Hydro Forming of Sheet Metal Pairs For Automotive Industry

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Abstract- *Hydroforming has emerge as an more and more appealing production method for the production of hole bodies. Numerous programs are recognized, in particular within the automotive industry where the trend is increasingly closer to more tricky geometries shaped from tubes and extrusions. In this contribution, a new class of hydroforming strategies is offered. They are characterized by way of the use of sheet metal pairs, consequently permitting an prolonged kind of shapes, but they require unique sealing and docking gadgets. Models, simulations and experiments have targeting the feasibility of 1 precise manner (the hydroforming of un welded sheet metallic pairs) and on the have an effect on of the various parameters at the procedure window as well as on the part geometry.*

Keywords- Sheet metal forming; Hydroforming; Modeling; Finite elements; Hollow bodies

I. INTRODUCTION

Structural components switch the static and dynamic loads inside the frame of a vehicle. They are designed to meet stringent needs: the need for weight financial savings related to environmental and economic problems prescribes high ratios of torsion and bending stiffness to weight. In a crash, they're to dissipate a good sized quantity of the impact electricity with the aid of deformation earlier than failure. As available space is reduced due to weight and design requirements, structural components have problematic geometries with multiple interfaces to neighboring practical units. Moreover, most of them are tremendously-loaded protection-applicable parts, that must be produced economically in mass production and with regular high first-rate. These necessities are currently quality met with the aid of steel hollow structures. Structural additives (especially frame and chassis individuals) are produced conventionally as stamped box section assemblies: two pieces of sheet steel are stamped in more than one stage and eventually spot welded collectively alongside a flange. The stamping technique is Tremendously effective and well understood with appreciate to tool-making, component-layout and first-rate. Current technological challenges lie in the forming of new materials such as high-strength steels, aluminum and magnesium alloys and pre-coated blanks; in the shortening of the time-to-market via rapid prototyping, rapid tooling and numerical process simulation; and lastly in the use of tailored blanks and: or patch working techniques with straight and curved seams.

Another strategy is based on the extensive use of extrusions made mainly of aluminum alloys. In the extrusion process, the material is given a pre-form which is close to the final geometry of the part. Substantial weight savings can be achieved by this so-called space-frame technology [1]. However, the quality standards for modern car manufacturing can nowadays only be met with heavy expenditure for the manual calibration of the bent extrusions. The main reason for this difficulty in producing net shape parts lies in the intrinsically non-uniform mechanical properties of the raw material (straight aluminum extrusions) and in the consequently widely scattered springbuck. Because of the restricted possibilities for varying the cross-section of the extrusion along its length and because of the difficulty of three-dimensional bending, the geometric complexity of the structure is mainly achieved via cast knots at the junction of two or more structural members Intense efforts are currently being made in order To gain higher reproducibility and running accuracy within the bending method. Particular interest has been committed in recent years to a in addition generation. In the hydroforming manner, a tube or an extrusion is first routinely bent and then submitted to internal stress by means of a pressurized fluid. Through the action of this inner pressure and optionally of an axial compressive load, the section of the component conforms regionally to the shape of an enclosing die hollow space [2,3]. Using this process collection, the geometric forms of tube and extrusion-based structural components may be prolonged, and stamped components with minor longitudinal modifications inside the surface of their segment may be replaced with hydro formed tubular, extruded or roll-shaped merchandise. The excellent mechanical Properties of hydroformed elements (smooth load glide, excessive torsional stiffness) and the total benefit taken of the to be had space because of the absence of spot-welded flanges provide an explanation for the growing range of business applications in the production now not only of exhaust structures however additionally of our bodies in white. Intense research and improvement paintings is currently being finished so that it will deal with the complicated forming mechanism and with the tooling device, and moreover to growth the monetary efficiency of the manner. In this paper, every other elegance of hydroforming procedures that is based on the use of sheet metallic as an alternative of tubes and which remains in a pre-commercial nation will be defined, and current outcomes of studies work on this topic are given.

II. PROCESS DESCRIPTION

In the hydroforming of sheet metal pairs, two blanks are formed at the same time in a single die set by means of an active pressurized fluid that is introduced in the cavity expanding between the two shells. The process starts with a free-forming stage, where the two blanks are formed into Either side of the die cavity, and ends with a calibrating stage, in which contact with the die occurs and eventually complete form-filling is achieved. Fig. 1 summarizes the process sequence that is examined. After a pre-forming stage, in which the two blanks are formed either by conventional deep drawing, or in the present special case by the hydroforming of un welded sheet metal pairs, the shells are joined, preferably by the laser beam welding of a flat face fillet weld and eventually hydrocalibrated [4]. The calibrating stage is carried out to ensure complete form-filling, to compensate for the distortions induced by the welding process and to restrict springback. The ultimate aim of the research is to integrate the laserbeam welding process into the forming system in order to use the forming tool as an assembly fixture [5]

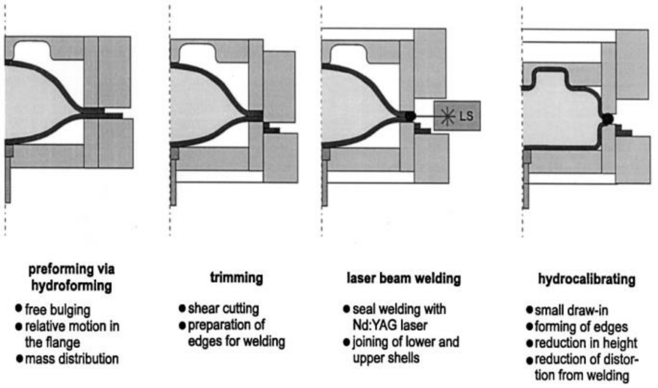

Fig. 1. Integrated forming, cutting and joining.

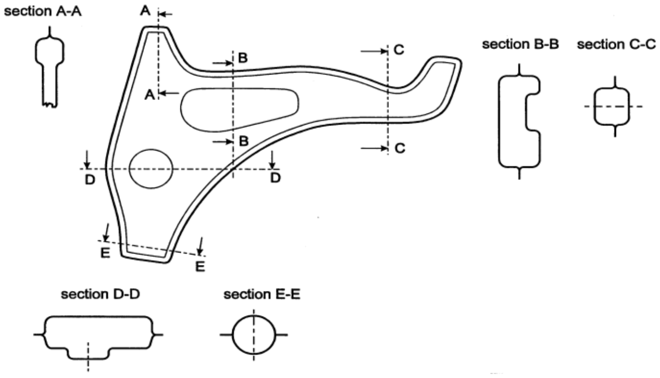

Fig. 2. Typical shape features of a suspension triangle.

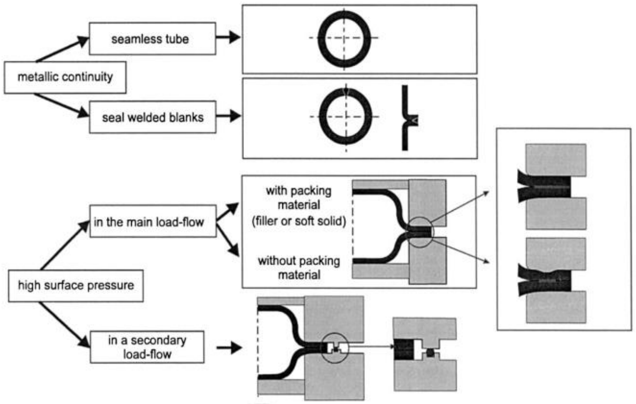

Fig. 3. Sealing variants.

The specific field of software of this generation is presently seen within the manufacturing of complicated hollow components, which include suspension triangles (Fig. 2), body knots, pillars and tanks. In comparison with the stamping technique in brief alluded to within the introduction, it's miles expected that this hydroforming of sheet pairs will bring about a shortening of the process collection in the production of hole Structures as the two shells are formed in a unmarried tooling set, in preference to in two tooling sets (consistent with forming step). Moreover, the shells can be joined collectively both earlier than forming, in the flat nation (which is pretty efficient), or in a pre-shaped kingdom, which can be carried out inner or inside the direct place of the forming gadget. Thermal distortions caused in the course of the becoming a member of may be compensated for within the final hydro calibrating step, as a consequence keeping off expensive straightening operations. This manner, tooling, device and managing fees can be reduced.

The design restrictions inherent in the use of tubular additives for conventional hydroforming are overcome, as really any clean shape (even a tailor-made clean) can be suitable for the hydroforming of sheet metallic pairs, whilst the fantastic impact of uniform hardening of the material is conserved. It should, but, be saved in mind that, as in any manufacturing manner, the hydroforming of sheet steel pairs calls for precise component-layout hints to be reputable (Section eight), which manifestly precludes a direct and standard substitution both of stamping or Conventional hydroforming. It however opens new cost cutting opportunities inside the manufacturing of bodies in White and fuel tanks.

III. PROCESS CHARACTERIZATION

The variants of the hydroforming process applied to sheet metal pairs which are currently under investigation can be simply characterized by the practical means by which the cavity between the two blanks is kept fluid tight and by which the fluid is introduced and later removed.

The tightening of the cavity is of major concern for the success of the forming operation as it is a pre-requisite of the pressure build up. As shown in Fig. 3, the seal can be achieved either by welding the two blanks together (welded tubes [6] or roll-formed sections, welded blanks [7,8]) or by generating a sufficiently high contact pressure between the two blanks along a closed curve in or around the flange of the hollow body. The second strategy, which is pursued here, has the key advantage of allowing a relative movement (sliding) between the two shells during the forming process. This way, shells with different depth can be produced without excessive thin-out of the deeper shell. Wrinkling of the larger flange should however be prevented. Moreover, as far as steel is concerned, a welding seam is substantially harder than the base material, so that the weld would render the draw-in more difficult and possibly damage the blank-holder surface. Special attention is to be directed to the sealing mechanism between the two rough, possibly textured surfaces of the deep drawing quality material.

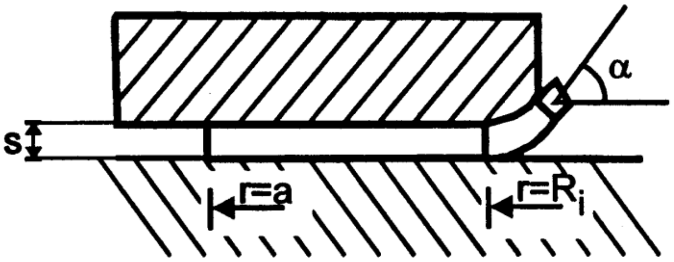

Fig. 4. Geometry of the axisymmetric flange.

As far as the introduction of the fluid is concerned, one can distinguish between the four docking systems in Fig. 4. In variant 1, the docking system is integrated into the blank holder and pierces one blank when the die set is closed [9]. This variant is mainly suited to welded sheet metal pairs without any draw-in in this zone, as the fluid has to flow through a channel formed between the blanks. Variant 4 is used in [10]: the docking stamp is driven by a hydraulic device and is laid between the blanks before closure. The seal is formed by metallic contact in a cone. A special type of docking system that integrates the sealing function of the die cavity would be the use of an intermediate plate between the two blanks [11]. Variant 2 does not hinder the draw-in of material in the flange. The docking component has to form a tight but non-permanent connection set up in a pre-forming step or upon tooling closure. In terms of efficiency, short cycle times require high filling flows, so that multiple-point docking systems with special filling pumps and pressurized reservoirs can be useful. A welded connecting piece has been used in initial experiments, and non-permanent joins with effective clamping of the contour of the hole in the blank have also proven to work well, provided that the in-plane load on the hole is restricted by suitable means. The design of the docking system moreover centers the shell when draw-in is permitted. It must however be adapted for easy removal from the outside.

IV. FORMING MECHANISM

The process control must allow the drawing-in of material from the flange into the forming cavity, as this has been shown to improve the formability of sheet material [12,13]. It is possible therefore to distinguish four zones in the formed part with different active forming mechanisms. The accuracy of the following description has been established in Fig. 5 by FEM-simulation of an axisymmetric free hydroforming process. For reasons of symmetry, only one of the two shells have been simulated. Under the blank holder, the sheet deforms in an assumed pure deep drawing modus with tangential compression and radial tension [14]. The stress field can be calculated by integrating the ideal forming and friction contributions (Eq. (1), The accurate measurement of the friction coefficients is of major interest.

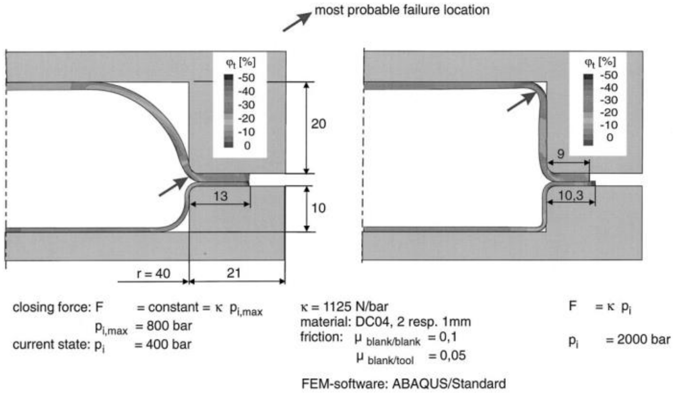

Fig. 5. Influence of the closing-force control on the draw-in.

V. LOAD PATH AND PROCESS WINDOW

Strategies for the conducting of this new manufacturing process need to be set up and, given a part geometry and a material, guidelines are to be developed to adjust the machine parameters. According to the focus of this study, the aim should be to allow controlled draw-in from the flange into the die cavity. This can be achieved by controlling the closing force F of the hydroforming machine that directly influences the friction force under the blank holder. The constraints on this load path F(pi) determine the process window, inside of which a successful forming process can be conducted.

VI. INFLUENCE OF FRICTION IN THE FLANGE

The tribologic system in the flange consists of three interfaces. This makes it necessary to analyse carefully the global behaviour of the material under the blank holder, all the more as high surface pressures are necessary when tightness is to be ensured in the flange. FEM-simulations were conducted in order to understand the various effects. For reasons of symmetry, it is admissible to assume the blank–tool friction coefficients to be equal on the upper and lower sides. Moreover, they are certainly smaller than the coefficient of friction between the blanks because the tool can be machined to a very smooth surface and can be optimally lubricated. Fig. 6 shows the shape achieved for a given set of friction coefficients (blank–tool 0.05, blank–blank 0.1, denoted ‘sim. 0.05:0.1’). The relative movement between the rims (originally with the same diameter) lead to good form filling of the deeper and shallower shells and yielded a uniform thickness distribution. These results show the importance of controlled friction conditions in the flange for good form-filling of complex asymmetrical parts and for uniform thickness distribution requiring draw-in and relative sliding in theflange.

VII. EXPERIMENTAL RESULTS

Initial experiments have confirmed the feasibility of the hydroforming process applied to unwelded sheet metal pairs. Fig. 14 shows a hollow body made of 1.5 mm thick DC04 steel formed in a single tool and calibrated with a pressure of 1250 bar. The parts show an overall draw-in of 15 mm and a base radius of 3.75 mm. The results of the wall thickness measurements are in qualitative accordance with the FEM-simulation (compare Fig. 13 and Fig. 14: note that the diameters of the cups are 80 and 150 mm, respectively). The center area is characterised by a homogeneous thinning by stretch drawing. A severe decrease of the sheet thickness can be observed in the lower outer region of the cup base. Starting from this point the wall thickness increases due to the deep drawing mode. It remains smaller, however, than the initial sheet thickness because of the uniform coining of the flange caused by the high closing force during calibration. Even when forming shells with noticeably different depth, as in Fig. 7, good form filling is possible due to the relative displacement of the flange rims.

The sealing limit provides a lower bound for the closing force: the contact pressure in the tightening zone must be kept greater than a minimum pressure pseal in order to prevent an opening of the gap:

F>piSeff_+bpsealSseal (6)

where Seff is the surface of the shell projected in the direction of F and subjected to fluid pressure and Sseal is the surface of the tightening zone. pseal is the surface pressure necessary to prevent leaking: pseal is greater than p0 (corresponding to a pre-load F0_bp0Sseal), the pressure closing all microscopic paths between the rough surfaces in contact and tends toward pi for great values of pi. Pressure p0 is obviously dependent on the surface quality of the blanks, including the potential effects of lubricants or special-purpose tightening materials b is a safety factor (b\1).

The press rating of the machine Fmax is an upper bound of the closing force. An upper bound of the pressure is given by material failure through excessive strain. This bursting pressure is not only strongly dependent on the part geometry but also on the chosen load path F(pi), which allowed or prevented draw-in and lead to lower or higher strain localisation [12].

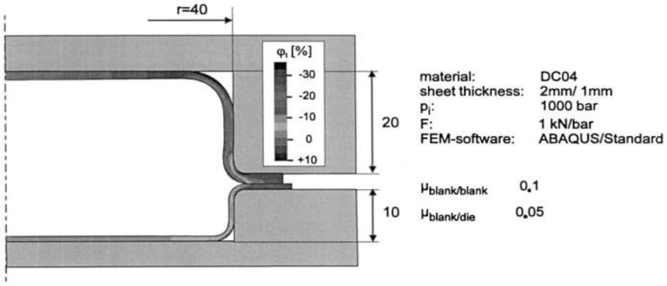

Fig. 6. FEM-simulation of the hydroforming process (low friction).

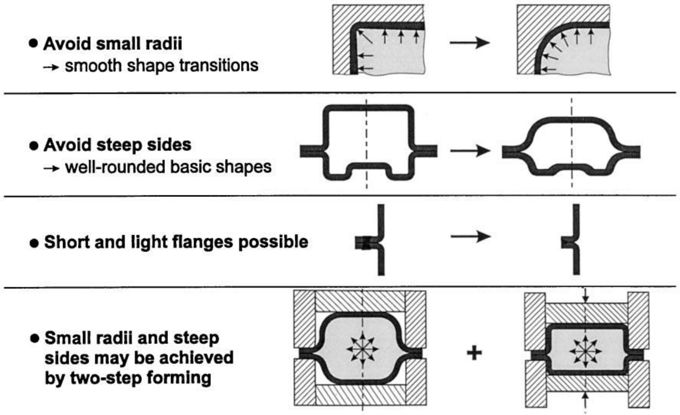

Fig. 7. Basic design guidelines for hydroformed parts.

VIII. DESIGN GUIDELINES

In hydroforming, a large fraction of the total deformation of the blank is released during the free-forming phase. The material is strained uniformly and work hardened over the whole surface of the blank. The designer can take advantage of this phenomenon by reducing the overall wall thickness of the part, but should, however, bear in mind that as soon as the material comes into contact locally with the die, further deformation is concentrated mainly in the remaining free-forming zone. The implied strain localisation can be reduced by good lubrication of the die, but sharp radii are basically filled with high calibrating pressures by final stretch forming. That is why small radii should be avoided and the overall shape of the part should principally respect the smooth geometry of free-formed bulges (Fig. 7). Ongoing research is heading towards a quantitative estimation of the achievable geometries: initial investigations are reported in [21].

The hollow body produced with the process sequence described in Fig. 1, including laser beam welding of a flat face fillet or a double-flanged weld, can have shorter flanges than those of a traditional spot welded box assemblies. This is an important feature with respect to weight-saving efforts. It is expected that sharper shapes could be formed in a two-step process: an initial pre-forming step at a medium pressure level provides the basic shape of the part so that merely auxiliary components and small radii (i.e. the base radius) need to be formed later. The subsequent calibrating step could be facilitated by a slight upsetting movement of the cup base plates, thuspushing some material in to the corners.

IX. CONCLUSIONS

Hydroforming of sheet metal pairs is a new field of investigation for manufacturing engineering. Numerical simulations as well as analytical models have illustrated the need for proper load-path control and for defined friction conditions in order to achieve optimal mechanical properties and geometric accuracy. The feasibility of the forming process has been demonstrated for an exemplary geometry. The results of these experiments confirmed those of the FEM calculation. Concepts for a complete lay-out of the process sequence have been elaborated, including the integration of cutting and joining steps in the manufacturing system.

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