend-pressure at any one time. This design can achieve ratios of one-to-one with the upper roll diameter. Given that one-to-one roll geometry, a roller rated for 3/8 of an inch, with a 10-inch top roller should consistently roll .187-inch plate to an 11.00-inch ID with little or no barrel effect.

Basic Operations

The setups vary from one roller configuration to the next, but as with press brakes, we need to choose one to work with. In this discussion we will use the most common roller, the initial-pinch, 3-roll system. Roll “B” is the pinch roll that moves up and down, slightly forward of the fixed top roll “A”. The bending roll moves diagonally, transiting toward and away from the fixed top roll.

The pinch rolls provides the “grabbing” force, while the bending roll’s position determines the forming geometry, figure 1.

Slip or plate rolls need to grab the material during rolling. That’s why, in any rolling operation, there is a narrow unbent flat section on the plate’s leading and trailing edges. An operation known as pre-bending reduces the length of these unbent flat sections. These flat sections should be no more than two to three times the material thickness for most rollers. Pre-bending the plate’s leading and trailing edges before performing the final rolling can remove these flats. Using most double-pinch and four-roll systems it’s possible to pre-bend the leading plate edge without removing...
the sheet or plate from the roller before performing the final rolling.

**Consistency**

Consistent roll forming involves controlling the forming roll pressure and location. Softer materials require less pressure than harder materials. The *yield strength* of soft material will cause it to start forming sooner than a high yield strength material will. That being said, different types of materials with identical in thicknesses and rolled to identical diameters have will dramatically different positions of the rolls.

When air forming on a press brake you have the three points of contact: the two die shoulders and the punch nose, and you have only one bend line. In rolling, there are hundreds of bend lines, the continuous point of contact between the rollers, so *springback* is not isolated to one area; it is continually being created and released.

On the press brake the bend occurs at the same location with every stroke, directly below the punch tip. But that's not the case with a roller. Every time the “forming roll” is raised, lowered, moved in or out, the roll changes. The more you raise, lower or move the rolls the more pressure you add or remove from the process.

A point of note, the closer the “forming roll” gets to the pinch rolls, the greater the required pressure but also the closer to the edge the radius will get.

**Springback**

As in any forming operation, rolling, too, has to deal with springback, a property of the material in rolling sheet metal that may require an overlap, sometimes by inches. But, just like springback on a press brake, when you release the part from the pressure it will spring back. If rolled to the correct diameter, a closed and an appropriate gap will be the result.

**Anti-Deflection and Crowning**

The goal is to achieve parallel lines of pressure. Again, like the press brake, the roller is rigid near the ends and deflects in the center. The roller can remain cylindrical, but is no longer straight. And, like the press brake, this deflection is a normal part of machine operation.

The rollers deflect in the same way the ram of the press brake does under load; it “opens” or “flexes” in the center, deflection, figure 3, which has the effect of lessening the pressure from the forming roll on the bend at center. So, like press brakes, many rollers employ some form of anti-deflection device or crowning system. One common anti-deflection method is for the rolls to have slightly larger diameters in the middle of the rolls than at the ends.

A roller supported from one only side is considered a cantilevered roller which will deflect in increasing amounts the further away from the supported end the workpiece gets. A roller supported from both ends will have maximum deflection at the center of the roller.

If there is not enough crowning the effect will be a “barreling”. This is where the ends of the cylinder hold a tighter diameter than the center. Too much crowning will produce the opposite
effect, the cylinder will have an hourglass shape, figure 4.

There are two possibilities for the barreling effect: there isn’t enough crowning in the center of the “forming roll” or the “pinch rolls” are not set correctly.

**Roll Distortions**

Knowing why and how the material will react to an increase in pinching pressure is the goal. Why does it work for some materials, but not with others? High yield strength materials can handle more pressure. But soft, low yield strength metals such as H-series aluminum, increasing the pinching pressure can distort the material. The material can thin and distort under excess roll pressure so some caution is required.

Every change in crowning pressure changes the amount of deflection in the center of the roll. A slight barrel shape confirms the center of the roll is deflecting away from parallel. Looking head-on, the line of roll pressure resembles a smile, figure 3, top graphic.

There may also be thinning or distorting of the edge of the workpiece. If this is the case, try decreasing the pinch roll pressure slightly. Allow the middle of the roll to deflect just enough that the rolling surfaces return to the parallel line of pressure that should be present across the width of the workpiece during rolling. This will not eliminate the barreling effect; in fact it will most likely make the barreling worse. With inefficient machine crowning shimming may also be required.

On the other hand, if you have excessive crowning a slight hourglass shape is the result. The line of pressure across the roll now looks like a frown. The frown turns into a straight line of pressure when the crowning is reduced.

**Shimming for Crown**

At some point you may need to shim a workpiece to create a crown. Placed in the center of the workpiece and in the center of the roller, the shims themselves can be pieces of cardboard, plastic, or even light gauge sheet metal, etc. This is a manual way to add crowning effectively. Just as shimming press brake dies start with a wide shim and gradually builds to a center, for example: six feet of shim, under four feet of shim, under 2 feet of shim. It is not a good practice, nor will you have good results if you try to place a thick narrow shim dead center.

It is also possible to shim along the edges of the workpiece to compensate for any excessive crowning and hourglassing that may be present.

**Gravity**

In thin-gauge rolling, you also have to worry about how the rolled cylinder will behave as it climbs up and over the centerline of the roll. Thick plates have the structural mass to maintain their shape throughout the rolling process. Thin sheet metal can bow under its own weight changing the radius and distorting the part. Gravity can change the point of bend! At first, it forces the material away from the “pinch rolls” and then toward the “forming roll”. For example, bend past 180° and gravity will pull the sheet inward.

For large or tight-tolerance work an additional overhead support system will be required; and if the material is
structurally weak, the sides of the roll may need to be supported and guided through the rolling process as well.

This may just be a bar that supports the part at the apex, or it may be a large curved table of rollers. Either way, you are going to need them, figure 5.

**Squaring the Blank**

In order for the rolling operation to work well, much care must be given to “squaring” the blank or sheet to the rollers. On a three-roll machine, squaring of plate is a very difficult process, and again one of the most important. It is also extremely difficult to control and square a sheet or plate over a six feet in length with just one person.

Three-roll manufacturers put a small groove in the forming rolls to help line the plate up and some have a perpendicular side bar similar to a shear. But with plate it normally requires two people to square plate properly. No matter how long it takes, there is no alternative; the plate has to be square or you cannot proceed. This process, on a three-roll, is time-consuming affair.

In order to obtain a perfect cylinder using a three-roll double pinch, it is necessary to work through several steps:

1. It is necessary to pre-bend the leading edge of material, done by pinching the plate between one of the forming rolls and the top roll; or pre-bend on a press brake.
2. Lower the opposing side roll to backgauge off from and square the blank for the first pre-bend. Because a three-roll machine is impossible to just load and roll, it requires the material must pass all the way through the machine in its stretched-out condition for the second pre-bend.
3. When the pre-bends are completed the roll position changes and the plate moves back to the center of machine. Then, position the forming roll in the correct position to roll the required diameter.

On a CNC controlled four-roll machine, the process is automatic. The squaring is done by lifting one of the forming rolls and using it as a squaring gauge. Once the material is in complete contact the lower “pinch roll” is brought up until it pinches the material.

This is a good place to mention the importance of having a firm grip on the material. If the plate slips and gets out of square, the bending roll movements will be out of synch and the material’s translation through the machine will be affected.

**Controllers**

As with all modern equipment, roller CNC controls are a matter of picking a shape and filling in the blanks: what are the radius, angles, flats or diameter, and the controller does the work, figure 6 and are unique to the four roll machines. The Initial and Double Pinch roller controls tend to be pretty basic, figure 7. The fact that a three-roll double pinch has six positionings used to achieve the diameter, it means it becomes a very time consuming task with a risk of creating a lot of scrap.

A four-roll machine, which requires only two positioning’s, never releases the metal until the final correct diameter is reached. These controller/machines may have hydraulic proportional valves that send and receive data from the controller; this is interpolation or real time. When the machine is capable of interpolation the controller is able to move the axes incrementally, continuously and simultaneously allowing for some complicated geometries.
A “Stop line” is imparted to any rolled part whenever the rolls stop and start; non-interpolated three-roll and four-roll machines leave these marks, but the interpolated four roll’s movement is continuous and therefore leaves a mar-free surface.

Programming and Rolling a Part on a Comal Roller.

**4 Plate Bending Machine**

Programming and Rolling on a 4-roll
Courtesy of Comal Italia

**Cone Bending**

Rolling a cone on a three-roll machine is very difficult at best, realizing that a cone is created by rolling the plate at two different speeds at the same time. It is very difficult to do.

Both the three-roll and the four-roll machines are capable of inclining the forming rolls in a positive attitude, figure 8, and both should have a hardened contrast die to control and slow down the speed of the small diameter, figure 9.

Guiding the small diameter and inclining the rolls are necessary to roll a cone. In this case you are creating an unnatural situation for the rolling process. Because on a three-roll double pinch machine all three-rolls are driven, it makes it difficult for the contrast die to retard the rotation on the small diameter while making the large diameter move faster.

A four-roll machine which has inclinable forming rolls and a hardened contrast die, will roll better than a three-roll.

The four-roll pinch roll can be inclined in a negative attitude and at the same time adjust the forces of the pinches allowing the roll to grip the cone only on the large diameter which needs to turn faster, and only with enough force to turn the part. This allows the small diameter to be slowed down.

The following video courtesy of Davi Rollers, gives a demonstration of the four-roll pinch roller and how it works.

**Roller**

Cone Rolling
Courtesy of Davi Rollers