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Review Article

A review on Hydroforming Processes

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Abstract

This paper gives overview of hydroforming technique, its history, and its position in the forming process, classification, advantages, limitations, and implementation. This technique gives idea to manufacture the components of light weight, complex geometry. This technique uses hydraulic press as machine to produce different components. This technique consists of several different sub techniques. Different sub techniques help us to form different components of automobile & aircraft systems, etc. This technique is used to improve fuel efficiency & to reduce mass of automotive components.

Keywords: *Hydroforming Process, Sheet Hydroforming, Shell Hydroforming, Tube Hydroforming.*

1. Introduction

Hydroforming is a material-forming process that uses a pressurized fluid (liquid or gas) in place of hard tooling (punch, die, mold, inserts, etc.) either to plastically deform or to aid in deforming a given blank material (sheet or tube) into a desired shape. Hydroforming technique can be used to form components of complicated shapes from sheet of metal blank or tube using water which is either used as punch or dies . This technique uses hydraulic press for manufacturing purpose. It is nothing but internal high pressure forming. Hydroforming is categorized as a cold forming process. It is used for the manufacture of geometrically highly complex hollow bodies from tubular parts.

2. Hydro Forming Processes

Hydroforming Processes are classified mainly in to 3 types as described below:

1) Sheet Hydroforming
2) Tube Hydroforming
3) Shell Hydroforming

2.1 Sheet Hydroforming

Sheet hydroforming has many names such as hydromechanical deep drawing, the aquadraw method, hydrodynamic deep drawing, hydraulic deep drawing with counter pressure, hydro-form, liquid forming, hydraulic bulging, twin-bulging, etc

Hydrodynamic deep drawing (HDD) is a typical method in sheet hydroforming as shown in **Fig. 1.** When the punch pushes the sheet metal with high pressure into the die cavity which contains liquid in it, presses the sheet metal onto the punch with equal but opposite pressure. Then, as blank slides between blank holder and die frictional forces are produced. This is called as friction retention. At the same time, the liquid in the die cavity flows out from the gap between the upper surface of the die and the sheet metal. Due to this fluid lubrication frictional forces are reduced. The hydraulic press of 100,000 KN is used for this type of hydroforming. The liquid can be used as a punch or as a draw die or as an assisting way to improve sheet formability.

The early sheet hydroforming technology was a forming technology that mainly used a rubber diaphragm, a rubber bag and was applied in the small batch production of automotive panels and aircraft skins in the 1980s.

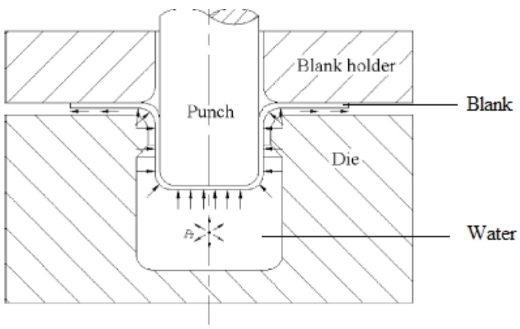

Fig. 1 Sheet Hydroforming Processes

Many materials can be used in this process, such as low carbon steel, stainless steel, high strength steel, aluminum alloy, magnesium alloy, titanium alloy, etc. Sheet Hydroforming has following common methods.

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Rubber Diaphragm Forming

1) Active Hydroforming also called as Hydro-Mechanical Drawing
2) Passive hydroforming also called as hydrodynamic deep drawing
3) Twin Hydroforming also called as Double Sheet Hydroforming

2.1.1 Rubber Diaphragm Forming

In this hydroforming process the hydraulic press is modified as upper part, called as female die element, which has a fluid forming chamber attached to the slides of a hydraulic press. A flexible rubber diaphragm is provided at the mouth of the chamber in order to retain fluid within the chamber, which serves as a universal die capable of accommodating any shape. A wear-pad which acts as a blank-holder is attached to the rubber diaphragm to protect the diaphragm. The lower part, called as male die element, typically consist of a punch or a cavity die in some cases, is mounted on to a hydraulic cylinder on the bed of the press. The punch is attached to a hydraulic piston and the blank holder, or ring, which surrounds the punch.

The forming process starts by placing a blank on the blank holder. The press is closed by lowering the forming chamber. Forming chamber is pressurized by applying initial pressure in the chamber. The punch moves upwards through the ring and into the flexible die chamber. The diaphragm supports the entire surface of the blank. It forms the blank around the rising punch, and the blank takes on the shape of the punch. When the hydroforming cycle is complete, the pressure in the forming chamber is released, the forming chamber is raised and the punch is retracted from the finished part. Typical forming pressures range from 5,000 to 15,000 PSI or 345 to 1,034 BAR.

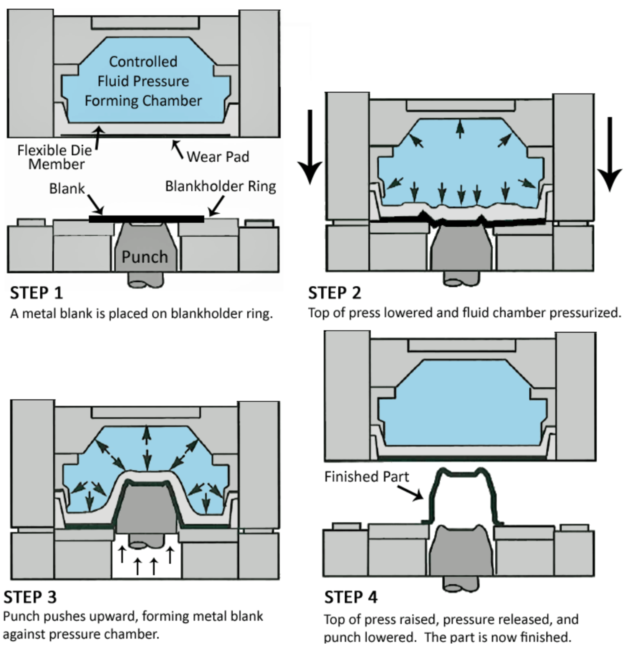

Fig. 2 Rubber Diaphragm Hydroforming Processes

2.1.2 Active Hydroforming

Active hydroforming is combination of deep drawing and bulging technology. The lower blank holder is a reservoir containing an oil and water emulsion as a fluid medium, while the top die holds the punch. As the press closes over the blank it forms a water tight seal between the die halves. At this stage, a part-specific gap exists between the clamped blank and the punch. As soon as the blank-holding force has built, the fluid is brought to a defined pressure. This pressure causes a controlled bulging of the blank over its entire surface, resulting in work hardening of the workpiece and a substantial improvement in buckling strength of the part. Bulging continues until the blank comes to rest against the center of the punch surface. After this pre-stretching process, the punch is lowered into the blank.

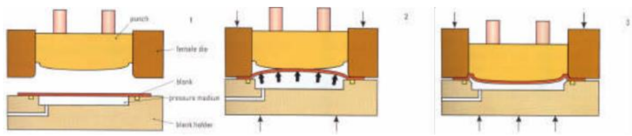

Fig. 3 Active Hydroforming Processes

Active Hydro-Mechanical Drawing is cost effective since only one die half needs to be machined to achieve the required part shape. This is used in fabricating large sheet metal panels and can improve the buckling strength of the finished part.

2.1.3 Passive Hydroforming

This is same as that of explained by Fig. 2. The passive hydroforming which also called hydrodynamic deep drawing (HDD), die filled with liquid as a pressure cavity in HDD process, it can significantly improve the forming limit compared with general deep drawing.

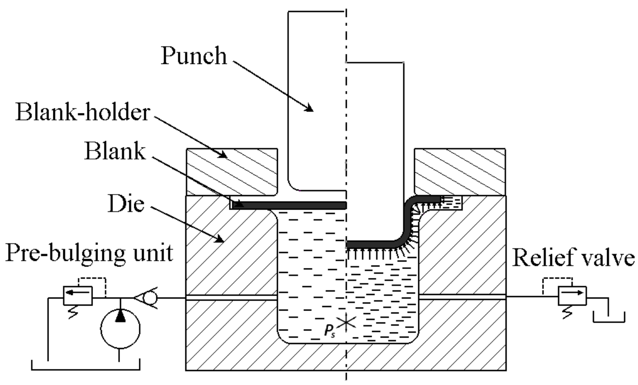

Fig. 4 Passive Hydroforming Processes

2.1.4 Twin Hydroforming

The part is produced using two flat or pre-shaped sheet metal plates, arranged in parallel and in contact with one another with the same or different sheet metal thickness and of the same or different type of material with identical edge dimensions and welded to one another at the edge. The double plate produced in this manner is inserted into a tool consisting of upper and lower dies; after the tool is closed, the edge area of the plate including the weld is located between the sheet metal retaining surfaces af the upper and lower tool part with higher or lower width. The component is shaped by a pressure medium between the plates. Depending on the material used and the component geometry, the flange can be clamped stationary or the flange can be allowed to flow into the tool die.

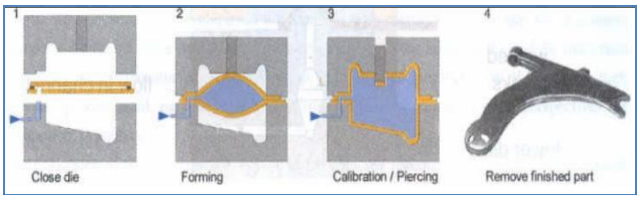

Fig.5 Twin Hydroforming Processes

Twin bulging is mainly used for the forming of hollow complicated parts, and large variations of the part intersections are permitted and fewer process steps than in conventional deep drawing are allowed for the production of light and strong parts.

2.2 Tube Hydroforming

Development of the techniques and establishment of the theoretical background of Tube hydroforming goes back to 1940s. Tube Hydroforming is a manufacturing process that consists of placing a tube into a die, then pressurizing the tube internally with liquid and simultaneously moving the side punches inward, to create axial compressive pressure, until it conforms to the shape of the die cavity as shown in **Fig. 3**.

Presently, the hydroforming process is widely applied to various fields, such as home appliance handles, external parts of electronics, structural body materials, fuel transfer pipes, and plant pipe installations, and has rapidly spread to other industrial fields.

It has many advantages such as part consolidation, weight reduction, improved part strength and stiffness, highly accurate dimensions and less spring back, lower tooling cost and fewer integrated processes, etc. which all promote rapid spreading of this technology in the automotive, household and aerospace industries.

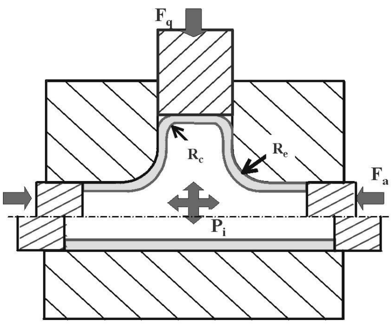

Fig.6 Tube Hydroforming (THF) Processes

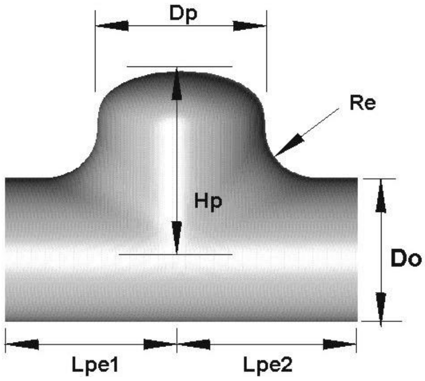

Fig.7 Product of Tube Hydroforming (THF) Processes

Elements of a typical THF process as shown in **Fig. 3** and **Fig. 4**

(Fa): Axial force,
(Fq): counter force,
(Pi): internal pressure,
(Rc): corner radius,
(Do): initial tube diameter,
(Dp): protrusion diameter or bulge width,
(Hp): protrusion or bulge height,
(Lp): distance between tube edge and protrusion.

2.3 Shell Hydroforming

Z. R. Wang from Harbin Institute of Technology developed a new technique to manufacture closed spherical, ellipsoidal, vessels without using dies which is termed as Shell hydroforming, also named as Internal Hydro Bulge Forming by Travis in 1996.

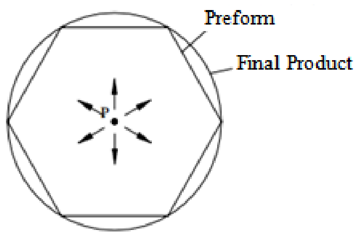

Fig. 8 Shell Hydroforming Processes

Firstly, in shell hydroforming process, the preform is prepared. The preform is polyhedron, multifaceted structure assembled and welded by using sheet metal blanks as shown in **Fig. 8.** Then high pressure is developed inside the preform either by using liquid pumped in to the preform or by detonating the explosive charge inside the preform.

Shell Hydroforming process is used to form water tanks, LPG tanks, large building decorative objects, pressure vessel heads and large-size elbow joints with a single layer or double layers as shown in Fig. 9.

A: a hydrobulged steel football of diameter 4000 mm,
B: a spherical vessel of diameter 2.8 m, Landmark of Harbin Institute of Technology, formed by hydrobulging, C: A tower-mounted spherical water tank of 8 m in diameter formed by IHBF, D: Two ellipsoidal communication tower (the bigger one has major axis of 5 m)

Fig. 9 Product of Shell Hydroforming (IHBF) Process;

Shell Hydroforming has following advantages over traditional shell manufacturing

- the shells can be formed without a press and dies,
- residual stress near to the welds can be reduced by applying over-loading during the process,
- as the forces acting on one half of the workpiece can be balanced by the other half, there is no need of balancing the counter forces
- shorter production cycle,
- low cost and easier manufacturing

The only drawback of hydrobulging process is that the wrinkles or buckles are easily formed in some area due to compressive hoop stresses.

3 Advantages and Disadvantages of Hydroforming Processes

Following are advantages of Hydroforming processes

- complex parts are easy to produce with high strength
- Used in large scale for production.
- Reduced scrap & fewer secondary operations.
- About 30% weight reduction compare to other processes
- 50% of cost of component is reduced compare to conventional drawing process
- Deep drawing ratio, high surface quality, high stiffness & rigidity in the component is obtained by this process.

Following are **Disadvantages** of Hydroforming processes

- Slow cycle time.
- Expensive equipment.
- Lack of extensive knowledge base for process and tool design.
- Efficiency of hydraulic press low.

4 Applications of Hydroforming Process

- In the industries of automotive and aerospace & as well as for household purpose.
- Many companies like Ford, GM, BMW, Audi etc. uses the part made by this technique.
- An aluminum rear axle (BMW, Germany), Engine cradle (Vari-Form, USA), Audi A etc. uses this technique to produce different parts.
- On the other hand, multi- layered systems are also suitable for chemical use in special environments: for example, a bimetallic CRA(corrosion resistive alloy)- lined pipe, which consists of a CRA and low-cost steel tube, has been applied in the nuclear and refining industries

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