Hydroforming and Latest Advances

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1. Introduction

The automotive industry, with an increasing demand for weight reduction in modern vehicle construction, has encouraged research and development work in the area of hydroforming technology, which offers decisive advantages regarding the manufacturing of complex shaped lightweight components. This article provides an overview of hydroforming and its application to automotive industry, along with latest advances like the use of heat energy to improve formability of lightweight materials.

Hydroforming uses fluid pressure in place of the punch in a conventional tool set to form the part into the desired shape of the die (figure 1).In the tube hydroforming process, the initial work-piece is placed into a die cavity, which corresponds to the final shape of the component, Fig. 1. The dies are closed under the force, F_s, while the tube is internally pressurized by a liquid medium to effect the expansion of the component (internal pressure, p_i) and axially compressed by sealing punches to force material into the die cavity (axial force, F_a). The component is formed under the simultaneously controlled action of p_i and F_a. [1]

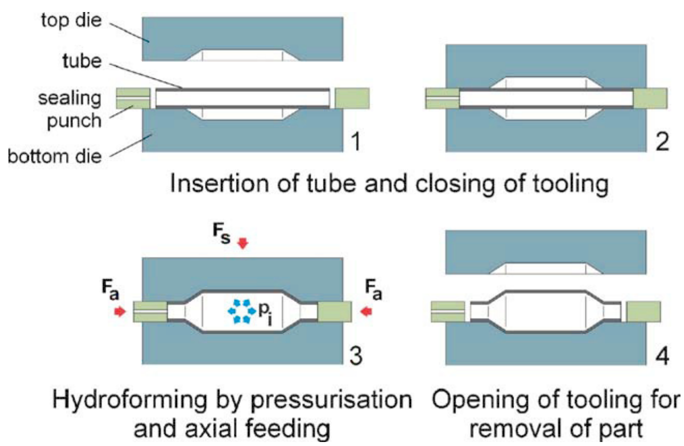

Fig.1 Hydroforming Principle [1]

Types of Hydroforming are:
Tubular hydroforming is used to form pre-fabricated sheet metal tubes into structural members.
Sheet hydroforming is used to form pre-fabricated sheet metal into structural members.
Low pressure hydroforming simply re-shapes tubes, producing a very good shape, but is not as useful if better cross-section definition is required.(less than 350 MPa)
High-pressure hydroforming totally changes the tube shape and alters the length to circumference ratio by up to 50%. It gives very good tolerance control, being a highly robust process.(greater than 350 MPa)

Machine and Processes:
Traditional hydraulic presses with one more large cylinders which both move the slide, carrying the top die and apply the closing force during the hydroforming process, Fig. 2(a). There exist also industrial used concepts with two press slides in one frame, which enables a more flexible use of the hydroforming technology.
(ii) Presses with a drive for a fast movement of the top die and with a mechanical locking or stop of the slide during the forming process, Fig. 2(b). One or more short stroke cylinders are used to apply the closing force. These short stroke cylinders can be located in the press bed or in the press slide. The direction of fast die

movement may be similarly directed or perpendicular to the direction of the closing force applied by the short stroke cylinders.

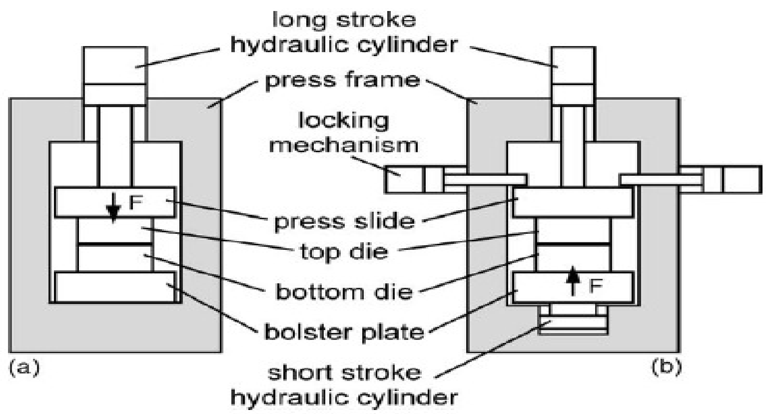

Fig 2 Principles of Common Hydroforming Presses for Industrial Production [1]

2. Application to Automotive Industry

The demand for weight reduction in modern vehicle construction has led to an increase in the application of hydroforming processes for the manufacture of automotive lightweight components. Hydroforming offers many advantages over conventional process like the assembly of car body parts from several stampings, which consist in the possibility to form complex shaped components with integrated structures from single tubes.

Chassis: A typical chassis component that would normally be made by pressing up to six channel sections and joining by spot welding can be hydroformed as a single part. Considerable mass savings are possible through eliminating the flanges required for welding and using thinner steel. Yet stiffness is maintained owing to the elimination of the discontinuous spot-welded joints.

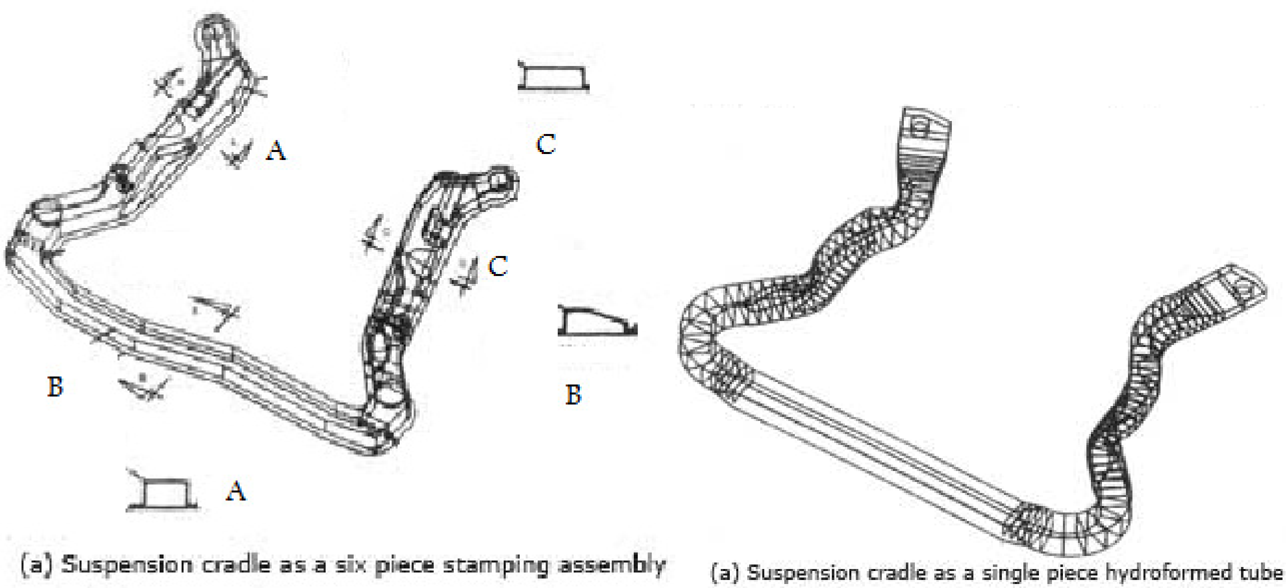

Fig. 3 Suspension cradle with Stampings and then redesigned into a single piece by hydroforming[9]

Engine Support: Engine support can be manufactured using tube hydroforming process. Hydroforming produces a whole component that would otherwise be made from multiple stampings joined together.

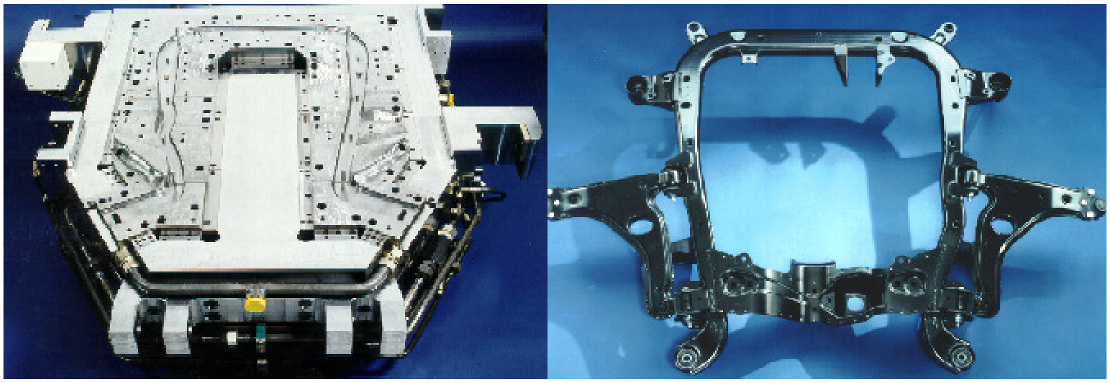

Fig. 4 Tube Hydroforming tool and Engine support with mounted parts.[1]

Comparison with conventional design:
30 % less weight
20 % cheaper
60 % less tool cost

Thus benefits offered by hydroforming compared to conventional techniques are forming complex shaped components with integrated structures from single tubes. The parts manufactured by hydroforming have higher stiffness and crash behavior due to the reduction of welding seams, and with reduced assembly costs.

4. Warm Hydroforming

In the automotive industry, there have been continuous demands for the use of lightweight materials to reduce lightweight materials to reduce fuel consumption. A 10% weight reduction in an average automotive body could improve the fuel efficiency by 6-8%. Aluminium alloys and magnesium alloys offer a great potential for weight reduction in vehicle construction due to their high strength to weight ratio. A weight reduction as high as 40-60% and 60-75% can be achieved by replacing steel auto body panels with aluminum and magnesium respectively.[1] However, the use of these alloys is in comparison with conventional steels restricted due to their low formability at room temperature. The use of temperature opens up the possibility of increasing the ductility and associated forming capability of the material along with reducing the yield point and forming pressures and forces required. [2]

Warm Hydroforming operating temperature is below recrystallization temperature, ranging from 0.2 to 0.5 times the recrystallization temperature.

Temperature Dependant Material Behavior:

Aluminum:

The use of elevated temperatures below recrystallization temperature results in lowering the yield point and strain hardening capability and greater achievable expansions.

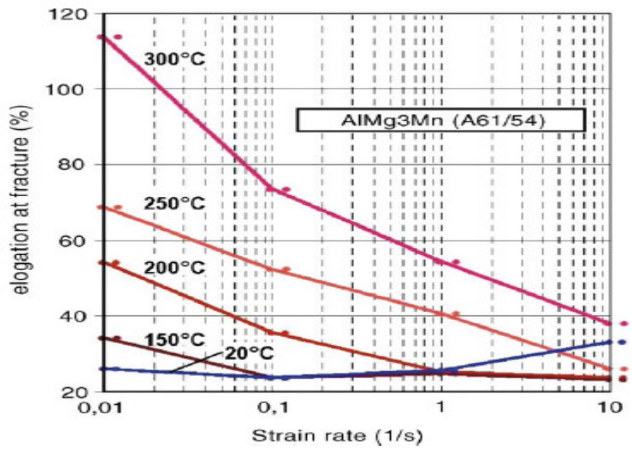

Fig. 5 Warm tensile tests of aluminium AlMg3Mn [1]

Results of Hydraulic Bulge Tests:

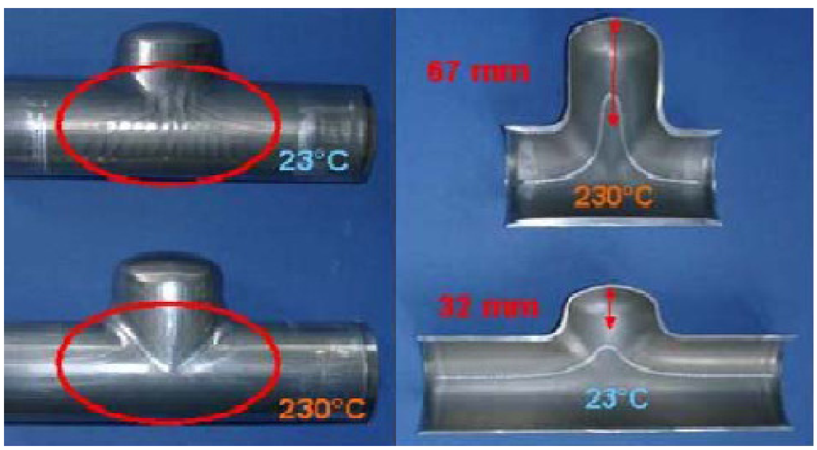

Fig. 6 Tests on Aluminum Alloy AW 5083 (ERCNSM Ohio)

1. The sample hydro formed at 230°C did not produce any wrinkles on the neck section
2. The strain observed is significantly higher at 230°C (hieght hd=97 mm) than at 23°C (height hd=32 mm)

Magnesium:

Because of its hexagonal lattice structure and the associated low number of glide planes, the restricted cold forming capability is a fundamental disadvantage of magnesium. To make it possible to use magnesium sheet metal to produce complex component geometries, it is necessary to activate additional glide planes; this is something that can be observed at forming temperatures of greater than 225°C.

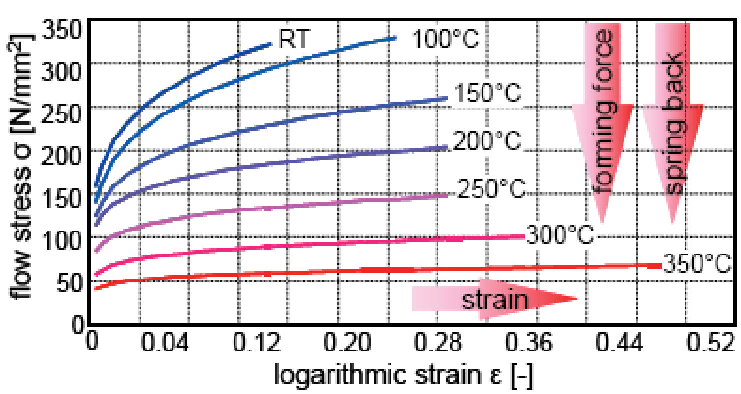

Fig. 7 Effect of Elevated Temperatures on the flow curve of Magnesium Alloy AZ31B [1]

Results of the Hydraulic Bulge Test :

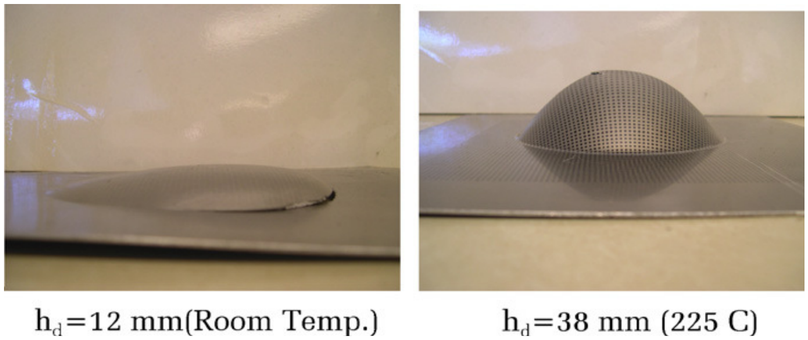

Fig. 8 Variation in formability at room and elevated temperatures

a. At room temperature maximum pressure required is 230 bar and at 225°C is 23 bar.
b. Circumferential strain of the tube formed at 225°C is significantly higher than that formed at room temperature. (40% compared to 20%)

Thus, Aluminum and Magnesium alloys show improved formability at higher temperatures.

Heating System:
Figure shows schematic of submerged hydroforming process. The formed part is totally submerged in a heated heat transfer fluid before and during the hydroforming process. The upper and lower dies are heated and submerged in the heating fluid tank and the axial punches feed the tube ends into the expansion zone during part forming. The heat transfer fluid preheats the tube to forming temperature, acts as the hydroforming pressurizing medium, and lubricates the dies. This concept suggests a novel method to eliminate part blank pre-heat and pressurizing fluid pre-fill time, making it competitive with conventional room temperature hydroforming.

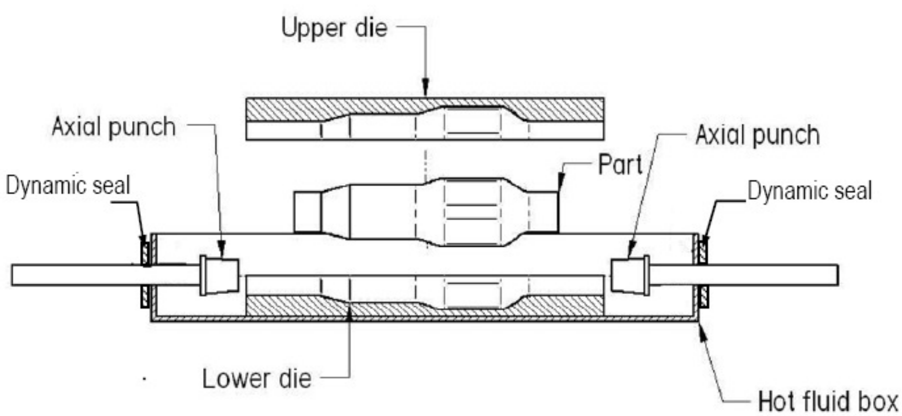

Fig. 9 Submerged heating for Warm Hydroforming process.[1]

5. Conclusion
This report gives an overview of the Hydroforming process and it's increasing application to Automotive Industry. In general, hydroforming is a technically elegant process. It is also a much more robust and practical process than many in industry will admit, and this robustness alone will ensure its increasing use. Hydroforming offers many advantages as compared to the conventional manufacturing processes. With the research and advent of Warm Hydroforming, the hydroforming process can be extended to lightweight metals

like Aluminum and Magnesium Alloys as well. In many cases, reliable computer simulations will help in developing more robust hydroforming techniques.

References:

[1] Ch. Hartl 'Research and advances in fundamentals and industrial applications of hydroforming' Journal of Materials Processing Technology 151 (2004) 237–241

[2] T Altan 'Future Trends and Advances in Stamping and Hydroforming Technologies'
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[3]Shijian Yuan, Jun Qi, Zhubhin He 'An experimental investigation into the formability of hydroforming 5A02 Al-tubes at elevated temperature' Journal of Materials Processing Technology 177 (2006) 680–683

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