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MODELING OF SHEET METAL FORMING USING QUASI-ELASTIC MEDIA

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ABSTRACT

In this paper a review on simulations using FEM for sheet metal hydroforming is presented. Hydroforming can be done either with a punch and a pressurized fluid that replaces the die or by using fluid under pressure instead of the punch and with a die. The main types of sheet hydroforming techniques are: with fluid, either directly or with a rubber diaphragm; or with rubber, that can behave like a fluid under a high enough pressure. There are different variations of hydroforming, using different types of fluids with different properties. Some of these hydroforming methods have been simulated by different researchers, using different FEM software, like Dynaform, Abaqus, etc. The purpose of these FEM simulations is to obtain results that are close to the results obtained experimentally, to be able to compare them, which can be quite difficult, because of the fact that there are multiple parameters that can influence the results.

KEYWORDS: metal forming, quasi-elastic media, modeling, FEM

1. INTRODUCTION

A classification of hydroforming types is presented in fig. 1[1]. The “pressurized media” can be different types of fluids, applied directly on the blank or on a rubber diaphragm that is in contact with the sheet, or a rubber pad that replaces the punch.

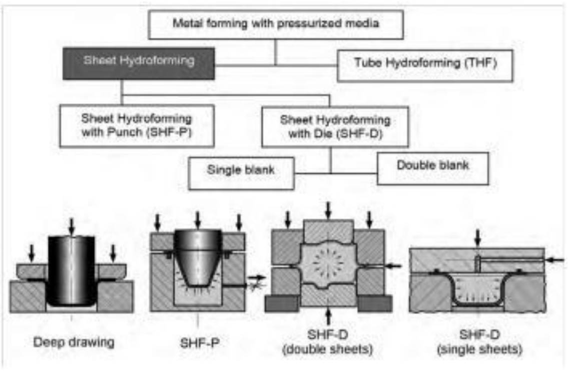

Fig.1. *A classification of hydroforming [1]*

Hydroforming has some important advantages over the regular deep drawing process. Some of these advantages are: the fact that sheets suffer less stretching and less wrinkling, more complicated shapes can be made with fewer operations and because either the punch or the die can be replaced with pressurized fluid results in lower costs [1].

Recently, many experimental tests are also accompanied by numerical simulations.

One of the reasons these simulations are done is to try to predict the results of the experiments or, if the experiments were done first, to obtain similar results, so as to be able to reduce the number of experiments and reduce the costs involved. The steps required for a simulation are:

- depending on the software used, the first thing that must be chosen is the type of analysis that will be performed, for example, for the software Ansys Workbench. In other cases, the analysis can be defined after modeling and assembling every necessary piece
- modeling all the required pieces, based on measurements or on what is intended to be created for the purpose of the experiments;
- applying material properties to each piece;
- meshing each piece. The shape, size, type, distribution etc. of the elements can be changed according to the type of analysis that will be performed and the level of precision and accuracy that is desired;

- if there are multiple parts that create an assembly, all must be positioned in their place in the assembly;
- defining the interactions between the pieces of the assembly, if necessary;
- applying boundary conditions and loading cases;
- choosing the desired results and starting the analysis.

H.Z. Poor and H. Moosavi have simulated, with the help of the Abaqus software and compared wrinkling and thinning in aluminum sheets subjected to conventional deep drawing and to hydroforming with a hemispherical punch. The results from the simulations and the experiments confirmed the fact that less wrinkling occurred in the hydroforming process and as long as the applied pressure wasn’t too high, thinning also showed an improvement [2].

In another FEM analysis, also done in Abaqus, M. Venkat Reddy et al. have modeled a “rubber assisted sheet hydro-forming process” and a conventional hydroforming process to make a conical shape. The material that was used for the blank was copper. From the results that were obtained, in the conventional hydroforming process the thickness reduction has a lower percentage than in the rubber assisted hydroforming process and increasing the angle of the cone forming results in a lower thickness for the wall of the cup [3].

In a paper done by Muamar Benisa et al. there is a simulation of a rubber-pad forming process of an aluminum blank made in Ansys. Three geometry types were done: a straight rib, a stringer and a rib with a lightening hole. The results from the simulation were comparable to the experimental results. The simplest of the three shapes, the straight rib, had the lowest plastic stain and stress and the rib with the lightening hole had the highest of those results [4].

Maziar Ramezani, Zaidi Mohd Ripin and Roslan Ahmad [5] have tested experimentally and simulated in Abaqus different hydroforming processes using three different types of rubber pads: a natural rubber pad, a polyurethane rubber pad and a silicon rubber pad. They have observed that even though the silicon rubber decreases the punch load when used as a flexible punch, the polyurethane rubber and the natural rubber have longer lifetimes, so the polyurethane rubber is the most recommended. The maximum thinning is lower when using a polyurethane rubber pad or a silicon rubber pad than in the case of the natural rubber pad and it isn’t influenced very much by the punch velocity. When compared to the regular deep drawing process, the rubber-pad hydroforming shows lower thinning in the formed parts.

Feifei Zhang et al. [6] used different element types for simulating a hydroforming process of a double-sided blank and they compared the results with an experimental test. The element types used were solid, shell and thick shell. The thick shell elements can predict more accurately the thickness distribution than the traditional shell elements, which tend to overestimate the thickness of the formed piece. Also, when talking about computational efficiency, the thick shell elements are better than the solid elements.

2. THE STUDY OF THE HYDROFORMING PARAMETERS USING NUMERICAL METHODS

When simulating a hydroforming test using FEM, there are multiple parameters that can influence the final results. The influences of some of the most important parameters, like the applied pressure, the blank holder force, the friction between the parts that come in contact with each other, etc. have been studied by multiple researchers.

Liu Wei et al. have shown in the paper named “Welded double sheet hydroforming of complex hollow component” [7] that two of the most import parameters that influence the formability of, in the case of their study, a double sheet hydroforming process are the pressure of the applied fluid and the clamping force, which must be chosen between certain limits (fig.2.). They applied three loading cases and observed how the shape of the blank formed in each case. For the lowest and the highest pressures and clamping forces there were fissures in the corners of the formed pieces, but in the medium loading case (a fluid pressure of 25 MPa and a clamping force of 880 kN) the formed piece had a good quality. Another aspect that was studied was the influence of the shape and size of the blank, which can produce fissures or wrinkles, if they aren’t appropriate for the desired hydroforming operation.

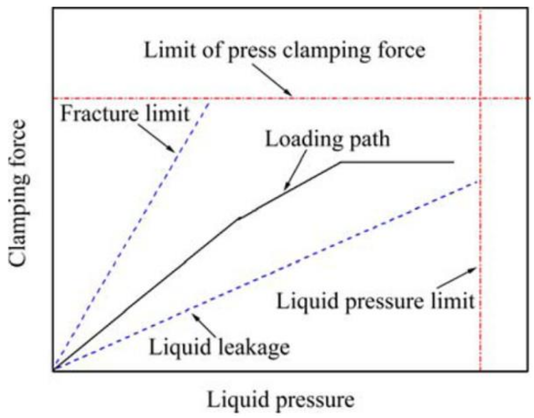

Fig. 2. *The optimum loading area [7]*

In another paper done by Liu Wei et al., they have also shown that the loading path is also important. They have observed the fact that better results were obtained when they used a multi-step clamping force, compared to a constant one [8].

Yi-Zhe Chen et al. concluded in one of their papers that a piece without wrinkling can be obtained by using a proper fluid pressure and another important factor to be considered, for finding the rupture pressure, is the quality of the surface of the punch [9].

Bharatkumar Modi and D. Ravi Kumar have developed an experimental setup for hydroforming parts with a square cup shape, mainly made of a certain type of aluminum. A constant and a variable blank holder force were applied separately. Finite element modeling and analysis has been done with the Dynaform software. The hydroforming with variable blank holder force showed less thinning and better results in general than in the case of constant blank holder force. The most thinning has been found in the bottom corners of the square cups [10].

In another study on the blank holder force and also forming force, done by Mohammad Reza Morovvati et al. [11], the influences of some material properties were observed. In order to avoid wrinkling, when using a blank material with a high strength, the blank holder force must be increased accordingly and the higher the ductility of the material, the less blank holder force is necessary. The forming force increases the higher the yield strength of the material and the bigger the initial blank diameter are.

A relation between fluid viscosity, radial pressure and thinning has been studied by Vahid Modanloo et al. [12] by performing hydroforming tests with two different pressurized fluids: water and oil. The pressurized oil generated a higher radial pressure and less thinning at the corner radius area of the punch than the water under pressure, which has a lower viscosity.

C. Prakash and K. Narasimhan [13] have studied the effect of other two parameters, the internal pressure and the coefficient of friction, for producing an oil tank in a two stage hydroforming process. They have shown the fact that the friction coefficient is important because it influences the wrinkling tendency of the material and more thinning is present in the blank material when there is more friction between the punch and the blank. Thinning also increases as the internal pressure increases.

The fact that less thinning occurs when lowering the friction coefficient is also confirmed by Fitsum Taye Feyissa and Digavalli Ravi Kumar [14]. They also mentioned that lubrication also improves the quality of the formed piece.

According to B. Zareh et al. [15], after performing three different hydroforming tests for obtaining a parabolic cup, a hemispherical cup and cylindrical cup and using a “FEM-based Taguchi method”, he observed that by increasing the friction coefficient between the blank and the punch, the maximum thinning ratio decreases. Another very important parameter that influences the thinning is the pressure of the fluid from the die cavity. For cylindrical cups, the die entrance radius also has an important effect on the maximum thinning ratio.

A parameter that can be observed after the hydroforming process that is influenced by other parameters is the thinning of the formed piece. MA Wen-yu et al. have concluded in one of their papers [16] that the blank holder force and the friction coefficient have the most influence over the minimum thinning and that the thickness deviation is mostly a result of the punch velocity.

3. THE STUDY OF THE SPRINGBACK USING NUMERICAL MODELING

Springback is the tendency of the hydroformed piece to return to its original form after the removal of the punch or of the fluid under pressure [1].

According to Peter Groche and Frederic Bäcker [17], springback is the curvature radius change that appears before and after unloading a piece that was formed. They analyzed the effect of stringers on springback and they concluded that they may lower the springback in a pure stretch forming, but a higher springback will be present in a bending case.

Cristina Churiaque et al. [18] studied the influence of a few parameters on the springback after a hydroforming process. Important parameters are the material properties, hardened materials having an increased elastic recovery.

In another paper, written by Zhiying Sun and Lihui Lang [19], the effects of a few different material properties on springback are analyzed separately. The parameters that were chosen were the elastic modulus, the yield strength and the sheet thickness. With the increase of each of these parameters separately, the springback decreased.

Rongjing Zhang et al. [20] have hydroformed three blanks stacked on top of each other and they observed the springback effect of each layer. The layer that showed the most springback and thickness reduction was the layer closest to the punch.

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