UNDERSTANDING FLOWFORMING

A PRECISION METAL FORMING PROCESS UNIQUELY CAPABLE TO ACCOMPLISH YOUR DESIGN OBJECTIVES.

PMF
INDUSTRIES, INC.

For hollow metal components that require precision, economy, and flexibility, flowforming has some unique benefits that will help you accomplish your design objectives. An advanced form of spinning, flowforming has been used for years in the military and aerospace industries to produce precise, thin-walled, seamless rocket motor and missile casings, nose cones, rocket housings, and, more recently, large cartridge cases. However, the process is being used for many other commercial applications such as for components in equipment for the aerospace, transportation, filtration, food and electronics industries, where there is a requirement for hollow symmetrical shapes with relatively close tolerance control, variable wall thickness and profile, improved tensile strength, and superior inside surface finishes.

> *“*
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The Process.

Flowforming is a cold metalforming process for the manufacture of rotationally symmetrical, hollow components. The process uses rollers to extrude and therefore thin or reduce the cross-sectional area of the wall thickness of a blank (called a preform), which is engineered to produce a cylindrical, conical or contoured hollow shape. The preform is extruded over a rotating mandrel. The thickness of the finished part is determined by the gap that is maintained between the mandrel and the rollers during the process. This gap can be changed or remain constant anywhere along the length of the part. Flowforming is the only metalforming process that allows the flexibility to vary the wall thickness to produce thicker and thinner sections in any combination almost anywhere the rollers come in contact with the part.

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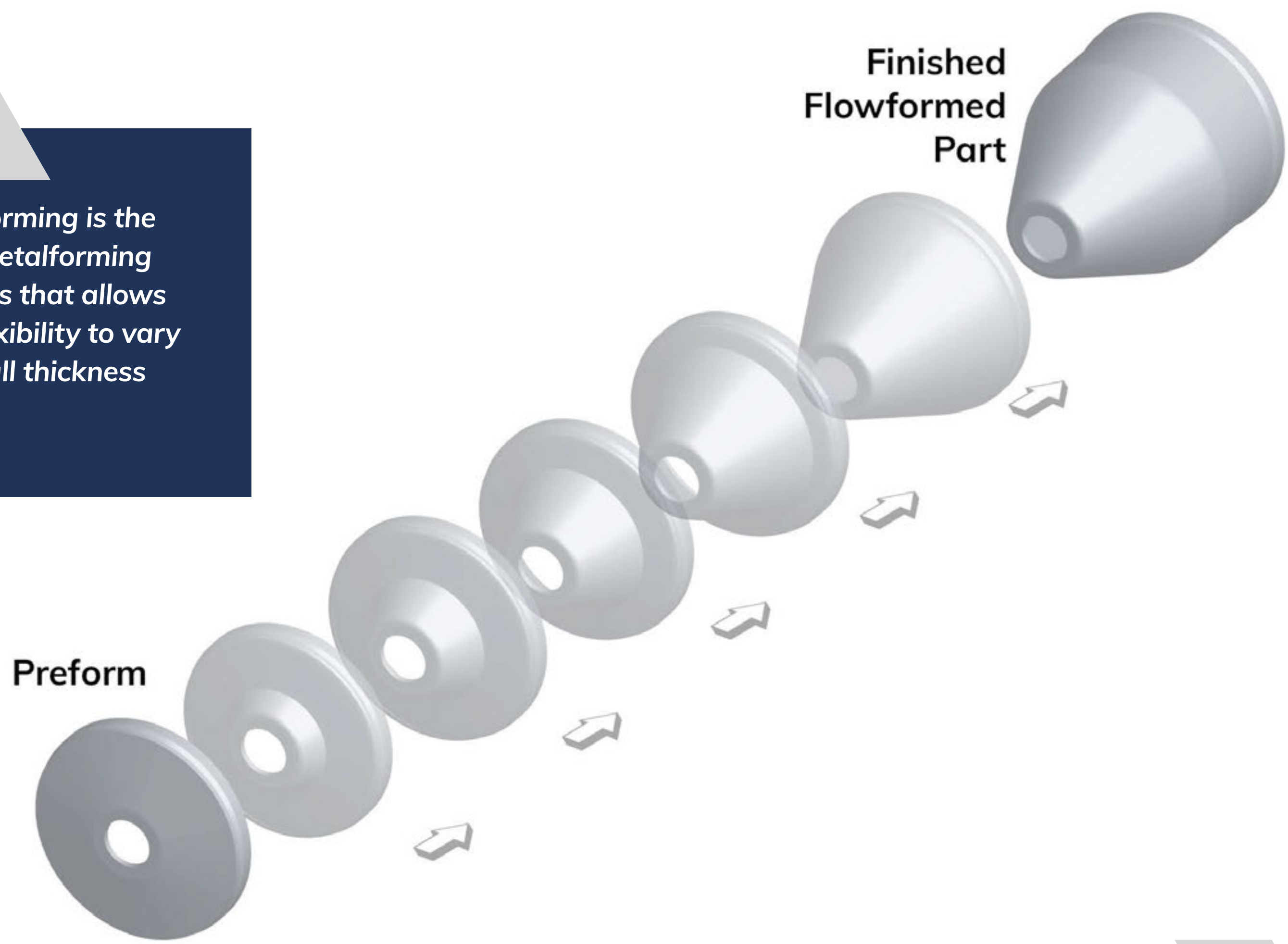

Pure Metal Spinning Compared To Flowforming.

> ***Flowforming is based upon a predetermined reduction of the thickness of the starting blank or preform.***
>
> ***When spinning cannot achieve the design objectives or tolerances required, flowforming is usually an excellent alternative.***

Flowforming is an advanced form of metal spinning. Metal spinning utilizes a relatively thinner piece of starting material than flowforming and produces the shape of the finished part from a larger-diameter starting blank than the largest diameter of the finished part – very similar to deep drawing. No reduction of the wall thickness is contemplated, but it is often experienced and is very difficult to control. Flowforming, on the other hand, is based upon a predetermined reduction of the thickness of the starting blank or preform, a reduction that is very accurately controlled. Flowforming machines are much more robust in construction than spinning machines and therefore can generate much higher forces required to extrude the metal through its entire thickness.

Both pure metal spinning and flowforming are valuable methods of forming metal and have their advantages over one another. In general, if a part can be produced by pure metal spinning and meets the customers' specifications, then that is usually the most cost effective choice, since it is geared to relatively smaller runs, and the tooling is less expensive. However, when spinning cannot achieve the design objectives or tolerances required of the part, flowforming is usually an excellent alternative. As will be discussed throughout this paper, flowforming has some unique features that make it ideal to solve many design problems.

Flowforming methods.

Tube Spinning

One method of flowforming is tube spinning, in which a tubular or cylindrical shape is generated. A tubular preform with a wall thickness, length and inside and outside diameter precisely calculated to produce the required final dimensions is placed on a cylindrical mandrel made of hardenable steel. Forming rollers with specific profiles are set at precise distances from each other and the mandrel. When the machine is activated, depending on the configuration of the machine, the rollers either traverse the mandrel, or the mandrel passes between the stationary, rotating rollers exerting as much as 75,000 pounds per square inch, per roller. The output is a tube whose material has been significantly cold worked and dimensionally controlled by the process to produce extremely uniform or variable wall thickness, diameter and length features.

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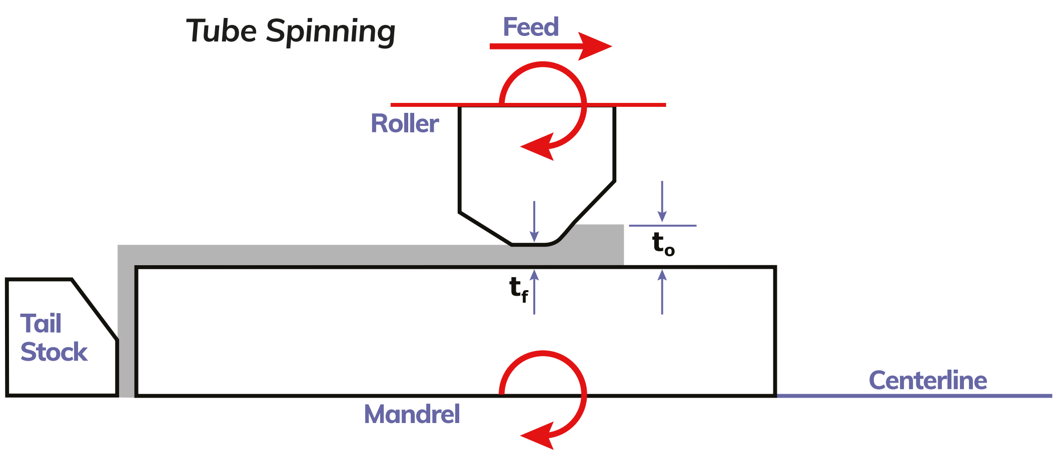
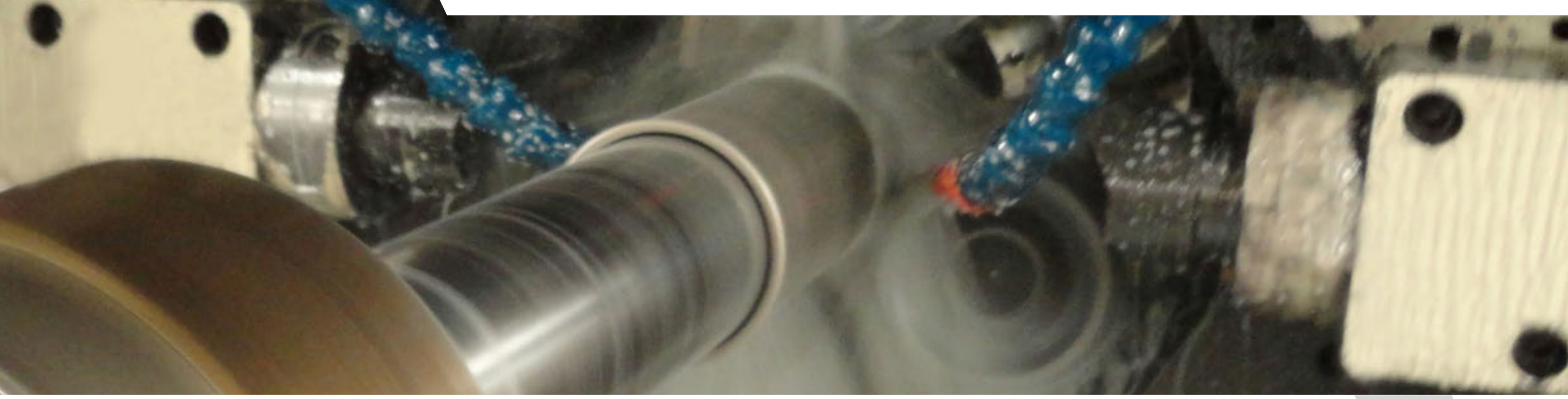




When the component has one closed or semi-closed end, such as a vessel, the bottom rests against the face of the mandrel, while the material being flowformed is moved in the same directions as the rollers. This technique is called forward flowforming. When the component has two open ends, such as a tube, reverse flowforming is used, in which the force applied by the rollers pushes the material against a serrated ring at the end of the mandrel. The ring is driven by and rotates with the mandrel. As the rollers compress and extrude the material against the ring, the material flows under, and in the opposite direction of, the rollers.

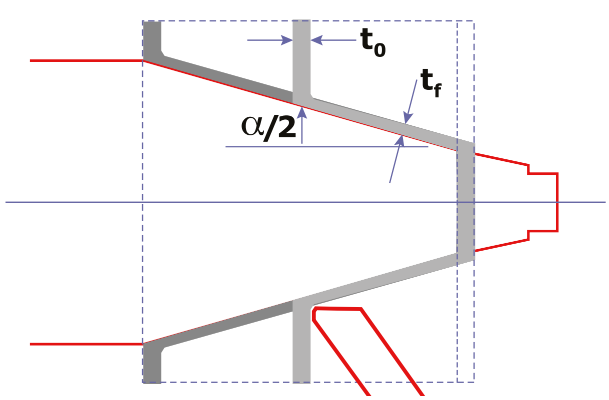
In either variation, the finished part is thinner and longer than the original preform, although the volume of material remains constant. As shown below, the final tube thickness, tf, is determined by the roller-to-mandrel spacing. Using multiple rollers that may be staggered and set at different gaps, it is possible to make multiple reductions in a single, economical machine pass.

> *The relationship between the initial and final material thickness can be defined mathematically by the Sine Law.*

Shear Spinning

In this second method of flowforming, conical and other axis-symmetric parts – i.e. hemispherical, hemiellipsoidal, or more complex profiles – are produced from a simple flat blank or more complex shape that is "sheared" by one or more rollers over a rotating mandrel. As with tube spinning no material is lost in the process. The relationship between the initial and final material thickness can by defined mathematically by the Sine Law,

Shear Spinning



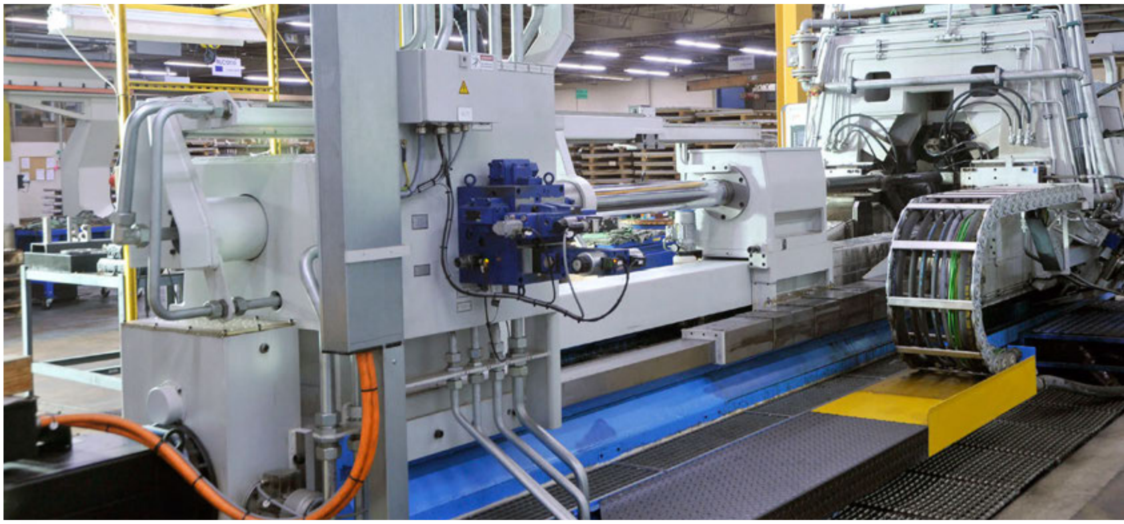
tf = to sin(½

where tf is the final component thickness, to the initial preform thickness, and ½ the mandrel half-angle. When shear forming is done following the Sine Law, the primary deformation mode is pure shear, as opposed to tube spinning, in which more complex deformation modes occur.

Flowforming Equipment

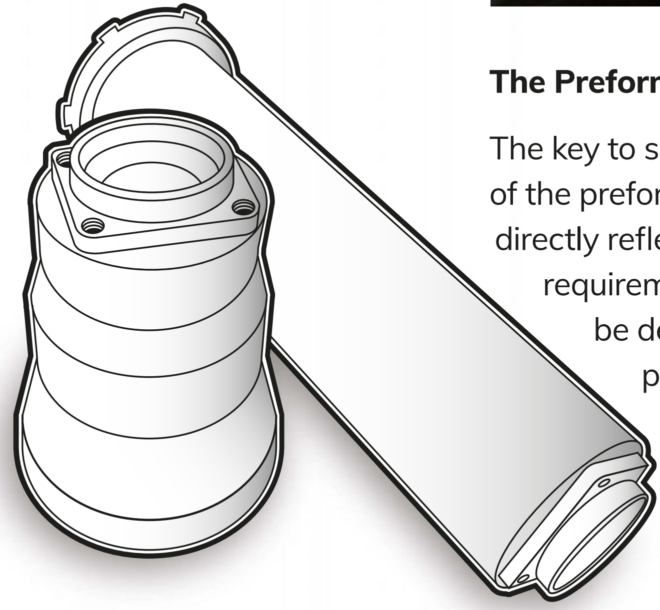
Modern flowforming equipment includes single or multiple rollers, computer numerical controls, and ball screws and positioners for the rollers and head stock, which, combined with significant pressures, yield exceptional accuracy and control of material deformation. CNC controls maintain the precise positioning of the rollers, facilitating variations in the machine-operating parameters throughout the part. Ball screws and positioners precisely locate and maintain the positions of the headstock and rollers.

The key to successful flowforming is the quality and design of the preform.



The Preform

The key to successful flowforming is the quality and design of the preform. The accuracy and finish of the final product directly reflect the dimensions and profile of the preform. If the requirement is a +/- .003 tolerance, then the preform must be designed and produced accordingly. The profile of the preform must also match the profile of the mandrel. This is particularly critical in shear spinning. In all cases, the process is volume-related. That is, a certain volume and profile must be at a certain point in the process, or the result is a broken part or one that does not meet one or more tolerances.



The success of the final part depends on a properly designed preform

As with any metalworking process, the closer the tolerance required the higher the piece price. This is due to the fact that machining a preform from solid or hollow bar or from a forging produces the most accurate preform. However, material cost is relatively higher, and the cost to prepare the preform by machining is relatively higher, than other methods that exist for producing a preform. These methods include starting with a forging, in which case the forging is closer to the shape of the preform, and less material needs to be removed with less labor involved. At the same time, forgings require medium-to-high volumes to offset the significant tooling cost for the forging. There is another alternative, which is to produce the preform from sheet metal. With this method, spinning machines or presses are used to form the sheet metal into simple or complex hollow shapes. The raw material is less expensive and is very uniform in thickness. And the labor cost to produce the preform, particularly when using presses, is lower. The one disadvantage of using presses is the initial tool cost. However, if the quantity is of medium volume (above 100 pieces) and/or there are repeat orders, the tooling can be amortized fairly rapidly. In other cases, this approach can work for even lower quantities when this method is the only solution to obtaining the design requirements, or if it can replace a much more expensive method of manufacture.

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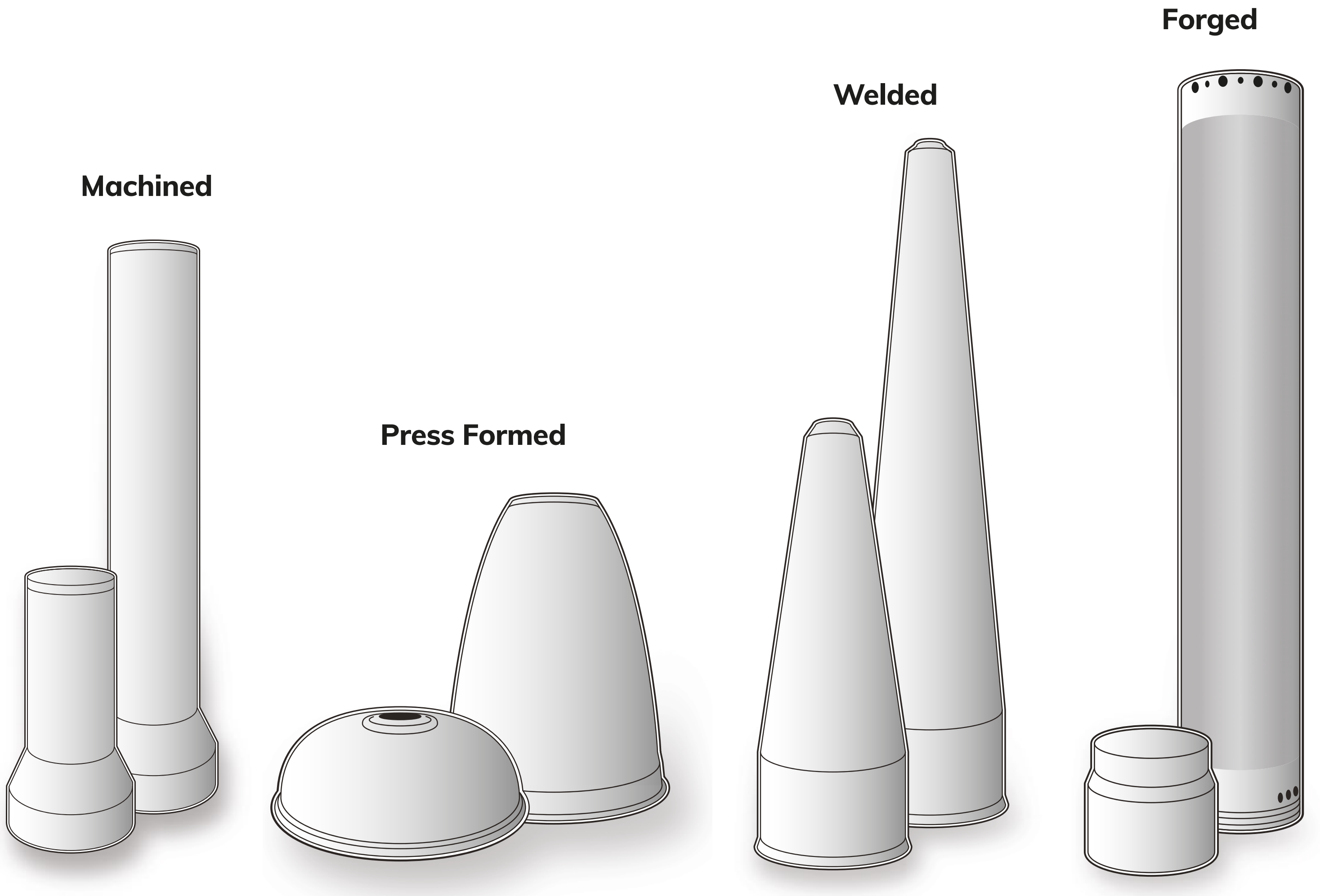
> ***Flowforming allows many options for how you create the preform: press forming, machining, forging and welding.***

Preforms and Flowformed Parts



A final alternative is to produce a welded preform. This approach is very cost effective for producing tubular or conical or contoured shapes or combinations of all these shapes. It is more labor intensive than a press formed or spun preform. However, it often requires less tooling expense. Therefore, it is ideal for lower quantities and/or larger parts. And finally, the flowformed weldment is superior in roundness, hardness, wear resistance and general appearance, compared to a weldment that has been conditioned and finished only by grinding and polishing. This is due to the plastic deformation of the weld, along with the base material that takes place during the flowforming process.

> *Flowforming's precision controls tolerances to within the range of machined parts.*
>
> *The material is only displaced, not removed.*
>
> *Engineers can design for thinner walls to reduce materials and save cost.*

Design Benefits

In general, flowforming offers precision, economy, and flexibility over many other methods of metal forming. Specifically, these benefits include:

Tolerance Control

Flowforming's precision over the length of the component, through variable contours and wall thicknesses, controls tolerances to within the range of machined parts. Components can be produced with diameters ranging from 1 to 25 inches, wall thicknesses from 0.015 to 0.250 inch, and lengths up to several feet. The feasibility and accuracy of these dimensions depend on the combination of material, wall thickness, length and diameter.

Variations in Thickness

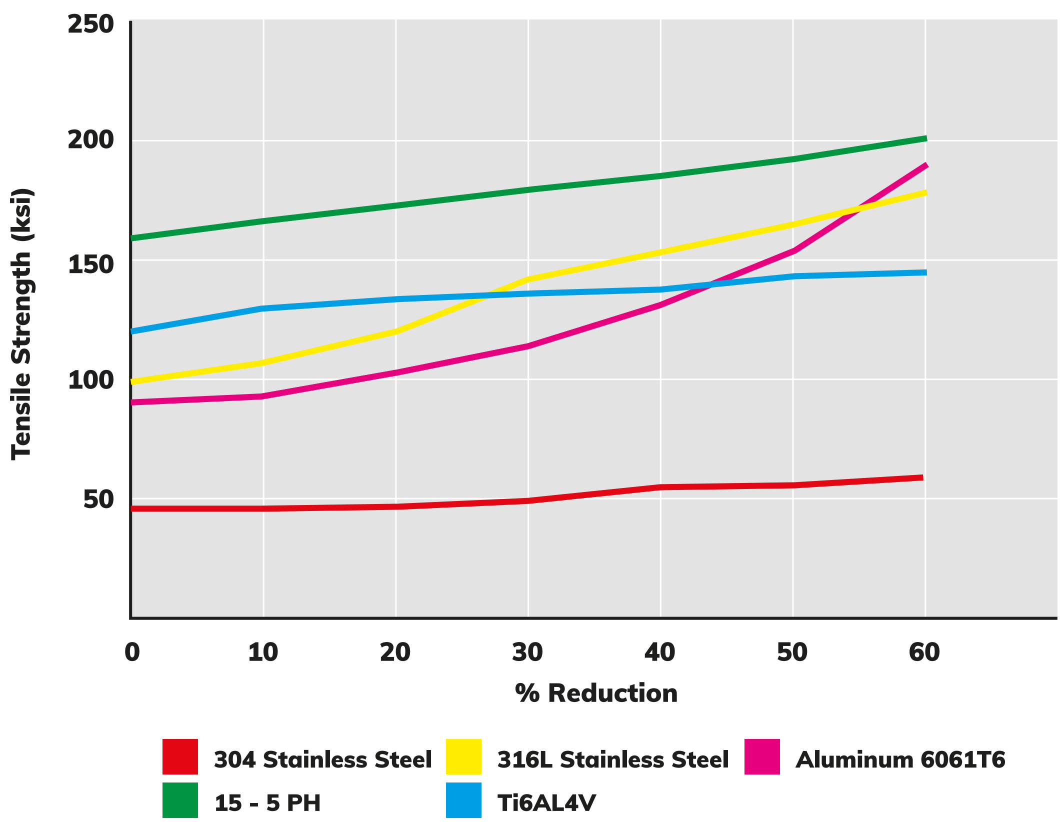
The wall thickness is controlled very precisely in flowforming. As a result a very uniform wall thickness can be produced, or one that varies very precisely along the length of the part. In addition, the material is only displaced, not removed in the flowforming process. These facts allow the engineer to use less material where it is not required while at the same time maintaining material thickness where more material is needed for strength or other purposes such as forming flanges or joining other components by welding.

> **“**
> ***The material’s mechanical properties are increased because of the cold working introduced during flowforming.***

Increased Mechanical Properties

Due to the pressure exerted on the material during the flowforming process, the material’s mechanical properties are increased because of the cold working that is introduced during the process. The amount of cold working is directly related to the percentage of reduction between the starting and the finished material thickness. Cold working is beneficial in product design, because it provides a uniform grain structure and increased mechanical strength and hardness. If a product is designed or redesigned with flowforming as the process of choice, engineers and designers can take advantage of these cold working benefits, which will allow them to design products with thinner sidewalls for pressure containment without the need for additional heat treatment. In addition, with the increased surface hardening, there may be no need for additional surface coatings to reduce material abrasion. The illustration below provides specific examples of the effect of cold working.

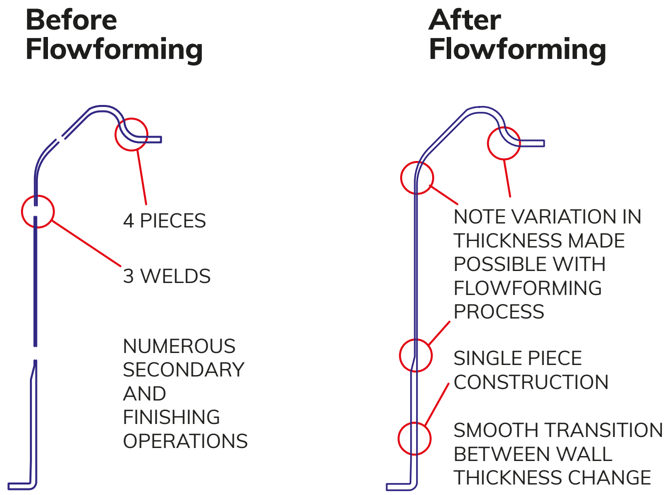
UTS Base on % Reduction



Seamless Construction

Flowforming can produce a seamless component with varying contours and wall thicknesses, resulting in parts with no or few welds, thus reducing welding and related testing costs and the need to maintain inventories of different components. Even if there is a welded joint in the preform, once flowforming has been done, the weld is virtually indistinguishable in the final component.

> *Flowforming can reduce the number of required parts and joining operations.*
>
> *Flowforming eliminates the need for extensive grinding and hand polishing of welds and interior surfaces*



Superior Finish

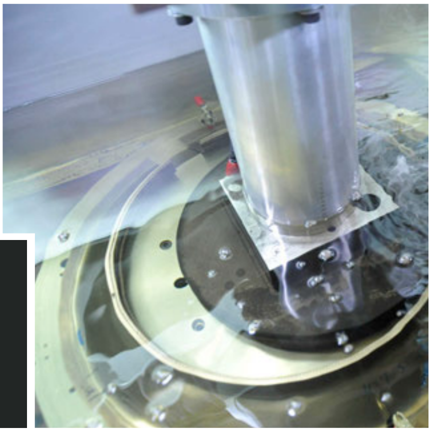
The compression of the preform against the hardened and polished tool steel mandrel causes the interior surface of the component to assume the finish of the mandrel. Combined with seamless production, the as-flowformed surface eliminates the need for extensive grinding and hand polishing of welds and interior surfaces. The exterior surface pattern consists of the feed lines of the rollers, which can be easily removed if the application warrants it.

The Right Combination of Supporting Processes

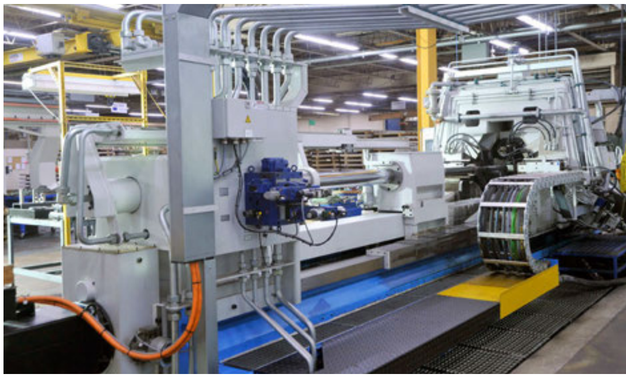
There is rarely one metalforming process that can achieve all the requirements of a design. Flowforming should be combined with other complementary metalforming processes to realize its full potential. Doing so will allow a manufacturer with flowforming capabilities to use the strengths of several processes to produce a part that meets the design requirements with minimal compromise or loss of material.











Typical Materials Used in Flowforming

- Stainless Steel
- Carbon Steel
- Maraging Steel
- Alloy Steel
- Precipitated Hardened Stainless Steel
- Titanium
- Inconel
- Hastelloy
- Brass
- Copper
- Aluminum
- Nickel
- Niobium

Conclusion

If you are seeking creative, cost-effective solutions to complex hollow metal components, flowforming is a viable alternative to traditional machining, deep drawing, and standard spinning. Across the spectrum of manufacturing industries, flowforming provides seamless, single-piece cylindrical and contoured components that answer the design needs for thin walls, increased tensile strength, dimensional accuracy, improved grain structure, and finish. Moreover, flowforming saves money by reducing assembly costs with fewer parts; by using less material; by reducing or eliminating welding, finishing and testing costs; and by reducing the number of component parts to outsource and keep on hand.

This article is provided as a service to the metal forming industry by PMF Industries, located in Williamsport, Pennsylvania.

www.flowformingplus.com

