

3 New Things About Vehicle Structures and Cost that OEMS Should Know About Hydroforming

A White Paper by Schuler Incorporated

With global standardization, reduced die costs and use of advanced materials such as AHSS, hydroforming is a viable and growing alternative for lighter designs and more economical solutions, and is already performing as a solution for vehicles of the future.

3 Recent Hydroforming Advances Every Vehicle Structure Designer Should Know

Hydroforming has been a viable technology for many industries, including the automotive industry for car and truck exhaust components and under-carriage applications, for many years. Recent advances in development and processing are allowing body-in-white designers to now reconsider hydroforming as an economically attractive solution for lightweight designs:

1. The costs of development and dies are more economical than ever before.
2. It is possible to standardize hydroform dies on global vehicle platforms
3. Advanced high strength materials can be hydroformed reliably for lighter weight, increased structural rigidity and improved safety performance.

Development and Upgradeable Dies: More Economical than Ever

There is a paradigm in the industry that hydroforming dies are too expensive. This is true if the OEM follows the path of separate designs for separate regions (using separate suppliers). This is also true if the OEM waits until they are ready to order prototype tooling to consider the impact of part design on tooling design and the production process. There are savings to be achieved to make the technology economically attractive as a solution.

Capitol investment can be lowered by reducing the number of dies required to get from R&D to full production. By using upgradeable dies, an entire die can be eliminated from the traditional development process (typically three dies: R&D, prototyping and production). To do this, the number of tools used to get to production can be reduced to two dies by building the prototype tool in a way that it can be upgraded to a production tool (see Figure 1).

Implementation of Upgradeable Tools

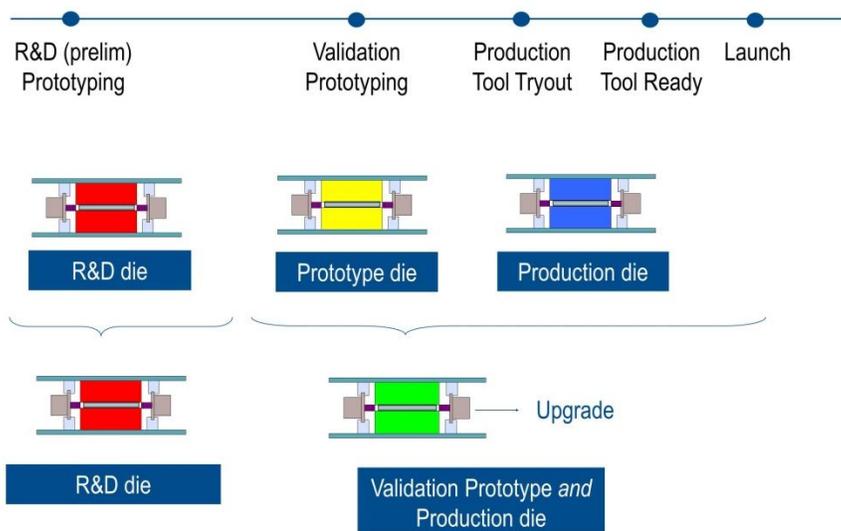


Figure 1: Capitol investment can be reduced by using upgradeable dies to get from R&D to full production.

As an example of capital investment for a global platform, consider a vehicle with six (6) hydroformed dies. Through the use of an upgradeable development die into a production die, there is an overall average cost savings of \$300K per die as compared to the 3-die development shown in Figure 1, and the ultimate savings for the program would be \$1.8M. This can be even more significant if one considers repeat development on a global vehicle program with multiple tier one suppliers.

While the capital investment of a hydroform die is higher than a stamping die, it is important to remember there are additional variable cost savings. Variable costs can be lowered by reducing the number of parts in an assembly and eliminating processing related to welding, joining and related logistics. Experience has shown variable cost savings over \$5 per vehicle.

Best practices for early collaboration through transparent communication, alignment of goals and strategic relationships support the implementation of new innovative designs. A good start for hydroforming collaboration involves co-training for hydroforming and part requirements. When vehicle designers are educated on the potentials and limitations of expansion for various advanced materials, and the hydroform process experts understand the final part requirements, the development process can be streamlined to avoid unexpected failures such as wrinkles with too much material or bursting with too little material and better prediction and compensation of spring-back. By predicting the forming early in the part design process, many reworks and project delays can be eliminated.

Global Standard: A Game Changer to Keep it Simple and Flexible to Reduce Costs

To significantly reduce the cost of development and dies, hydroforming is transitioning from black box technology to a commodity based process. OEM designers and hydroform experts with global launch experience can collaborate early on the part design and take advantage of feasibility studies – with standardization in mind.

The current common development practice within the industry is for the hydroform part supplier to design the part and die to fit their press and process. This brings variations in final parts from different suppliers and keeps lessons learned in-house. It also reduces production flexibility in two ways. First, the make-or-buy production decision, as well as supplier selection, must be made earlier in the development process. Second, if the production needs to be moved to another location, it may come with the expense of new dies - because hydroform dies may not have been designed and produced to be easily moved (as the equipment may vary by region and manufacturer).

By designing the part and die as a standard, one time – decision and production flexibility are increased for the OEM. Designing the part and die as a standard reduces development costs and related development die expenses. It also allows more time for the OEM to make decisions about where and how to produce the part, and avoids the costs associated with moving production if the need were to arise in the future (see Figure 2).

Schuler's Hydroform Development Process

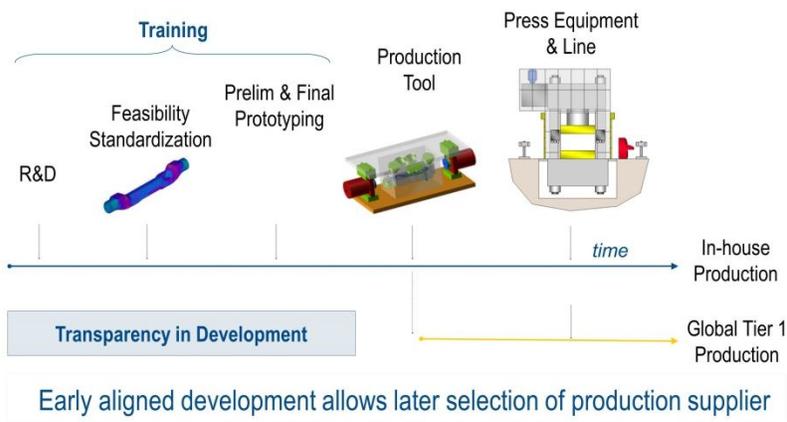


Figure 2: A standard part and die design improves decision and production flexibility.

It is now possible to design a hydroform part and related die that will fit into almost any hydroform press globally. Rather than each hydroform part supplier designing a die and process, the new approach is to design one part, made from one die design and one process – that can be made the same in virtually every location.

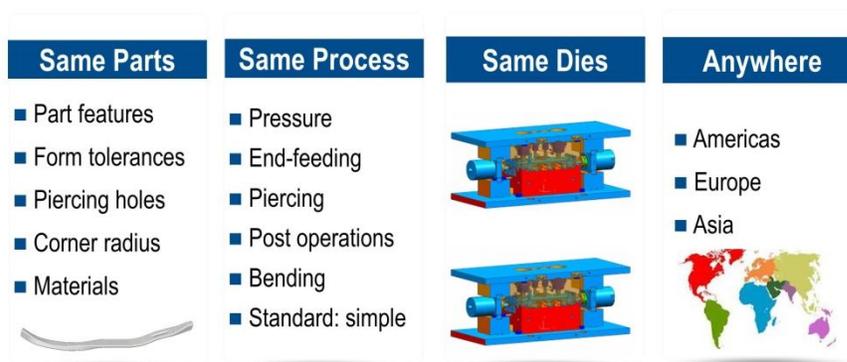


Figure 3: Hydroform dies can now be designed to fit into systems in every region.

While it may sound easy to design a standard hydroform part for production flexibility, it is complex because of the variety of hydroform press systems operating in the tier supply market. The successful approach to accomplish this is to standardize the tool for forming and process, and design the connections with flexibility to adapt to various hydraulic, water and electrical connections.

Another hidden benefit of global standard hydroform dies is the ability to improve launch efficiency and quality. Lessons learned can be consistently and quickly shared with the tier supply base to adapt processes and overcome any issues that may arise.

Advanced High Strength Materials Can Be Hydroformed Reliably

While the stamping industry has a longer experience with Advanced High Strength Steel (AHSS), the hydroform industry is catching up quickly. The use of DP 1000 hydroform tubes in body-in-white structures will continue to increase over the next decade. Hydroformed roof rails and B-pillars made with AHSS are being used in several high volume vehicle platforms by various OEM's globally.

In the case of Dual Phase Steel DP 1000, the material offers good strain hardening to deliver structural rigidity and high tensile strengths that make the material suitable for energy absorption during impact. For example, the Ford Fusion uses a hydroformed DP 1000 roof rail extending from the bottom of the A-pillar to the C-pillar rearwards (See Figures 4 and 5). This design has resulted in a 4.2 kg (9.3 lb) weight savings/car compared to a design using hot stamped components /1/. Additional use of DP steel stamping and a hydroformed B-pillar has resulted in significant improvements in the vehicle's torsional and bending stiffness. (Source: S. Morgans presentation at Great Designs in Steel, May 2013).

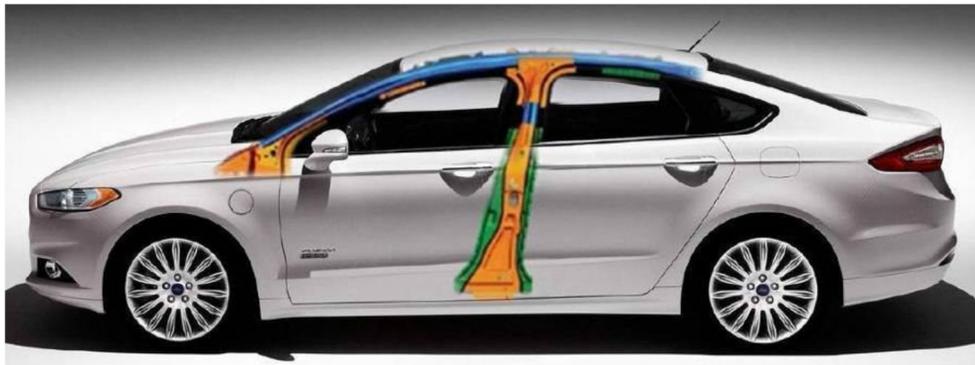


Figure 4: 2013 Ford Fusion with hydroformed DP1000 roof rail and B-pillars



Figure 5: Hydroformed DP1000 roof rail and B-pillar for the 2013 Ford Fusion

Research has been done to overcome the challenges of AHSS in part, die and process design:

- low formability
- high spring-back
- difficulty to meet dimensional characteristics

The high yield and tensile strengths of AHSS that deliver desired vehicle structural performance also deliver the challenge of spring-back. If the production process involves multiple steps (e.g. bending, pre-forming and hydroforming), the spring-back creates significant challenges to designing robust, statistically capable production tools and processes.

The various effects on part geometry due to spring-back can be categorized into three categories: *Global Spring-back*, *Crowning* and *Twisting*. In reality, spring-back of a hydroformed tube consists of a combination of these three effects – and primarily depends upon the yield of the material, variations in material properties, the geometry of the part, tube thickness and the number of process steps the part encounters.

Global Spring-back occurs when the cross section of the tubular part is correct, but the overall geometric shape of the part is incorrect. In this case, the tube tries to return to its original straight geometry. Longer hydroformed parts results in higher spring-back. Production experience of longer parts have experienced up to several millimeters of Global Spring-back at each end.

Crowning is a local occurrence on the part geometry, where the hydroform cross section tries to go back to its original round geometry. This is often seen in long, flat sections. After hydroforming, the surface bows outward.

Twisting occurs as the cross section of the tubular part rotates against the targeted CAD geometry – it is the most complicated type of spring-back to compensate.

FEA simulation is used to predict spring-back, and experience with applications is quickly improving the predictive capabilities. While the prediction of formability is fairly good, the spring-back after hydroforming is limited – the direction of spring-back is predicted fairly well, but the magnitude is less accurate.

While there are established calculations and methods for predicting and compensating for spring-back, it is much more complex to predict for multi-step stamping or hydroforming of DP1000. Custom spring-back methods are continuously improving using the latest advances in simulations, laser scanning and custom CAD modules.

Stamping die manufacturers have reported the need to re-cut the die 7-8 times in order to compensate the part to yield closer to nominal values. Current simulation work in hydroforming has already reduced the number of die re-cuts required down to 5, and the

realistic short term goal is to reduce this process down to 3. This knowledge and experience presents savings to the overall production tooling budget and program development timing.

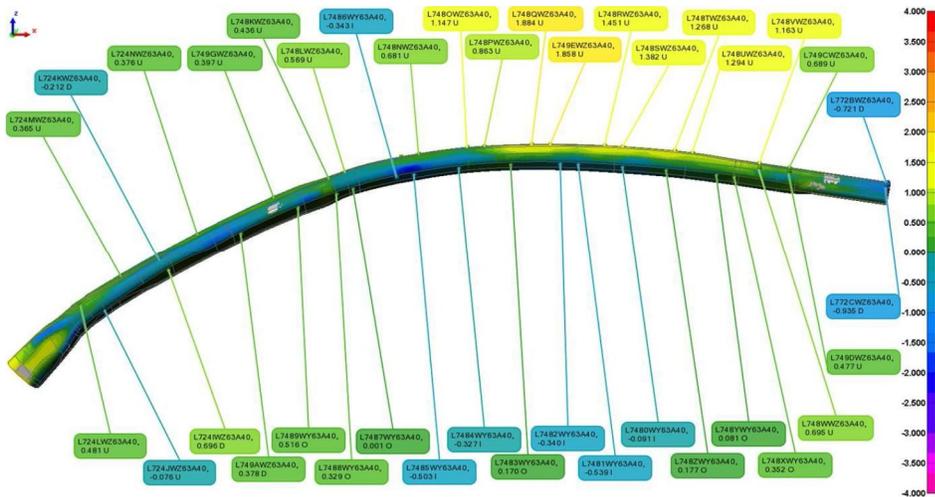


Figure 6: Full CMM scan of a typical roof rail during prototype development



Figure 7: Spring-back approaching 10mm (0.4 in) at each end on a part 2000mm (6.5 ft) in length

Summary

To achieve the increasing demand for fuel efficient vehicles while increasing safety requirements, vehicle structure designers must select from a variety of processes and materials to achieve desired performance while meeting the cost requirements of the particular vehicle platform.

Three recent advances in hydroforming make this technology more feasible than ever before. By collaborating early with hydroforming experts in the part design phase, designers can deliver new designs that will compete on a global scale using AHSS, aluminum and other emerging materials.

Changes in business processes to develop standardized global designs for flexible production improve launch efficiency and quality while reducing risk in the supply chain. Shifting paradigms and accounting practices for die costs - and recognizing the savings of fewer parts and logistics can open the door to significant overall savings.

With better performance, lighter designs and more economical solutions, hydroforming is a viable and growing alternative that is gaining more attention for the vehicles of the future.

References

- /1/ Morgans, Shawn
Advanced High-Strength Steel Technologies in 2013, Ford Fusion
Great Designs in Steel, 2013

About the Schuler Group

Schuler is the global leader of innovative metal forming systems and technologies, which enables the company to deliver highly-productive solutions that positively impact profitability, flexibility and efficiency for its customers. The company supplies equipment, turn-key production lines, dies, process consulting and services for the entire metal forming industry, including car manufacturers and their suppliers, as well as companies in the packaging, household equipment, forging, aerospace and defense.

Schuler is also the market leader in coin minting technology. The company employs 5,500 people and operates facilities and sales offices in 40 countries around the world. The Schuler Group includes Müller Weingarten, which it acquired in April 2007.

Schuler Incorporated, headquartered in Canton, Michigan, represents the Schuler Group in North America. The company offers sales management and project coordination for state-of-the-art metalforming system solutions. Its after-sales service, spare parts, PM programs, and retrofit and rebuild programs are able to support new and existing metalforming systems. Schuler Inc. also offers a full spectrum of hydroforming services, including part design, FEA analysis, consultation, prototyping and commercial production for both large and small quantities.

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