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ABSTRACT

The hydroforming technology has gained in importance over the last few years. Today the lightweight construction of automobiles is one of the main fields of application. This paper gives an overview of the fundamental principles of hydroforming processes and their variants. The correlations between the work piece geometry and the design of tool and process and the forming result are exemplarily illustrated.

Hydroforming is a cost-effective way of shaping malleable metals such as aluminum into lightweight, structurally stiff and strong pieces. One of the largest applications of hydroforming is the automotive industry, which makes use of the complex shapes possible by hydroforming to produce stronger, lighter, and more rigid unibody structures for vehicles. This technique is particularly popular with the high-end sports car industry and is also frequently employed in the shaping of aluminum tubes for bicycle frames.

Hydroforming is a specialized type of die forming that uses a high pressure hydraulic fluid to press room temperature working material into a die. To hydroform aluminum into a vehicle's frame rail, a hollow tube of aluminum is placed inside a negative mold that has the shape of the desired end result. High pressure hydraulic pistons then inject a fluid at very high pressure inside the aluminum which causes it to expand until it matches the mold. The hydroformed aluminum is then removed from the mold.
CHAPTER NO. 1

INTRODUCTION

Hydro forming is a relatively new process, which uses water pressure to form complex shapes from sheet or tube material. Design studies suggest that automobiles can be made much lighter by using hydro formed components made of steel. Structural strength and stiffness can be improved and the tooling costs reduced because several components can be consolidated into one hydro formed part.

As the automobile industry strives to make car lighter, stronger and more fuel efficient, it will continue to drive hydro forming applications. Some automobile parts such as structural chassis, instrument panel beam, engine cradles and radiator closures are becoming standard hydro formed parts.

The capability of hydro forming can be more fully used to create complicated parts. Using a single hydro formed item to replace several individual parts eliminate welding, holes, punching etc... Hydro forming simplifies assembly and reduce inventory.

The process is quite simple - a blank with a closed-form, such as a cylinder, is internally pressurized using fluid. The fluid is frequently water. The applied pressure is usually in the range 80-450 MPa. Its resultant plastic expansion is confined in a die of the desired shape.
**Fig. 1 Equipment for hydro forming**

Hydro forming equipment consists of a hydraulic hydro forming press, pressure intensifiers, hydro form water system, and a hydro forming unit.

**Fig. 2 Hydro formed components**
Fig. Hydro formed automobile Component

fig. Hydro formed bellows, beginning with cylinders

Fig. Hydro formed handle bar

fig. Hydro formed T-junction
CHAPTER NO. 2
LITERATURE REVIEW

1. Masaaki MIZUMURA et al:

Masaaki in his report presented that recently hydroforming has been applied for auto parts however it has problem that forming condition is difficult. In this report, hydroforming tests and FEM analysis with simple shape were carried out and deforming behavior during hydroforming were observed. It was found that the loading path of internal pressure and axial feeding has effect on hydroforming deformation. Next hydroforming allowance evaluation method was developed. By this method, the effect of material properties was proved. The conventional hydroforming machine is large and expensive, but a compact machine was developed. By these results, hydroforming market becomes larger.

2. Nader Abedrabbo et al:

Nader presented an approach to optimize a tube hydroforming process using a Genetic Algorithm (GA) search method. The goal of the study is to maximize formability by identifying the optimal internal hydraulic pressure and feed rate while satisfying the forming limit diagram (FLD). The optimization software HEEDS is used in combination with the nonlinear structural finite element code LS-DYNA to carry out the investigation. In particular, a sub-region of a circular tube blank is formed into a square die. Compared to the best results of a manual optimization procedure, a 55% increase in expansion was achieved when using the pressure and feed profiles identified by the automated optimization procedure.
3. Kim Dongok et al:

Kim dongok studied hydro forming process for aluminum alloy sheets have been largely accepted by automotive industries for the production of components characterized by good surface quality, high dimensional accuracy together with high drawing ratio and complex shape. However, the process parameters with its stress distribution have not fully studied. The main aim of this research is to compare the residual stresses between experiment and finite elemental method in order to predict the stress development after hydro forming process.
CHAPTER NO. 3
METHODS OF HYDRO FORMING

There are two types of Hydro forming

1. Tube Hydro forming
2. Sheet Hydro forming

Sheet hydro forming converts the irregular shaped material into a finished and uniform thickness sheet. The tube hydro forming process is used to form parts in materials such as steel tubes and aluminum extrusions by applying hydraulic pressure.

3.1. TUBE HYDRO FORMING

Tube hydro forming is a kind of soft-tool forming technology and developed rapidly in the past decades. For taking tubes as processing blanks and liquid as flexible punch, it is more suitable for manufacturing special tubular components, such as different kinds of hollow shafts, discharge pipe of automobile & aero planes, sectional pipes etc..

Tubes were placed in the die and sealed on the end. Then under the co-action of compressive axial force and internal pressure, it is forced to deform from elastic stage to plastic stage. With the increasing of the applied load, the deformation increased correspondingly. Finally, under the extremely high pressure, the tube assumed the internal contour of the die precisely. In tube hydro forming, a cylinder is pressurized internally with 80 to 450 MPa pressure by a fluid like water.

Compared with traditional processing technology, tube hydro forming always manufactures components at one step. So it can enhance part quality, such as tighter tolerance and increase rigidity, and lower production costs and reduction in production cycle. In this method the tube is placed in die and as press clamps the die
Valves, low pressure fluid is introduced into tube to pre forms it. One the maximum clamping pressure is achieved, the fluid pressure inside the tube is increased so that tube bulges to take internal shape of the die. Simultaneously additional cylinders axially compress the tube to prevent thinning and brushing swing expansion. It is possible that some parts of the component thin excessively during hydro forming. This can sometimes be rectified, in the case of tube hydro forming, by applying axial pressure to feed material into the bulges, thereby reducing bulging.

Fig. 3 Schematic illustration of the hydroforming of a bulge in a tube

fig.4 Tube Hydro Forming
3.11. TUBE HYDRO FORMING PROCESS

Tube Hydroforming (THF) has been called with many other names depending on the time and country it was used and investigated. The first industrial applications for this process, namely the production of T-shaped joints, were published in papers in the 1960s; the use of these processes increased rapidly when in 1980 the automotive industry turned its attention to this process and, more importantly, to the possibilities for light weight constructions. Throughout this paper, THF will be used to describe the metal forming process whereby tubes are formed into complex shapes with a die cavity using internal pressure, which is usually obtained by various means such as hydraulic, viscous medium, elastomers, polyurethane, etc., and axial compressive forces simultaneously.

Figure shows the process principles for tube hydroforming. A tube is placed in the tool cavity, whereby the geometry of the die corresponds to the external geometry of the produced part. These tools, in most cases separated in longitudinal direction, are closed by the ram movement of a press, and the tube ends are loaded by two punches moving along the tube axis. Each of the loads applied to the tube ends for sealing the tube’s interior must be at least equal to the force calculated from the product of the tube’s internal area and the tube’s internal pressure. However, the axial forces may be increased to a higher value if the forming job requires it. Then additional tube wall material is brought into the tool cavity. During the process the internal pressure is increased until the expanding tube wall comes into contact with the inner surface of the die cavity. This process principle may be used for hydroforming both straight and pre-bent tubes.
Fig. 5 Process principle for tube hydroforming.

As shown in figure, the applicability of the process implies that failures caused by plastic instabilities such as buckling, folding and bursting can be excluded. The risk of buckling is posed as he start of the process by too high axial loads on the initial tube, and it is also present for the entire starting phase. So that this risk of buckling can be avoided by compensation the unsupported tube length with increasing in the section.

Modulus of the tube cross section through the simultaneous expansion of the tube wall.

In the intake zone of the expansion shape, a formation of folds cannot be avoided; these folds, which are symmetrical to the longitudinal axis, can be reversed by an increase in internal pressure during the final phase of the expansion process. However further folds can occur at the centre of longer expansion forms as a result of too high axial forces: these can be avoided with a proper process controller.

The risk of bursting is a result of too high internal pressure and is initiated by a local neck in the tube wall, whereby the onset of this local necking significantly depends on the initial tube wall thickness. To prevent this risk it must be ensured that the tube wall briefly comes into contact with the wall of the tool at the latest before the onset of necking.
The hydro forming process varies slightly depending on the component, but here’s a general look at the overall procedure.

1. First, a computer-controlled machine cuts a length of straight ‘metal tubing’, also called a blank, to the proper size and feeds it into a machine, where it is pre-bent into the approximate contour of the finished part.

2. Next, the blank is inserted into the die, which is pumped full of highly pressurized water.

3. The water fills the blank, which conforms to the die walls. The water shapes the blank into the desired form.

4. At the same time, the machine compresses the ends of the blank, which eliminates thin spots on the outer wall of the blank, and prevents wrinkling on the inner wall, as well.

5. The component is then removed from the hydro forming press, the ends are trimmed and mounting holes are pierced with lasers and cutting torches.
Fig. 5 Steps in hydroforming
Step 3

Step 4
3.12. HOW CAN TUBE HYDRO FORMING BENEFIT THE AUTO MANUFACTURER

1. Increased strength to weight ratios
2. Improved stiffness torsion and bending rigidly
3. Improvement in NHV Factor
4. Incorporation of hole punching, slot making, embosses swing hydro forming process.
5. Reduction in number of manufacturing stages, hence tooling.
7. Reduction in production cost
8. Reduced floor area
3.2. SHEET HYDRO FORMING

Sheet hydro forming involves forming of sheet with application of fluid pressure. During the sheet hydro forming process, the hydraulic pressure varies in the range equal to or less than 100 MPa A sheet metal blank informed by hydraulic counter pressure generated by punch drawing sheet into pressurized water chambers. The water pressure effectively punches the sheet firmly against punch to form required shape.

The major advantage of fluid forming is increased drawing ratio. The process take place in two stages performed during one press stroke. The sheet is performed by applying low fluid pressure while it is clamped firmly by a blank holder pressure. Performing achieves on evenly distributed strengthening in the component center. In next step fluid pressure increased gradually and blank holder pressure is controlled relative to sheet reformation.
Fig. 6 Sheet hydro forming
3.21. NEW CONCEPT IN SHEET HYDRO FORMING

Double Sheet Hydro Forming

Structural component with closed components are formed by this process. Some advantages of this process are:-

- Integration of more parts, further reduction of components & thus steps.
- Stiffness increase and reduction in overall spring back due to closed box section & continuous weld section.
- A complete component is made in one single hydro forming step, with only top and bottom die.

Fig.7 Double sheet hydro forming
CHAPTER NO. 4
FORMING LIMIT DIAGRAM

During hydro forming process failure occurs due to thinning, this is due to the excessive deformation in a given region. A quick and economical analysis of deformation in a forged part is analyzed from forming limit diagram.

The ability to detect point to point variation in strain distribution generally requires circle diameter between 2.5 to 5 mm. The sheet is then deformed, converting circles in to ellipse, and the distorted pattern is then measured and evaluated. Regions where the area has expanded are locations of sheet thinning Regions where area has contracted have undergone sheet thickening. Using the ellipse on the deformed grid, the major (Strains in the direction of larger radius) and associated minor strains (Strains perpendicular to the major) can be determined for variety of locations and values can be plotted on the forming limit diagram.

If both major and minor strains are positive deformation is known as stretching, and thinning will possible.

Graph 1. Forming Limit Diagram
CHAPTER NO. 5
HYDRO FORMING PROCESS CONTROL

A typical hydro forming system would include a press capable of developing necessary forces to clamp the die valves together when internal pressure acts on fluid; a high pressure water system to intensify water pressure for forming component, looking including aerial cylinder and punches, depending on component and a control system for process monitoring.

Since the entire process of operation takes place inside a closed die, one cannot see what actually happens during forming. Therefore the controller plays a vital role in displaying, monitoring and controlling the different parameters of forming in real time.
Fig: 8 Schematic Diagram of Tube Hydro forming and Process Control
CHAPTER NO. 6
HYDRO JOINING

Usually after hydro forming, additional joining operations are required to form assemblies. To reduce manufacturing time and number of process steps, joining operation are being integrated into hydro forming process. This also reduces tool cost. Two approaches to hydro joining are punch riveting hydro clinching.

In punch riveting, pressurized fluid acts on one sheet while a moving punch acts on other sheets from opposite sheet. Punch is moved against rivet and under the fluid counter pressure; it spreads to form a solid, visually attractive joint.

In hydro clinching, high pressure fluid action the punch. The prescribed fluid presses the material to be hydro formed part through a note in sheet to be joined.
CHAPTER NO. 7

ADVANTAGES OF HYDROFORMING

Deep drawing, using the Hydroform method, requires only a draw ring (blank holder) and male punch. No die maker's fit is necessary. Set-ups are quick and simple. The tooling is self-centered and self-aligning. The flexible diaphragm minimizes and often eliminates shock lines and draw marks normally created by matched die forming. Because pressures can be controlled over the entire blank, a higher percentage of reduction is possible and material thinout can be kept to a minimum.

Two or three conventional deep draw operations can often be replaced by one operation using the Hydroform method. Hydroforming can sometimes accomplish up to 90% or more of the forming required in spun shapes. Alternatively, a blank, pre-formed by spinning, can often be completely formed in one operation using the steel spinning chuck as the Hydroform punch. Main advantages are:

1. There are numerous automotive components well suited to hydro forming of sheets.
2. This is especially true in area of outer skin with its extreme demand of surface quality and dimensional accuracy.
3. Longer outer skin parts for passenger cars, utility vehicles and truck such as goods, doors and tender as well as complex structural components can be formed.
4. Low capital cost. Fewer and simpler dies.
5. Better NHV (noise, vibration and harshness factors) factors.
6. Reduction in weight.
7. High process capability.
8. Reduction in cost of component.
7.1 Specific Advantages of Hydroforming

**Inexpensive Tooling:** A male die (punch) and a draw ring (blank holder) are generally the only tools required. The rubber diaphragm in the Hydroform machine acts as a universal female die. Hydroform tools normally cost at least 50% less than conventional press tooling.

**Versatility in Forming Complex Shapes and Contours:** Irregularly contoured shapes are easily formed using the Hydroform process because matching dies are not required.

**Minimal Material Thinout:** Hydroforming flows the metal rather than stretching it. Therefore, material thinout is minimal -- usually less than 10%. Wall thickness at the open end of the part is typically nominal or greater (a big advantage for trimming, welding and assembly). This often results in material savings because thinner blanks can be used -- a particularly important factor when expensive alloys or a large number of parts are ordered.

**Savings in Tool Materials:** Hardened tool steels are rarely required. Most punches and draw rings are made of meehanite (cast iron) -- an inexpensive, easily machined material that provides an exceptionally long tool life. Kirksite and cast plastics may be used for very short runs.

**Savings in Finishing Costs:** Matched die methods of forming can cause scuff marks, shock and stretch lines. In the Hydroform method, the wrapping action of the flexible diaphragm virtually eliminates these faults. Savings of up to 90% in finishing costs have been realized.

**Materials Versatility:** Practically all sheet metals capable of being cold formed -- carbon steel, aluminum, stainless steel, copper, brass, precious metals, high strength alloys, and others -- can be Hydroformed. Thickness of materials can vary within the limits of the machine without need for tool revisions.
Precision: The Hydroform method forms parts with extremely difficult configurations while at the same time working to precise tolerances.

Ease of Design Change: Development cost can be a large part of tooling cost with conventional deep draw techniques. With Hydroforming, material or metal thickness can be altered usually without any tooling change being necessary. Hydroforming can also eliminate or minimize the number of multiple draw operations required, with a corresponding reduction in tryout costs.

Low Work-Hardening: Hydroforming does not cause work-hardening of material at the same rate as conventional drawing operations. Consequently, annealing between draw operations is rarely required. The need for multiple draw operations can often be eliminated, too.
CHAPTER NO. 8
RECENT TRENDS IN HYDROFORMING

Recent innovations are aimed to improve competitiveness of hydroforming technology by reducing initial investment cost, increasing production rate, and material utilization, consolidating more parts into single parts, and finding ways to eliminate draw backs such as excessive thinning. As mentioned before, new press or clamping device concepts are under development and trial to reduce the amount of initial capital investment as well as increase the productivity by having rapid strokes. Even some hydroforming systems without a press or clamping device are discussed and seem feasible only for low production rates. In order to increase the material utilization and avoid excessive thinning, following innovations are being tested and used nowadays:

(a) tapered (conical) tubes for long structural parts having substantial expansion degrees between two ends,

(b) tailor-welded tubes for minimizing thinning at high expansion zones which are usually at the middle sections of a long part for which other innovations cannot be utilized practically,

(c) double tubing is used to increase the strength of the final part while minimizing the weight. Particularly used for front rails where extra care has to be taken for excellent crash properties,

(d) multiple tubing seems to be an innovative way of producing whole assemblies at once, which is an excellent way of consolidating more parts into one. Tubes of different pre-formed shapes are connected to each other, and placed into a hydroforming die altogether.

Use of aluminum alloys and high strength steel is seen as another way of achieving lighter parts. Companies and institutes are looking into every chance and opportunity to make cost effective production with lighter and stronger products. For instance, consolidation of lubrication into tube making is considered one way of increasing production rate. Application of various welding types, such as gas metal arc welding, laser welding, electron beam welding, is investigated to search better material properties.
CHAPTER NO. 9
FUTURE SCOPE

There are various industrial as well as non industrial fields of application of hydroforming processed parts, where in future hydroforming will play a very important role. Such fields are:

- **Aerospace:** There are many parts used in aerospace applications which can be easily manufactured by hydroforming. In this field generally light weight materials are preferred like aluminum and its alloys, Titanium and Stainless Steels, these metals can be easily hydroformed.

- **Automotive:** we know many parts and assemblies of automobiles are manufactured by using hydroforming now a days and its percentage is going to increase with time. Parts such as floor pans, dual phase frame rails and assemblies, engine cradle assemblies, battery tray assemblies, a-pillars, d-pillars, dash panels, wiper beam assemblies, IP assemblies can be easily produced by this process.

- **Alternative energy applications:** In future requirement of alternative energy will increase drastically because of limited resources of energy generation. And with it requirement of equipments will increase and hydroforming will play an important role as various parts requires for solar, nuclear, wind and battery industry can be easily produced by it.
CHAPTER NO.10

CONCLUSION

During the last 12 years, general awareness of hydro forming has grown steadily. Although interest in hydro forming is wide ranging, the vast majority of application are in automobile industry.

Hydro Forming is not solution for manufacturing all automotive parts. The benefits of automotive light weight resin and weight reduction achieved by hydro forming can be measured in kilogram. It cannot be applied to every components, one has to study inability of hydro forming the part and the economic and technical payback.

Just like transistor revolutionized the electronic industry, hydro forming has taken the vehicle manufacturing industry a step up to evolutionary ladder, allowing auto component for vehicle. Although hydro forming has not taken off rapidly as it should have, is only matter of time before this technology is absorbed in the industry.
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