Plate rolling rolls on
Advanced controls make a highly variable process more predictable

Advanced controls make a highly variable process more predictable. Abstract: Experience is still important when it comes to plate rolling. But the more knowledge industry has gained about the materials being rolled, the more "intelligent" plate roll systems have become.

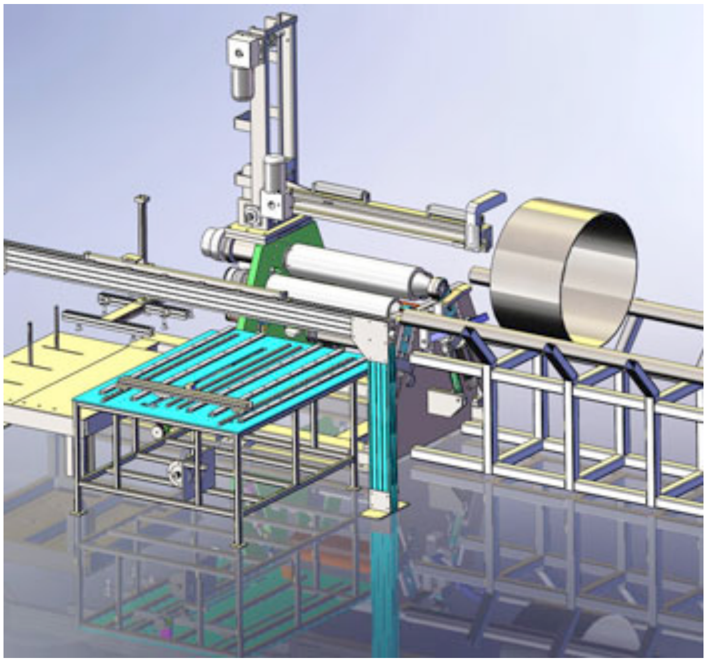
Image 1

Smart controls and a library of rolling data make automated plate rolling possible.
Plate rolling is one of the most complex metal fabrication processes. Changing just one variable directly affects numerous others. When a plate roll is set up, spring-back is a major factor, as is the material's chemical composition and work-hardening characteristics.
For years machine operators learned the seemingly black art of plate rolling simply by doing it repeatedly, usually for months and years, where experience remained important. The more knowledge industry has gained about the materials being rolled, the more "intelligent" plate roll systems have become.
Today many plate rolls have CNCs with data tables that draw from decades of rolling experience, which has made the process much more predictable. With predictability also comes automation. Some plate roll operations now have automated the loading, rolling, and unloading, producing precisely rolled workpieces time after time *(see Image 1)*.

Basic Material Considerations

When rolled into a round or arched shape, the sheet or plate will spring back by a certain amount, and that amount depends on many factors. In fact, as highlighted by studies and tests carried out in various parts of the world, the precise amount of workpiece spring-back can only be determined experimentally.
Regardless, some basic factors usually apply:

- Thinner sheet - more spring-back
- Larger radius - more spring-back
- Smaller radius-to-thickness ratio - less spring-back
- Bending sheet in fewer steps (when rolls move to produce a different radius) - less spring-back
- High yield strength - more spring-back
- High elastic modulus - less spring-back

Add work-hardening factors into the equation as well, especially when rolling material like stainless steel. Consider some classic stainless materials, ASTM 304 and 316, which have certificates that often indicate yield strength close to 220 MPa (about 32,000 PSI). When a sheet of this material is rolled, its yield strength increases proportionally to the number of bending steps, until the yield strength reaches a value close to 360 MPa (50,000 PSI). This is why such work-hardening (or self-hardening) phenomena should be taken into account when evaluating the rolling capacity of a particular machine. The material's chemical composition influences yield strength and hardness. A brief look at a sheet's certificate can tell a fabricator a lot about how the metal will behave in the plate roll. Key elements to observe include carbon (C), nickel (Ni), chromium (Cr), manganese (Mn), molybdenum (Mo), and silicon (Si). More carbon makes steel harder. So does more chromium, the alloying element in stainless steel. Both manganese and molybdenum can increase the hardness. And so can silicon, which can also decrease elongation characteristics.

Changing the amount of each element alters a sheet's rolling characteristics, as well as rolling capacity considerations. An ASTM 304 stainless steel the identical size and thickness of a carbon sheet,obviousl,will roll very differently. Even for two sheets of 304 stainless with certificates showing identical chemical makeup, the rolling results still may be different, thanks to different heat-treatment processes.

CNC and the Plate Roll

Plate rolls have followed a similar path as other machine tools. What was once a manual process now is guided by electronic automation. This has led to greater precision in plate rolling, higher operating speeds, and greater throughput. The need to roll not just cylinders, but complex geometries, requires an automation system that is not rigid, but flexible, so that the movements of specific rolls can be interpolated as required. With a CNC, the operator is in a position to improve production in terms of quality, quantity, and safety. The CNC works with various sets of data including basic machine parameters, roll programs, machine geometry variables, as well as data tables like those for material correction.

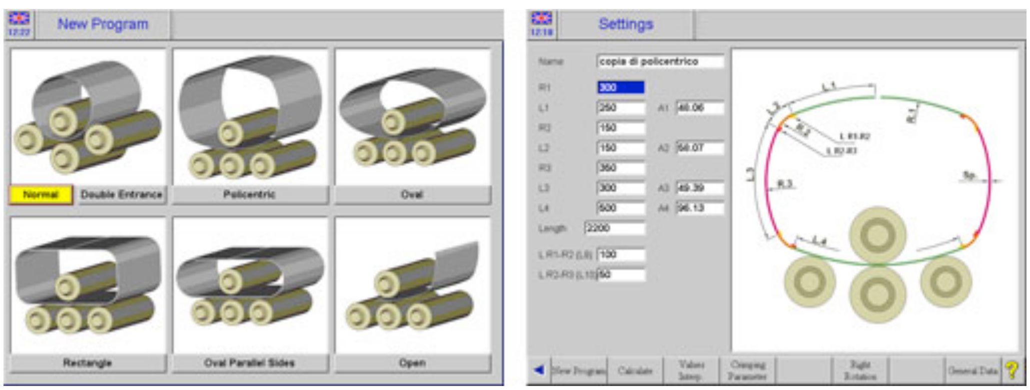

Image 2

Modern controls allow technicians to choose specific workpiece geometries (on left), and then enter specific values for various portions of the rolled section (on right).

A standard four-roll system with a CNC may have up to 11 axes to control, including pre-bending (to minimize unbent flat sections at the plate edges), bending, gripping, roll rotation, and (if required) overhead supports that prevent thin sheet from bowing during the operation. These controllable axes allow technicians to program various shapes, from a conventional round cylinder to one that is polycentric, with multiple radii throughout the cylinder circumference. These can include a standard oval, an oval with parallel sides, a rectangle, as well as an open arc *(see Image 2)*.

Like other machine tools, modern plate rolls now feature greatly simplified programming with a graphical user interface. The operator can choose the shape he wants and enter the desired length and radius for each rolling step. He runs the job and then, based on the results, alters the program as necessary. These jobs can then be saved in memory and called up again as needed. And if the sheet metal characteristics change, the operator need not manually alter all the data points, but instead insert the correction as a percentage change from the original parameters.

The rolls themselves can be programmed to move up and down at different speeds, depending on the precision desired for each step in the rolling program. The roll can move rapidly to a predetermined point near the programmed value and then, to obtain maximum precision, move slowly until it reaches the exact position. If a high degree of precision is not required, the roll can move into position in a single, rapid movement.

Production Rolling

Technology advancements have turned the plate roll into a high-production system. Certain production machines that roll thin sheet can use seemingly simple two-roll systems, with one roll placed above the other. The upper roll is fitted with special liners (called spindle pipes) to set the required workpiece diameter.

Such rolls can be integrated with material handling systems that automatically load and unload the thin-sheet workpieces. Other automated systems integrate such rolling with subsequent welding. Some rolls may be coated with neoprene or undergo special treatment to protect against markings and similar wear from repeated contact with workpiece after workpiece.

Similar automation may be integrated with common four-roll systems as well. Four-roll machines minimize prep time when it comes to procedures like pre-bending. On a typical three-roll system, for instance, to minimize the unbent flat section near the weld joint, both the leading and trailing edges of the sheet must be pre-bent prior to rolling. But with a four-roll system, the machine accepts the plate, pre-bends the leading edge, rolls the geometry, and then bends the trailing edge. This gives the four-roll system a slight productivity boost, which is why it has become so popular in production-rolling environments.

Unbent flat sections are less pronounced on thinner sheet, but the pre-bending requirement remains for precision work. Bowing, however, becomes more pronounced with thin-sheet cylinders, which tend to bow under their own weight as they form into their final shape. This is where material supports come into play. When the workpiece reaches an overhead roller support at the 12 o'clock position, that roller supports the workpiece and ensures the thin-gauge material remains where it is programmed to be, and not bowed downward and distorted.

Ultimately, advanced rolling systems must be designed with reliability in mind, because machine uptime is paramount. After all, production rolls, many designed with custom-built loading and offloading systems, need to keep on rolling.

The Math Behind Plate Rolling

The plate rolling process involves two groups of important variables. The first group hinges on the machine, such as the number of rolls, their diameter, position, and how they move. All these depend on the machine being used. The second variable group deals with the workpiece involved, such as the maximum plate width (W), maximum plate thickness (Th), and the minimum workpiece diameter (Ø), as well as the type of metal and its yield strength (YS). These variables can be plugged into an equation: W x Th2 x YS/g = K, where K is the constant and g is a parameter that takes into account the workpiece diameter and the machine geometry.

Applying such equations requires detailed application information, of course, but the important takeaway here is the factor Th2. Note that the sheet thickness value is squared, implying that a small change in thickness can have a dramatic effect on roll parameters.

By: Francesco Massa

Francesco Massa has worked as a senior development engineer at several European plate roll manufacturers.