

## Tube Hydroforming 4.0: Opportunities Created by Efficient Processing

### Tube Hydroforming - A Brief History

Since arriving on the automotive scene as a way to make structural parts in the late 1980's, tube hydroforming has move through 3 stages. The first started with development and subsequent production in 1990 of low pressure hydroforming (LPH). High pressure hydroforming (HPH) followed soon after in a somewhat parallel manner. Proprietors continued developing their processes and market opportunities for several more years as the automotive OEM's and their Tier 1 suppliers learned about, recognized, accepted and started to access the benefits hydroforming could provide.

The 2nd stage was a rapid expansion in interest from OEM's, their suppliers & many others and the number of parts where hydroforming was used. It was an exciting time for those in the industries affected by these changes in manufacturing methods. New applications were numerous as were the number of companies that felt compelled, by the desire to be competitive, to quickly take on this technology with less than detailed knowledge.

The 3rd stage has seen a slowing of the fast-paced expansion. It is caused principally by the perception that cost is too high to be justified by the beneficial design features that are provided. Cost concerns seem likely to be at the root of the fact that many that made the move into hydroforming have not grown significantly and some have even exited the market. In spite of this, some companies continue to find new applications and grow. Another trend has been the decrease in forming pressure discussed and used compared to the period where high pressure was portrayed as a good thing, to now where it is seen as being a substantial cost factor that is better reduced.

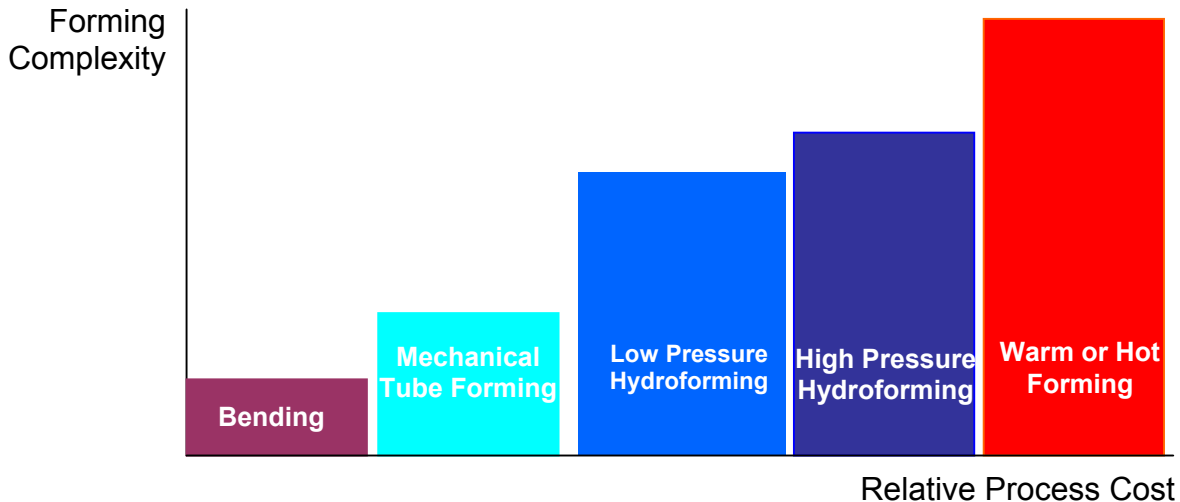


Figure 1

### Tube Hydroforming Today

Today tube hydroforming seems to have plateaued in popularity, predominantly because it is often perceived as expensive, an unfavorable quality, particularly in the hyper-price-sensitive automotive industry. The capital investment to produce parts has been costly in many cases, but an even more significant concern is multiple factors that relate to piece cost. As the industry has developed, it has become standard practice that tube hydroforming requires an intense focus on process simulation to predict as many challenges as possible upfront to allow altering the design or devising a suitable process. HPH can require special material, special tube manufacturing methods, lubrication,

performing, end feeding, annealing, and other measures to improve formability. These aim to reduce process instability that was problematic.

LPH does not have the same concerns, since it follows a different methodology to form parts and with suitable tooling and product design encounters fewer challenges.

In a few cases hydroform parts have been replaced by stamped & welded assemblies, which is part of a reassessment of where hydroforming makes sense and saves pounds and dollars. However, new hydroforming applications continue to be developed. It seems we are likely in the midst of a period where a 'sense' of what should be hydroformed is becoming more common.

### **Hydroforming Better Structures**

Structures are made to hold things up, together and withstand stresses applied to it in several ways (usually remaining undeformed plastically), ideally unobtrusively and efficiently. Performing the required tasks or functions without failing is crucial, usually addressed with prediction of load size and a factor of uncertainty or safety (larger as prediction accuracy is lower). Doing so with a minimal amount of material and resources is where the design is judged to be well done or not.

Historically uncertainty was mostly due to:

1. The size and nature of loads
2. Our ability to predict what they are
3. The options to make them efficiently - structurally and chosen manufacturing methods have increased.

The uncertainty of first 2 factors caused engineers to make larger, stronger & heavier structures to prevent failure with a large factor of safety. The 3rd factor has also tended to cause the same response mostly to address stress concentrations, such as joints and part features, and their effects.

The fundamental appeal of hydroforming is the ability to use the structurally more efficient tube (vs. flat sheet) and manipulate it to avoid joints and provide a smooth transition shaping ability, which both reduce stress concentrations.

There are 4 basic functions that can be performed while the part is being hydroformed. They are:

1. Changing cross section to the desired, more ideal flowing shape along the length.
2. Decreases the number of joints, which also substantially reduces the parts inherent flexibility
3. Increased rigidity due to joint elimination and more advantageous cross section shapes
4. Reduced thickness, weight and cost for reasons 1,2 & 3.

Determining how to maximize these potential advantages can facilitate creating the best structural parts. This question of what process is best has been the subject of contention for a long time. As evident in the discussion earlier, the process options were delineated based on internal forming pressure. Companies and individuals have proven to have a strong allegiance to what they are accustomed to. Perspective, history, and the perception of benefits all reinforce the conviction that one process or the other is better. Few have experience with both HPH & LPH, which limits the objectivity of performance assessments. This is unfortunate since the best designer or part supplier would use all potential tools to make the most capable part for the lowest cost.

### **Where Should Hydroforming be Used?**

It should be used wherever it provides sufficient benefits to justify the added cost (compared to stampings); namely weight or cost reduction or performance improvement. The first arises from more expensive raw material (tubing vs. flat sheet or strip) and additional processing (ie bending, slower forming and postform trimming).

Hydroforming can potentially be used to satisfy the requirements of any structural or fluid flow application, in many industries. Interest in adopting it will be directly related to how beneficial it is. Possible applications must be identified and assessed for feasibility and benefit determination.

### **What Hydroforming Process To Use?**

The short answer is the one that has the ability to provide the features you need for the least cost. This is, of course, easier to say than it is to do. For guidance it is best to follow the general concept of knowing what features are needed, as well as how to achieve them at the required quality level and lowest cost. This is more direct and advantageous than focusing on a particular process.

While most parts that can be hydroformed may be produced by either HPH or LPH, certain part features that are achieved easily with one process may be difficult or impossible to make with the other. An example is sharp cross-section corners at one or more locations. LPH can handle this quite easily, while it is very difficult for HPH. On the other hand, small expansions that can be done only in the hydroforming die are easily made with HPH, but LPH may have trouble achieving small corner radii.

An overriding principle to be emphasized is that when a process is favoured, it should be for the right technical reasons. The choice must be made based on proven advantages, not predispositions, uncertain understandings and what was used before. The right process steps to make the part in question may have elements of LPH, HPH or other valuable innovations. The method that does the job most effectively is the key, not past allegiances.

### **It's All About The Pressure. Or Is It?**

The common impression of the main difference between LPH & HPH is the amount of pressure, which is also referred to in their names. The real difference is in the forming mechanics. Pressure required for the proper functioning of each is simply a result. LPH harnesses the closing force of the die and press to push material into shape compressively, aided by the fluid inside the tube. HPH forms the material in tension by expanding the part outward to the die cavity.

The added element of forming for LPH is very important since it facilitates making challenging parts with fewer resources. Also it costs more to generate and contain higher fluid pressure. You should use as much as you have to, but not more. When there is a way to use less, it will be beneficial if there is not a loss of part design flexibility. Considering such options is key to remain competitive.

### **Elements of Efficient Processing**

So, what is efficient processing? It is retaining the ability to make the part that will perform the required functions while using fewer resources. These resources can be capital, tool or piece cost factors. Some of the main factors are:

1. Equipment cost - most pointedly the hydraulic hydroforming press (1000 vs. 5000 tonne)
2. Material - use of normal or special materials or tube making
3. Cycle time

Minimizing these and other cost factors while forming what is needed, will improve efficiency. Further improvements and development will extend efficient production even further.

It is common to have preferences to a particular way of making parts and be resistant to alternative approaches. This is understandable, but can become a disadvantage if it stands in the way of using a more capable or lower cost process.

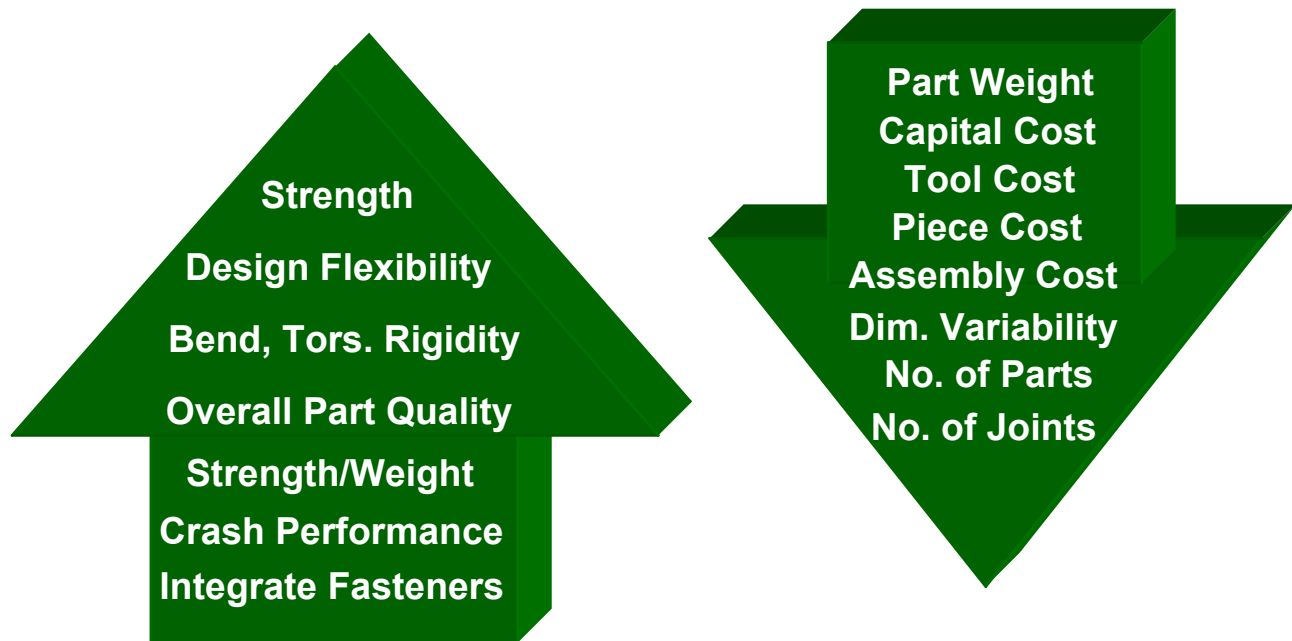


Figure 2

### Why Has Hydroformed Application Growth Slowed?

There are a number of reasons, some of which pertain to particular company situations, including the turbulence in the fortunes of the some OEM's and their trickle down effect on suppliers (some see it as a flash flood). Some other contributing reasons are:

1. For some past applications, unplanned added operations & costs like special material, annealing and inadequate process stability have substantially increased cost, which was poorly received.
2. Available part features & design limitations may seem too constraining for some part features.
3. Forming high strength steel (HSS) (which is quickly getting more popular) with HPH is very difficult and apparently not feasible beyond about 600 MPa yield strength.
4. Cost for capital, tooling and parts are often perceived as too high. (Seemingly the biggest reason)

Hydroforming use can be extended dramatically by addressing these issues. Using LPH forming principles prevents the situation in #1 and largely extends the capability in #3 with HSS. LPH can improve on the challenges expressed in #2 in some respects and often reduces cost substantially.

Development work to use elements of LPH and HPH to further address these challenges has been done and continues. In short they can increase the capability of producing advantageous features and reduce weight and cost.

### Are New Processes Replacing Tube Hydroforming?

People are often looking for predictions of what is going to happen and the question frequently arises 'will other technologies replace hydroforming?'. It seems highly likely that new technologies like warm or hot forming are complementary to tube hydroforming rather than replacements. These processes are like tools in a toolbox. Getting other new tools does not mean having to throw something else out. It simply means there is one more avenue to use in the right situation to aid in the unending quest to make the most efficient, effective parts for the lowest cost. So some parts beyond the abilities of hydroforming will be suited to hot forming, but cost will mean that what can be done either way should be made by the cheaper process.

In this way new processes tend to complement current ones by extending the range of formable parts. Also in cases where cost ranges of the current and the new overlap, some portion of the market for the current process will flow to the new one.

## **Opportunities In Automotive Structures**

Although hydroforming has been used for a number of industrial purposes, the most common and widespread use has been in the automotive industry and even more specifically to passenger cars and trucks. Automotive parts that have been hydroformed in the past include:

- Frame Rails
- Front & Rear Cross Members
- Engine Cradles
- Radiator Enclosures
- Instrument Panel Beams
- Roof Rails
- Front End Structures
- Exhaust Parts

There are a number of other parts performing structural tasks in vehicles that could benefit in 1 or more ways by being hydroformed. Some may have been considered in the past, while others were not. These new developments and design approaches may be advantageous.

The potential is to multiply the number of the above parts where hydroforming makes structural and economic sense. Additionally, a number of new applications are likely to benefit from hydroforming, but must be designed to maximize it.

It has often been pointed out that hydroform production is too slow. Cycle times in the 20-30 second range are normal, but glacial compared to stampings. The counterpoint was that they replace 2 or more stampings and the assembly operations to attach them to each other. This justification, while true, did not seem to satisfy critics. Development work that has been done offers the prospect of cycle times that are half of the values above or lower depending on the part forming requirements.

The large capital investment associated with many new production lines has created the perception that tube hydroforming is only suitable for high volume applications. Hydroforming can make lower - medium numbers of parts repeatably, capably and economically. It is not inherently a high cost process. The way it has often been applied creates this impression. It can be used inexpensively as well. This further opens the door to applications that were not considered, or seen as uneconomical in the past due to volume.

Feasibility assessment must be done carefully and properly to capture the benefits while avoiding surprises. Assistance is essential, especially for those relatively new to hydroforming.

## **Other Potential Hydroforming Opportunities**

Concentration of the technology in the automotive industry, particularly in the passenger car & truck markets, has created the perception that it is only suitable for that sector. As mentioned, it can prove beneficial for many other structural and fluid carrying parts in other industries.

Some examples where hydroforming offers potential benefits are:

- Other Vehicles - the benefits of hydroforming have the greatest value for mobile structures.
- Aftermarket Accessories
- Plumbing Fittings
- Complex Tube-Like Assemblies
- Furniture Frames
- Building Products
- Lifting Devices
- Medical Applications

## **Conclusions**

Ultimately those requiring parts to perform as part of a structure of any kind should not need to care how the parts are made, with what process, unless they are making such parts themselves. For those buying them, they simply need to work with a company with a sufficient breadth of metal and hydroforming knowledge to rely on them to make the right decisions and design suggestions to arrive at the most efficient solutions. The focus needs to be on what is demonstrably the best part design for the price, not overadherence to a particular processing sequence.

However, it is beneficial that everyone involved in designing these parts has some knowledge to ensure that decisions made will make sense.

With product and process advancements the time seems right to reconsider how hydroforming is applied and where it will be beneficial. This is also motivated by other factors that encourage new approaches to address product need, such as energy use reduction, conservation of resources, improving efficiency, lightweighting, cost reduction and response to overseas competition with advancements, to name a few reasons.

Hydroforming is ready to advance to stage 4, extend its breadth of application dramatically and facilitate improvements like these. All that is required is seeing a need, a desire to improve some aspect(s) and hydroforming experience and innovation to determine how it can be of best benefit.