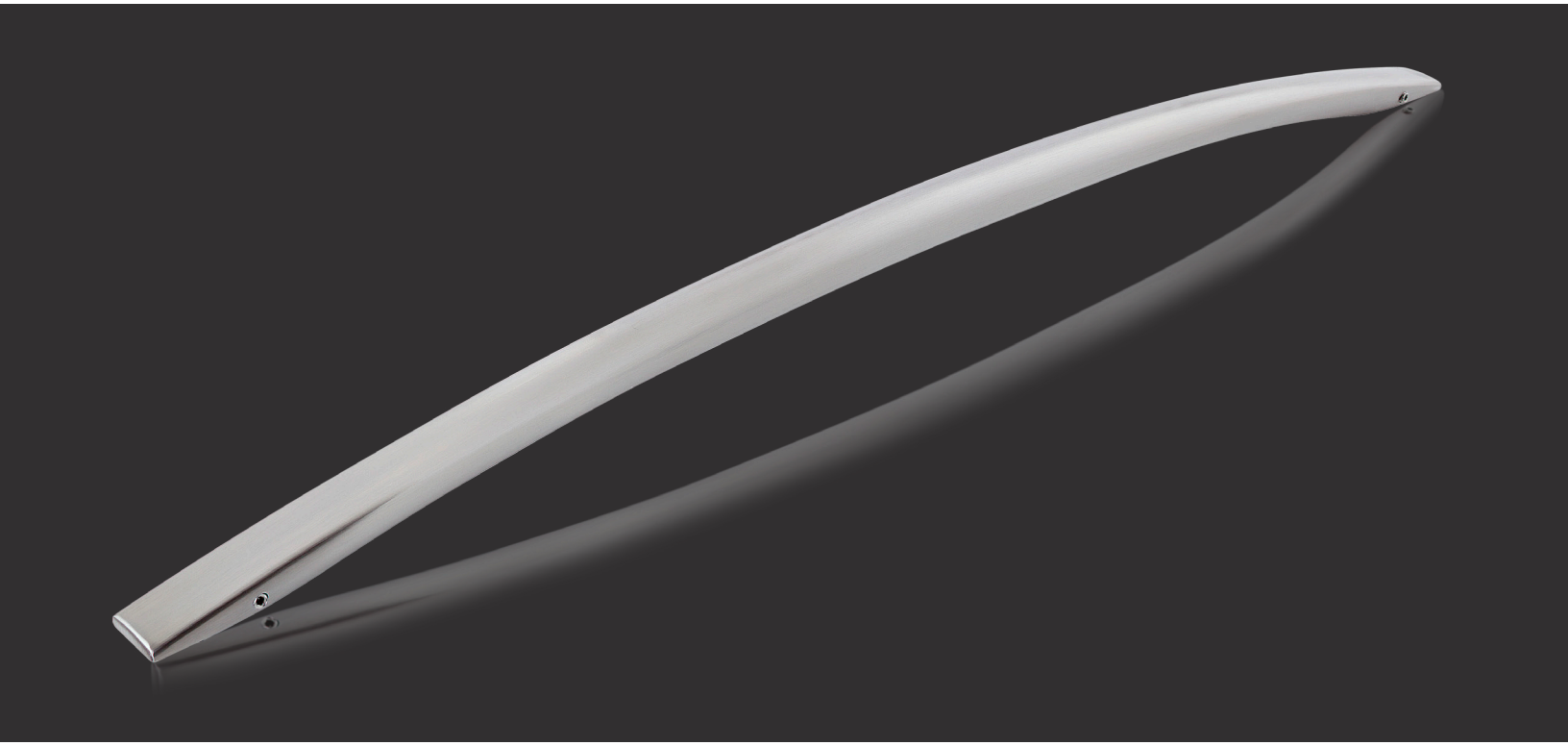
MILLS PRODUCTS INCORPORATED ENGINEERED WITH IMAGINATION



HYDROFORMING DESIGN CONSIDERATIONS

Hydroforming is ideal for producing strong, lightweight parts that require complex designs and superior aesthetics. Mills Products specializes in thin wall tubular hydroforming, which in many cases is a cost-effective alternative to extrusion or die casting.

The following design guide will help you take advantage of tubular hydroforming's benefits, including:

- High dimensional stability and design flexibility
- Class-A surface finishes in fewer operations than stamping or welding
- Simple, low-cost tooling is achievable depending on design and material requirements
- Form multiple metal parts with same tooling (as long as the two metals have approximately the same formability parameters)
- Complex shapes, including large radius sweeps and multi-sided cross sections for stronger, lighter vehicle unibodies
- Cross-sectional shape transitions from round to elliptical
- Variable expansions of diameters up to 35%

MATERIAL SELECTION

Hydroforming responds well to a wide variety of material types and provides excellent surface finishes without producing burrs, stretch lines or scuffs associated with traditional forming methods.

Common Hydroforming Materials:

Cold Rolled Steel
- Economical
- Forms well
- Many finishing options

Brass
- Aesthetic appearance
- Corrosion resistance

Stainless Steel
- Decorative capabilities
- High luster capabilities
- Corrosion resistant

Aluminum
- Light weight
- Wide variety of finishes

Copper
- Decorative capabilities
- Corrosion resistant
- Conductive/high-heat transfer

Titanium Alloys
- High strength-to-weight ratio

Note - The above list in not inclusive of all material capabilities. As a custom component manufacturer, we can work with a wide variety of materials and forming processes.

TOLERANCES

Hydroforming allows precision tolerances without springback, allowing the production of "net shape" or highly accurate parts. The hydroforming process also produces considerably less waste than most forming processes. The result is cost-effective production of everything from prototypes to large production runs.

Hydroforming is typically used when condensing multi-part assemblies into single, lightweight hydroformed parts. Our capabilities include hydroforming machines capable of up to 1,000 tons, bed sizes up to 120" X 60" and maximum capacities of 30,000 PSI.

Note - Tolerances are not necessarily limited by current hydroforming machine capabilities. We have built machines in-house to fulfill a part need, including designing and building custom cold saws to fit the specifications of some our earliest hydroformed parts.

DESIGN PARAMETERS

Design parameters are part specific. Each part has to be analyzed independently by our team of engineers and hydroforming experts before determining applicable parameters.

Note - The following "maximums" may be affected by other design considerations, especially if expansion or shape change is radical.

I. **LENGTH**: Max is approximately 40"

II. **DIAMETER**: Max is approximately 5"

III. **PART THICKNESS**: Max is <.080"

IV. **BENDING:** Radius should be >1.5 times the diameter of the beginning tube diameter

V. **SQUEEZING**: The cross section of a finished part cannot be less than the starting diameter of the tube

VI. **EXPANSION**: Largely dependent on material and location of the expanded area of the part

Note - A part can be expanded more on the ends than in the middle. Expansion rates of up to 50% can be achieved 5 to 8 times the beginning diameter of the tube from the end of the part, whereas the expansion in the middle may be limited to 20% or less

TOOLING CONSIDERATIONS

Hydroforming tooling is often 50% less expensive to produce than matched die tooling. However, tooling cost reductions are ultimately dependent on design requirements.

Tooling Considerations Include:

I. **SHAPE**: The more complex the shape or features, as well as the size of the tool has an impact on cost. Tool cost for a simple non end-fed part may be as little as $8,000-$10,000, whereas a large end-fed tool could reach $100,000 or more

II. **SURFACE FINISH:** Most tools have to have a good quality surface finish to minimize the effects of friction, so this has little impact on costs

III. **HARDNESS**: Most end-fed tools have a cutting edge hardness of Rc of 55-60 (so that wear is minimized). Non end-fed tools are typically flame hardened to a lesser Rc and are more cost-effective to manufacture - both because of heat treat methods and material content

Contact a Mills Products design engineer to discuss your specific application requirements.