Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 6, June -2017

ADVANCES IN SHEET METAL HYDROFORMING TECHNOLOGY

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ABSTRACT:- *Hydroforming is technology which is based on influence of fluid under high pressure to the inner or outer side of work piece wall. Implementation success of hydro forming process depends of a correct election of: die, material, fluid pressure and other process parameters. Hydroformig process should be implemented by using optimal parameters of the forming process that would allow stable and successful hydroforming process. Sheet metal forming by fluid under pressure is applied in deep drawing, stretching of sheet, hydroforming of welded sheets, hydroformig with metal heating etc.The basic tendencies of development of sheet metal forming process by fluid under pressure are to be improvement of sheet deformability, improvement of tribological forming conditions, optimization of forming process, development of new forming processes and new materials, automation of forming process, application of flexible tools, and implementation of flexible and intelligent systems. Hydroforming is a cost effective method of shaping metals into lightweight, structurally stiff and strong components. The automotive industry is one of the largest applicators of hydroforming, which makes use of the complex shapes possible by hydro forming to produce stronger, lighter, and more rigid unibody structures for vehicles. The hydro forming manufacturing technique is frequently employed in the shaping of aluminium tubes for bicycle frames and sheet metal panels. Hydro forming uses a specialized type of die combined with high pressure hydraulic fluid to deform the metal at room temperature into a shape forming die. Hydroforming allows complex shapes with concavities to be formed, which would be difficult or impossible with standard solid die stamping. Hydroformed parts can often be made with a higher stiffness to weight. Virtually all metals capable of cold forming can be hydroformed, including aluminium, brass, carbon and stainless steel, copper and high strength alloys.In hydroforming sheet there is bladder forming (where there is a bladder that contains the liquid, no liquid contacts the sheet) and hydroforming where the fluid contacts the sheet (no bladder). A work piece is placed on a draw ring (blank holder) over a male punch then a hydraulic chamber surrounds the work piece and a elatively low initial pressure seats the work piece against the punch. The punch then is raised into the hydraulic chamber and pressure is increased to until the pressure forms the part around the punch. Then the pressure is released and punch retracted and hydraulic chamber lifted and the process is complete. This paper represents advances in sheet metal hydroforming technology.*

Key words *: Hydro forming,sheet metal hydroforming,fluid pressure,bulging*

1. INTRODUCTION

Sheet-metal forming processes are technologically among the most important metalworking processes. Products made by these processes include a large variety of shapes and sizes.Typical examples are automobile bodies, aircraft panels, appliance bodies, kitchen utensils and beverage cans(1-2). Among the various sheet-metal forming processes, hydroforming is one of the nontraditional ones. This process is also called hydromechanical forming, hydraulic forming or hydropunch forming. In hydroforming process, liquid is used as the medium of energy transfer to form the workpiece. The part is formed on a female die, with the liquid under pressure acting in place of a conventional solid punch. Hydroforming is applied more and more in the modern manufacturing industry(3-6). Comparing with the solid punch stretching process, hydroforming process results in a better strain state in the workpiece, so that a deeper draw can be achieved. The friction between tools and blank is greatly reduced. The advantages of hydroforming include low tooling cost, flexibility and ease of operation, low tool wear, no damage to the surface of the sheet, and capability to form complex shapes . Hydroforming process is divided into two main groups; sheet hydroforming and tube hydroforming.

The hydroforming process technology is relatively new and lack of extensive knowledge for process and tool design, as such all those factors need to be studied carefully to improve from its trend. Nowadays, hydroforming process replaces conventional stamping process in most automotive industries and other industries(7-8).In stamping,component required a set of blanking, forming and trimming dies and corresponding process operations before the part is ready for the assembly, and amount of material scrap for stamping operations can be 20%-30%,whereas the amount of scrap for hydroforming is usually less than 10%, and for some design it can be zero percent, hydroforming has many applications in an automotive industry, such as automotive engine cradle, rear cradle, instrumental Panel beam, camshaft, and exhaust Pipes etc. The hydroforming process design consists of computer simulation techniques. The results of the analysis can be used to optimize parameters. The main objective is to produce a component design that is cost effective and optimize for hydroforming(9-12).The method to achieve this is to conduct a timely computer simulation.Process design helps to determine any possible shape defects, bursting or whickling in the planning phase and allow designers to improve their die design before tool manufacture. Hydroforming is a manufacturing process, where fluid pressure is applied to ductile metallic blanks to form desired component shapes. The blank are either sheet metal or tubular sections(13-15).If sheet metal blanks are used, the process is called sheet metal hydroforming, and if tubular section blanks are used, it is called tube hydroforming. The tubular geometries can be used for manifesting space frames, camshafts, I/P beams, and exhaust skims.

Sheet hydroforming is one of the metal forming processes used in industry to produce complex shapes with high limiting drawing ratio. In recent years, increasing attention has been focused on hydroforming technology due to the rapid development of automobile production and the aerospace industry (16). Many methods of sheet hydroforming have been proposed to meet practical and theoretical applications, such as hydromechanical deep drawing (17), hydrodynamic deep drawing (18), aquadraw process (19), and hydroforming deep drawing (20).

2. SHEET METAL HYDROFORMING (SHF)

The most important global demands of current designs, such as economic efficiency of technical solutions, careful handling of energy and raw materials, optimized workpiece properties innovations in processes and approaches, near to more conventional solutions, are developed. Moreover it is to consider that the increasing technological demands concerning the function of products, for instance in structural parts of cars, in medical instruments or in household hardware, are further reasons for increasing difficulties in the production of more complex work-piece geometries. At last it is to consider that consumer behaviour is changing: the trend is going away from mass-production articles towards the more custom made products; in fact, if the low-cost production of mass-products has in the past always been in the foreground, today new processes are being developed, which are making the economical small-lot production of custom-made products possible. Conventional sheet metal forming processes will not be able to meet these varieties of demands and new manufacturing technologies, such as Hydroforming, using fluids as a replacement or support of rigid tools, could prove to be more flexible and efficient: this would enable the production of distinctly more complex component shapes with high surface quality and optimized structural properties(3). This will lead to a completely new category of sheet metal formed parts, made of sophisticated materials, produced in only one manufacturing process, offering new prospects for light-weight constructions and for cheaper products taking care of the environment.

All working media based methods can be classified into groups according to:

- the working media role (punch or die);
- the blank-holder presence or absence;
- the form of contact between the work-piece and the working media (direct or indirect).

So it is clear that by combining all the previous possibilities, the number of potential versions increases.

3. HYDROMECHANICAL DEEP DRAWING

Hydromechanical deep-drawing with working media as a die and adjustable blank-holder force is very controllable process and the products quality is very high.If a hydraulic counter pressure is applied during deep-drawing of rotationally symmetrical sheet metal parts,the heet metal is pressed against the punch(6). The counter pressure is generated by penetration of the punch, i.e. by “passive” compression of the hydrostatic medium (fig.1). When the punch ends his stroke and is situated at the lower dead centre, it is possible that the sheet is not completely formed and does not perfectly adhere to the punch, especially in the concave zones with small curvature radius; so the smaller the contour radius *R* and the higher the sheet thickness *t*, the higher the pressure for calibration, to make it completely adherent to the punch.

Pmax = f (Rmin, s , t)

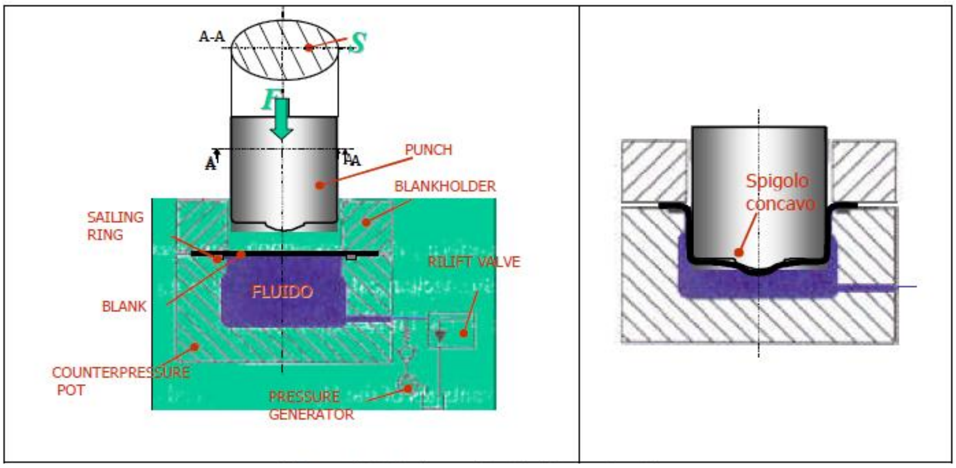

Fig.1 Hydromechanical deep-drawing

Therefore, it is indispensable some times to increase the pressure up to 250 MPa (2500 bar) in the counter pressure pot, actively, by a pressure generator. The material flow in the forming zone is affected by the blank-holder force and, when it is absent, the effective control of the sheet draw-in is difficult, so the blank-holder task is assigned to the working media. Consequently the force that restrains the sheet flow on its horizontal plane is proportional to the working media pressure, so that, with high pressure values, a hydromechanical stretch forming process is obtained(7). It is characterized by tractive stresses along both principal directions on the sheet plane instead of tractive stresses along one direction and compressive stresses along the other one. The main technological advantage of this process over conventional deep-drawing is the greater material adhesion to the punch already during first forming steps; this behaviour prevents localized thinnings, especially close to convex contour. Furthermore, the higher thickness uniformity in hydromechanical deep-drawed parts allows to gain limiting drawing ratio ß (the ratio between the maximum initial blank diameter possible to draw without tearing and the punch diameter) higher than those attainable by conventional deep drawing, so parts which could be formed with a certain number of different steps, here can be performed in a single operation. With this forming method there is the possibility of reducing the product specific tool and die costs to a significant degree and thereby reducing the production costs; in fact the Hydromechanical deep-drawing method requires instead of a complex lower binder (female die) a simple and easy to manufacture counter pressure pot.

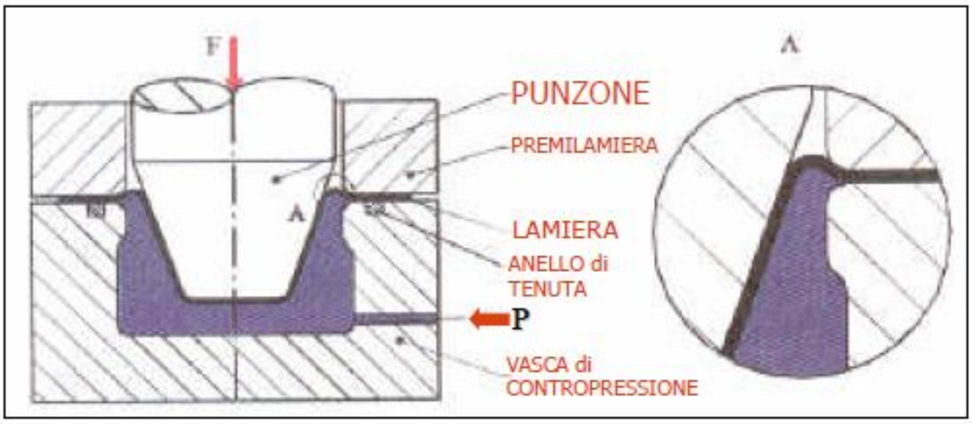

Fig.2 Process limit bulge against the drawing direction

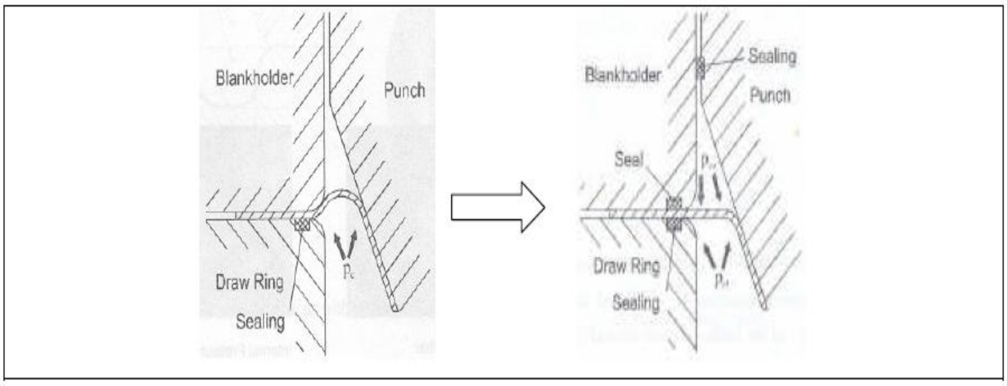

Fig.3 Pressure support chamber to avoid the bulge

The main process limits are related to the whole system cost (presses and pressure intensifier), to the slowness and particularly to some technological intrinsic limits such as wrinkling, tearing and "bulging against drawing direction", between the draw-ring radius and the sheet metal/punch contact line (fig.2). In the first case the blank-holder force is not enough high to avoid the upload from its plane and when this appends, the material flow in the forming zone become uncontrollable, with wrinkling; in the third case, especially with tapered components, when the counter pressure is higher than its bursting pressure, we can have the bulge bursting(9). One possibility concerning the reduction of the bulge against drawing direction and concerning the prevent of a burst in the bulge, establishes an integration of an upper support chamber in the upper binder (fig.3). It is possible to build up this pressure support chamber through a sealing between the punch and blank-holder as well as through a sealing between the blank and the blank-holder and the draw-ring.

A different version of the previous method consists in a combination of hydraulic stretch forming and hydromechanical deep drawing, also known as “Active Hydromech” or “Prebulging”. As shown in fig.4, with flat parts it is possible to initially perform hydraulic stretch forming with active pressure built-up from an external pressure source in order to achieve work hardening the middle areas of the part. After stretch forming the panel to approx. 2% of the principal strains in the middle area, reverse drawing can be accomplished by travelling the punch downwards. In this case the pressure is generated passively by penetration of the punch, i.e. by compression of the hydrostatic medium.

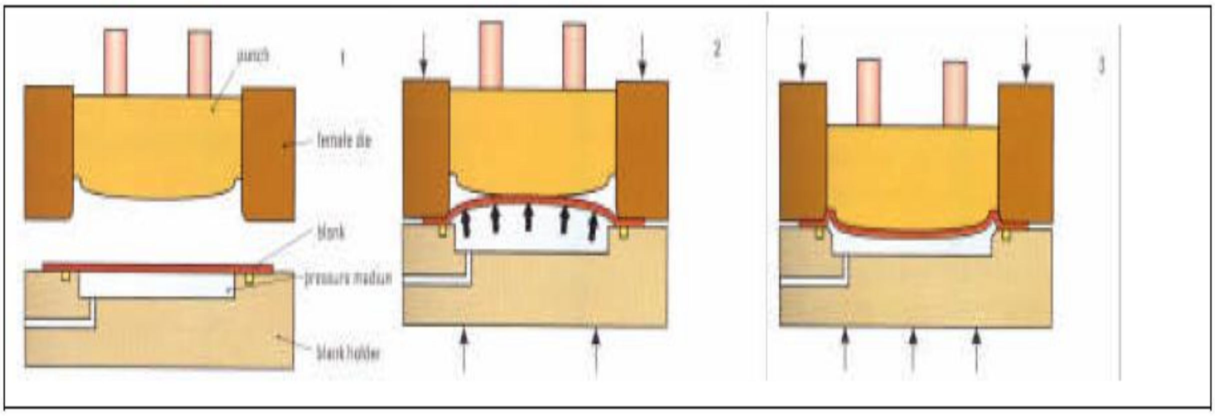

Fig.4 Combination of hydraulic stretch forming and hydromechanical deep-drawing.

4. FLEXFORMING

The trends in sheet metal forming industry appear to be towards a wider variety of models on few platforms, shorter development and program cycles, and more low volume production. Increased quality and safety requirements have, at the same time, resulted in increased development costs for prototype building and testing. These trends and circumstances continue to increase the industry’s interest in low investment/short lead time sheet metal forming methods for the manufacture of development and production sheet metal parts. Flexforming is one such method for the manufacture of development and production parts, and at considerably lower cost and with shorter lead times than can be achieved with traditional methods. Flexforming is a sheet metal forming method that requires only one rigid shape-defining tool half to form and, if desired, trim a part to final shape(1). The sheet metal blank is forced to assume the shape of the rigid tool half by a flexible diaphragm pressurized by a high-pressure fluid. Fig.5 shows the principle of a hydroforming cycle.

The blank is positioned on the single rigid tool half, which is placed on the press table; the table is moved into the press frame, where the other tool half, a flexible diaphragm with oil back up, is located. The oil is pumped into the press above the diaphragm and forces it to wrap the blank around the rigid tool half. The high and uniform forming pressure ensures close tolerances and makes undercuts and trimming possible. After decompression of the pressure fluid, the diaphragm returns to its initial upper position, leaving the formed part on the single rigid tool half to be removed after the press table is moved out of the press frame. Although very high forces are required in flexforming processes, maximal attainable pressure are anyway moderate, so this process seems to be particularly fitted for high dimension parts with small drawing ratio. For very deep and complicated deep-drawing parts, a movable punch is used also with a flexible rubber diaphragm as the other universal tool half. Generally the blank-holder is not present and the blank is holded by the flexible diaphragm, which is pressurized by the overhanging fluid; so that the material flow depends only on the pressure value and it results less controllable process, which requires dies and punches careful design and shrewd selection of initial blank dimensions(13). The minimal concave curvature radii attainable depends on blank material and thickness *t* and on the maximal forming pressure. Moreover its value is limited by the presence of the flexible diaphragm, which sometimes, to resist to the high pressure value, has higher thickness than the blank, so that circumstance make it difficult to penetrate in small cavities. Another flexforming characteristic is the possibility to integrate in the forming process, a trimming operation, which is feasible because of the presence of the rubber diaphragm: when the metal begins to tear during trimming, the diaphragm continues to seal off the pressure fluid and maintains the high pressure required to complete the trimming operation.

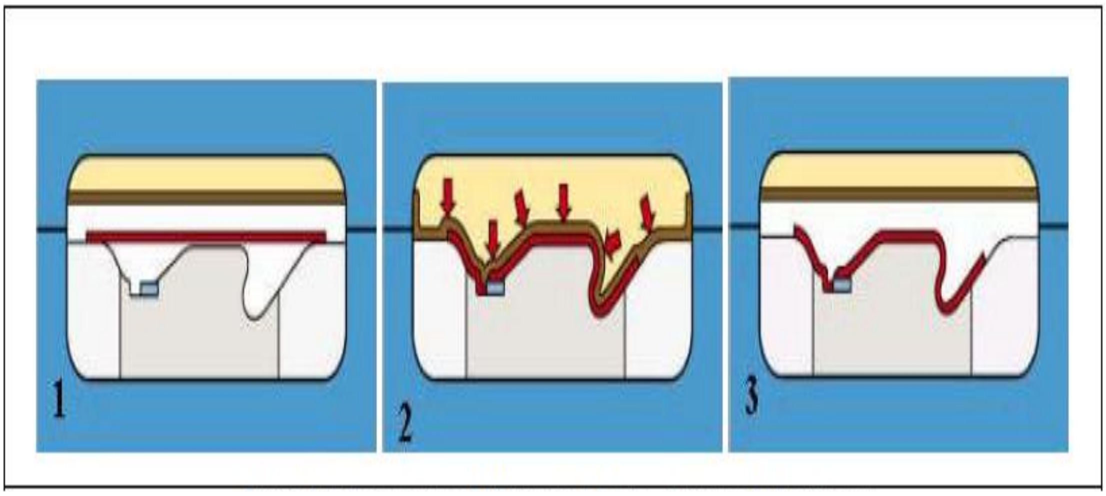

Fig.5 The principle of flexforming, before, during and after forming.

The main advantages of applying Flexforming for the low-volume production and development parts are:

- only one single rigid tool half is required to form a part;
- tool cost reductions of 50 – 90%;
- reductions in tool and part lead time of 50% and up;
- various blank materials and different thickness can be formed using the same tool half;
- the single tool half can easily be modified at low cost to accommodate part design changes;
- parts have higher quality and closer tolerances due to the fact that the parts are formed to finished shape and hand forming/finishing is reduced or eliminated.

5.RESULTS AND DISCUSSIONS

In the hydro forming manufacturing ,the fig.6(a) presents the variations of internal pressure with punch stroke for the hydro forming of part. As it is seen from the figure, the maximum forming pressure is about 5.5 MPa that is very low, compared with the results of warm forming(16), which formed simple parts with other hydroforming processes. As it can be seen from fig.6(a), the internal pressure in the final stage of hydro forming oscillates. This is due to forming the special internal profile of the work piece. The fig.6(b) illustrates the load-punch stroke curve of the work piece. As it is seen from the figure, the maximum load is about 60kN which is not so high.

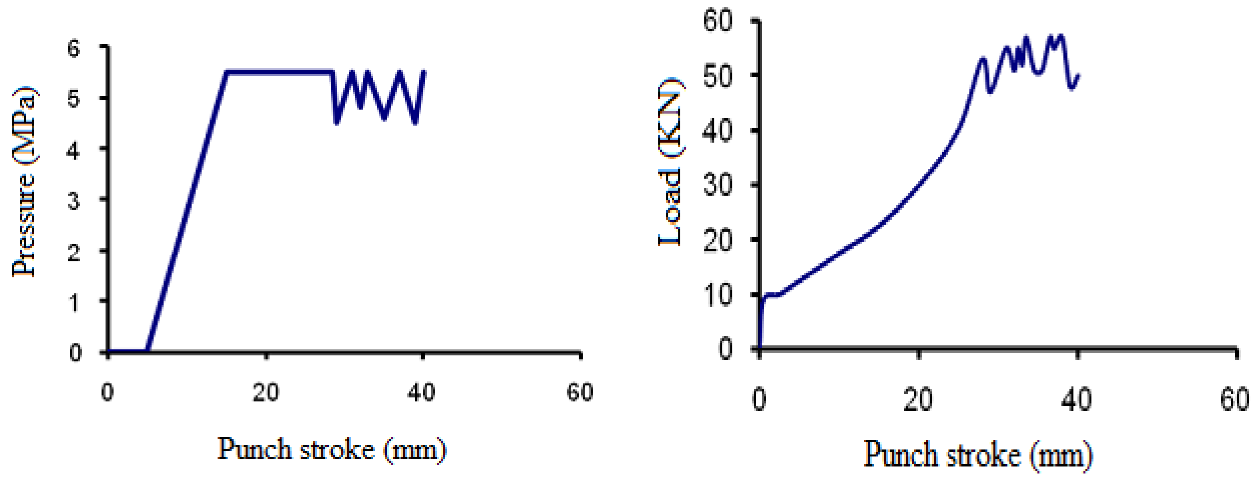

Fig.6(a) Internal pressure-punch stroke curve, (b) load–displacement curve,

The fig.7 shows the typical pressure path used in this study of hydroforming manufacturing.In this path, OA is the initial pre-bulging pressure (2 MPa) applied before the punch moves down. BC is the constant maximum pressure. The liquid outflows from control valve by applying this pressure.SAE10 hydraulic oil with a viscosity of 5.6 Centistokes was used

as the pressure medium(18). Due to the strain-rate sensitive behavior of the viscous medium, the punch velocity has significant effect on the internal pressure generation. Thus, in the pressure path of fig.7, AB is the linear pressure path and its slope depends on punch velocity and work piece shape and thickness. In this research, a punch velocity of 200mm/min was applied. To measure the cup thickness, a mechanical thickness measurement set was used.
According to the fig.7, for each certain maximum pressure, a pre-bulging pressure, OA, and a pressure path AB with different slopes are definable. The slope of AB changes with punch velocity, work piece shape and sheet thickness. The punch velocity was fixed at 200mm/min. Thus, for each certain part with defined shape and thickness, one specific slope was obtained.

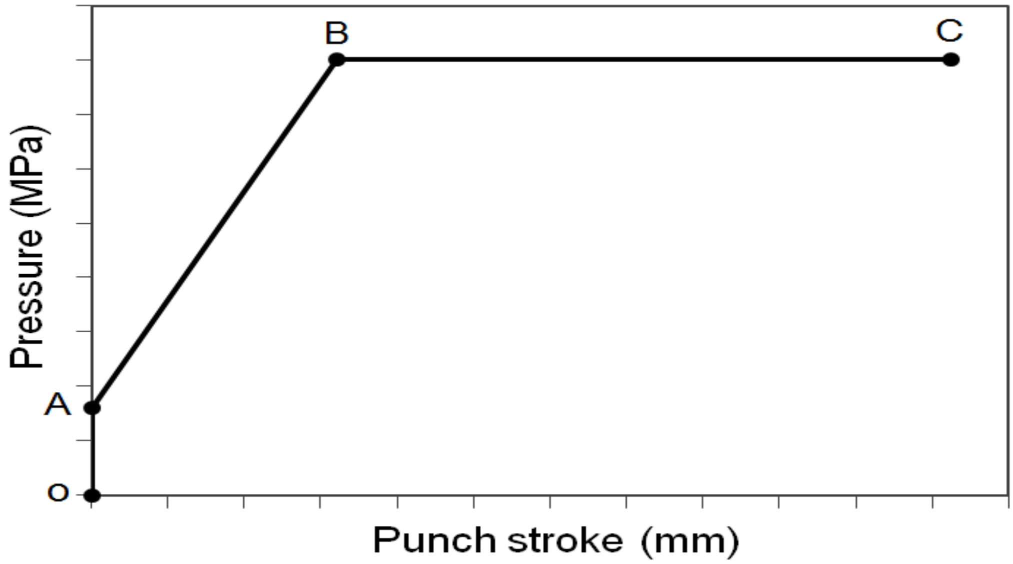

Fig.7 The typical pressure path applied in the investigation in Hydroforming

The schematic of the modified die-set used in hydro forming for producing of industrial parts. The photograph of the used punch is considered in tool set-up section. To form this part, several pressure paths have been examined by finite element simulation and the appropriate pressure path is shown in fig.8. As it can be seen in the figure, the maximum forming pressure is about 5.5MPa which is very low, in comparison to the results of the other relevant references, which formed simple parts with other hydroforming processes.

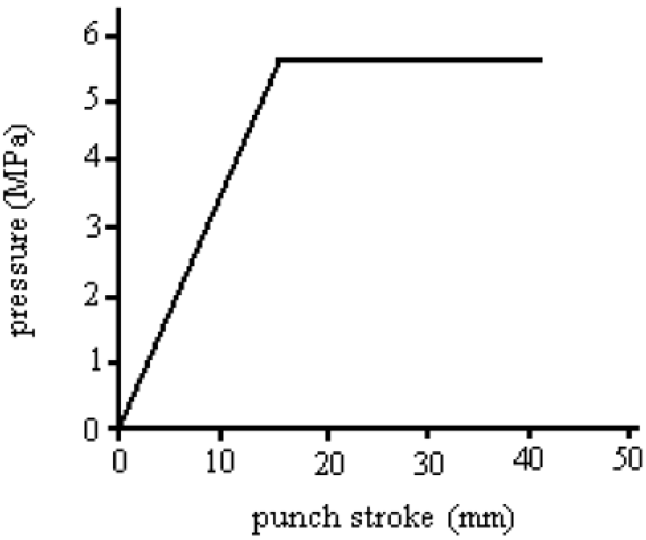

Fig.8 Pressure path used to form the lightning industry part

Punch force is related to the forming force and internal pressure in vertical direction. As it can be seen in fig.9, the punch force increases when it moves down to reach a maximum force, and as the punch continues to move downward the punch force decreases(19). By increasing the maximum pressure, the more punch force is needed. This is because the vertical direction force increases.

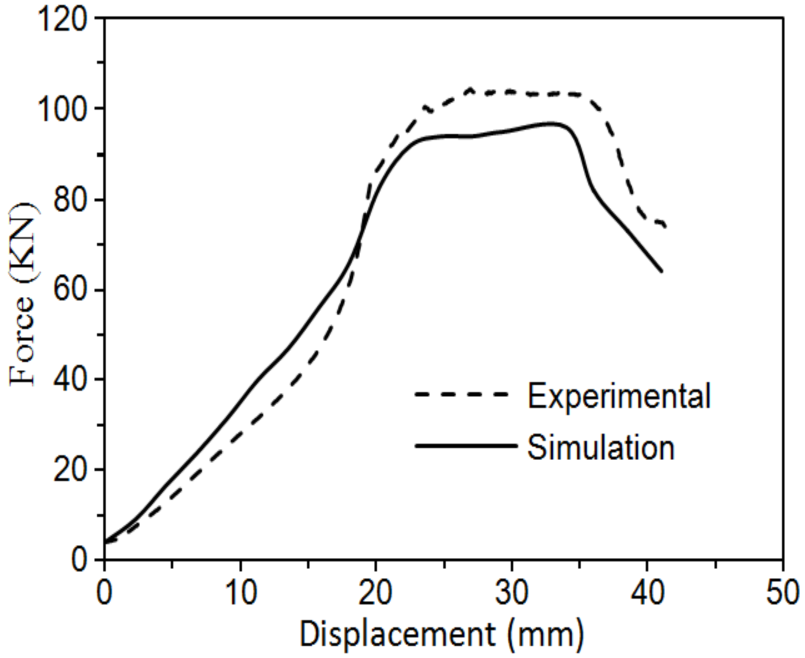

Fig.9. Force - Punch stroke curve

6. CONCLUSSIONS

Sheet metal hydroforming process would be useful in reducing weight and cost simultaneously by improving structural integrity, strength and rigidity. In addition, this process satisfies these requirements with utilizing the common and available material efficiency. Saving in tooling, material, design, production and assembly will altogether contribute reducing the overall cost of a sheet hydro forming part. Elimination or decrease of welds and welding operations is an additional of the overall cost. A reduction in number of production steps and components in an assembly will be obtained with this process. This would reduce dimensional variations, and facilitate assembly operations.
The following potential gained with the use of sheet metal hydro forming technology

- Reduction in weight
- Increase in stiffness and rigidity
- Economic material utilization
- Complex shaped and various part types
- Reduction in number of steps during manufacture and assembly (reduced welding and associated fixturing)
- Reduction in overall cost per part or cost of assembly
- Tight tolerances with good dimensional characteristics and less variation
- Good surface finish
- It has a very complex shape with special internal profile that should be produced with high precision and surface finish
- Improved such as the high drawing ratio, control of wrinkling, and ease of applying internal pressure.
- It enables the use of a high-pressure liquid of viscosity, thereby improving the lubrication of the drawing process.
- Lifting the sheet metal off the die radius and thereby eliminating the die friction in drawing process
- Pre-bulging the sheet metal and thereby increasing the contact area between the sheet metal and the crown of the punch before substantial drawing action takes place.

The given advantages, allow automation and action optimization what the top of plastic forming processes make hydro forming. Hydro forming gives a better finish, reduced costs, cost effective for product development and helps achieve exceptional tolerances in the field of manufacturing.

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