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The Hydrodroforming Process of an Automotive Part

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Abstract:- Tube hydroforming (THF) is currently an active area of development in the automotive industry on account of its advantages it offers in comparison to other manufacturing processes. In this paper, four simulations were carried out having the same cross sectional area but different axial feeding and load paths to improve the process design in THF process, in order to help establish the feasibility of the THF processes for specific components and have the potential to reduce the number of forming trials required to standardize the process for production of high quality hydroforming components.In addition, the studies also focus on development of an experiment simulation procedures for the entire hydroforming process. The simulation results focus on the % reduction thickness. It has also focus on the axial feed and load paths which becomes an important and useful method for planning the process design analysis, design of forming process and also planning of the tool. Since they play an important role and also determine accordance of forming limits such as wrinkling, bursting and crushing .The geometry model is analyzed base on different axial load and load paths. The key issues include geometry modeling, materials selection, meshing, boundary conditions, load definition and contact between the tube and the dies.On the base of the simulation, an optimized process parameter combination has obtained and has been verified by the instrument panel frame hydroforming experiment. The works show that:

Keywords:- Tube hydroforming, Simulation, Load path, Process design.

SIGNIFICANCE

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.

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.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.

INTRODUCTION

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. 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.

A generic tube hydroforming setup comprises of the tube hydroformed, along with the hydroforming die halves and mechanisms for end sealing as well as for axial feed of the tube ends. Figure 1-Schematic of tube hydroforming shows a schematic of the tube hydroforming process. Many tubular hydroformed components require the tube to be pre-bent to the general shape of the component so that it can be accommodated into the die cavity.

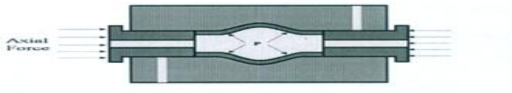


FIG 1.0 Schematic of tube hydroforming process.

App1ication of internal pressure and axial feeding allows the tubular blanks to makes the die. Tube material properties and formability will determine whether the final part can be formed under the existing process condition. Initial estimate of the process parameters (i.e. internal pressure, axial feeding and counter pressure) can be obtained through analytical calculations or computer simulation to reduce the development time.

For reliable prediction of formability condition in tube hydroforming, accurate material data (flow stress, diameter and anisotropy) and process information (internal pressure, axial feeding, counter force and friction) need to be provided to the computer simulations. The input data should also include the strain history (Harding of the material during the bending and prediction) prediction of the thickness distribution in a structural component[Koc 2001] [1]. Each step in the manufacturing process simulation starting from the bending operation and the strain history was carried over to the next step to improve the accuracy of prediction.

The reason for the computer modeling in the tube hydroforming process is mainly economical. Since the majority of the tube hydroforming process require high pressure it is not possible to do try-out using soft tooling to verify the process control parameter such as internal pressure and axial feed variation in time. If major modifications are require on tooling after it is manufactured it will be very costly and time consuming. Therefore, computer simulations are used increasingly to verify and fine tune the initial design before the hard tooling is built.

MATERIAL AND METHOD

Various parts for automotive and appliance are produced by the technology. Parts that are produced by tube hydroforming process vary over a wide range of shapes as discussed below:

Exhaust system parts; usually made of stainless steel for obtaining required structural thermal and corrosion properties; those consist

a. **Protrusion**: Tee and Y protrusions are manufactured to provide connections particularly in exhaust parts.

b. **Bulging**: it is local expansion of a tube either freely of into a die cavity for closure.

Design of the system is of special importance since high hydraulic pressure and complex shaped parts involved the system needed for THF consists of the following:

- Presses or clamping devices for closing the dies.
- Tooling.
- Pressure system; intensifier.
- Hydraulic cylinders and punches; for sealing the tube and move the material.
- Process control systems; comparators, data acquisition transducers etc.

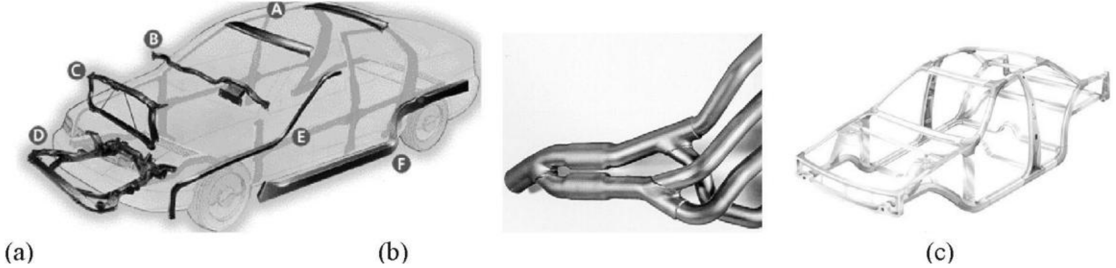


Fig.2.0 Represents few examples of parts produce by tube hydroforming in automotive applications.

There are several parts in development, such as camshaft, crankshaft and differential casting etc. It also illustrates structural frame members for automobile application. As shown above, In a (a) roof headers (A),Instrumental panels (B), radiator frame (C),engine cradle and rear axle (D), roof rail (E) and lower rail frames (F) can be manufactured by tube hydroforming.

2.2 Process principle for tube hydroforming

Figure 3.2 Shows the process sequence of typical tube hydroforming, the tube is placed and positioned for the die closure, minimum internal pressure is applied to the tube. During this process the internal pressure is increased until the expanded tube wall comes into contact with inner surface the die cavity. Each of the loads applied to the tube ends for sealing, the tube interior must be at least equal to the force calculated from the product of the tube internal area and the tube internal pressure. However, proper control of counter pressure punch is necessary at this stage, during the process, axial feeding is controlled simultaneously to improve the material shaping capabilities and the axial feed may be increased to higher value if the forming job required it. Perhaps, this may require large pressure since calibration is done by stretching the material at the corner by increasing the internal pressure only.

At the end of the steps the press is opened and the part is rejected from die cavity, this process principle may be used for hydroforming both straight and pre/bend tubes.

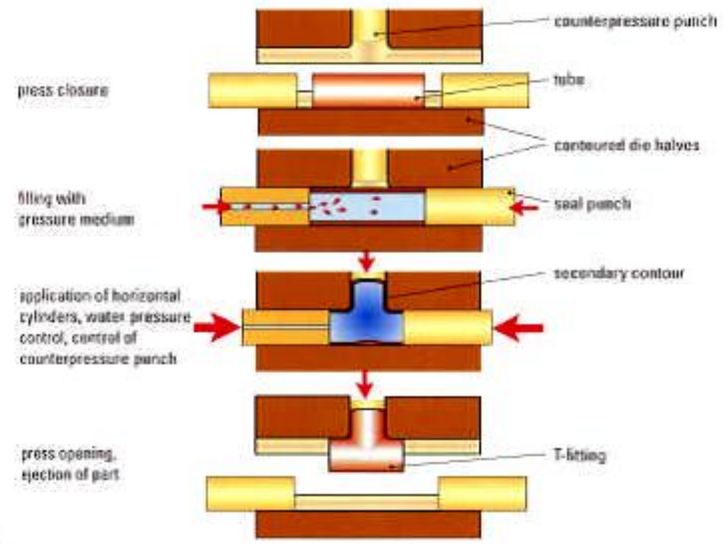


Fig2.1 Represent process principle for tube hydroforming process

Fig 2.2 Shows the front view and plan for instrumental panel beam prebending design of the i/p beam and its requirement, the diagram also showed the geometry parameters that could Be used for process design experiments.

FEA model and the boundary conditions

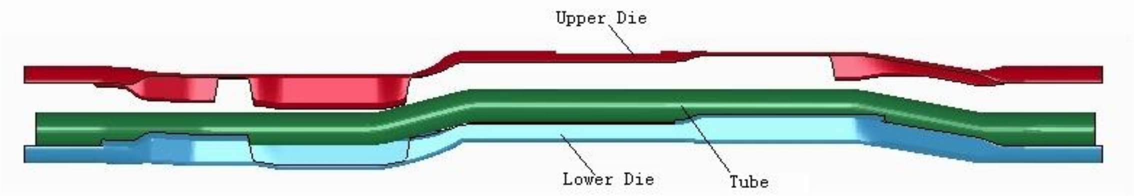


Fig 2.2 the geometry model of Tube Hydroforming

Fig 2.3 FEA model

As shown in Fig 2.3 tube hydroforming model consists of three parts: the upper die, the tube and the lower die, the dimension of inner wall of upper die and lower die at the circular arc is Φ55mm. Tube is prebended from low carbon steel straight pipe with the dimension of Φ53mm×L1662mm×t2mm. Element mesh adopts *shell163* shell element, upper die and lower die is supposed to be rigid body model, the material of tube is low carbon steel, The mechanical performance of components is shown in the following table (Table 2.1)

Table 2.1 The mechanical performance of components

	Density(kg/m^3)	Elasticity modulus（Gpa）	Yield strength（Mpa）	Poisson ratio
Upper Die	$7.83{\times}10^3$	207	Rigid（∞）	0.3
Lower Die	$7.83{\times}10^3$	207	Rigid（∞）	0.3
Tube	$7.83{\times}10^3$	205.5	175	0.3

Table 2.2 The stress-strain curve of the tube

Strain	0.0	0.04	0.08	0.12	0.2	0.24	0.3	9.9
Stress(Mpa)	175	249.2	289.9	316.6	353.9	368.3	386.7	0.4

Boundary conditions and loads

1. Constraints of the die. Lower die uses fixed restrictive conditions, while the upper die moves to the lower die vertically along the Y orientation, all the other degrees of freedom are constrained.

2. Bulging pressure. As soon as the two dies meshed, the bulging pressure is imposed. The bulging pressure is applied on the tube inner wall all the time, and the direction is consistent with the normal orientation of the cell. Then, the tube expended and obliged with contact constraints as the result of pressures.

0DISCUSSION OF RESULTS

3.1 Die closing

The upper die moves to the lower die vertically at a fixed velocity, the two die is closed at 20ms, then applied the bulging pressure and the feeding. The states of each parts of the model at different moment are shown in the following figure (Fig 3.0 and Fig 3.1).

Fig3.0 The position of each parts of the model at t=0ms, t=10ms, t=20ms, t=25ms

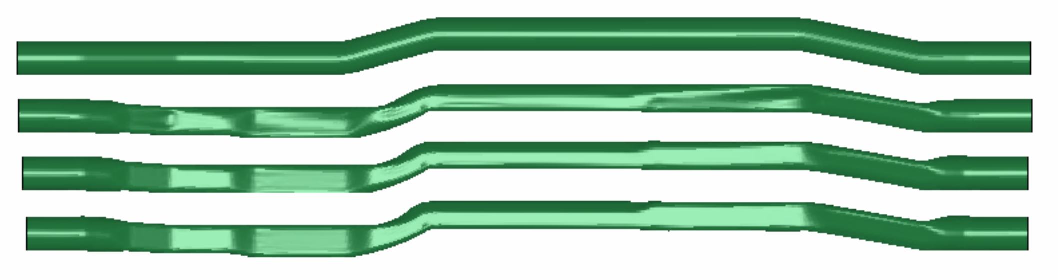
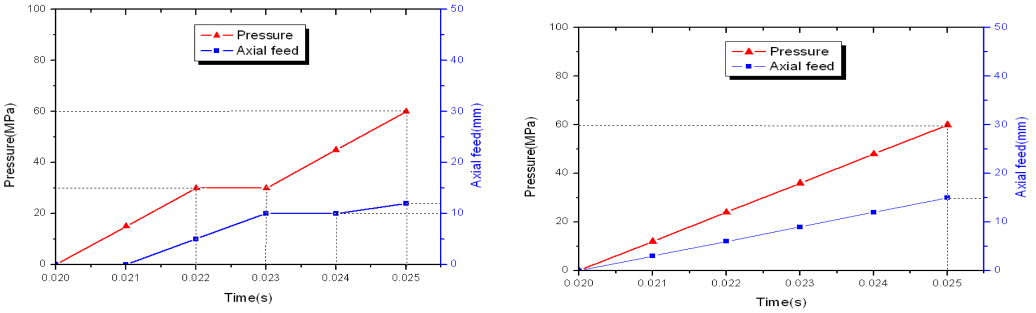


Fig 3.1 The figure of the deformed tube at t=17ms, t=21ms, t=23ms, t=25ms

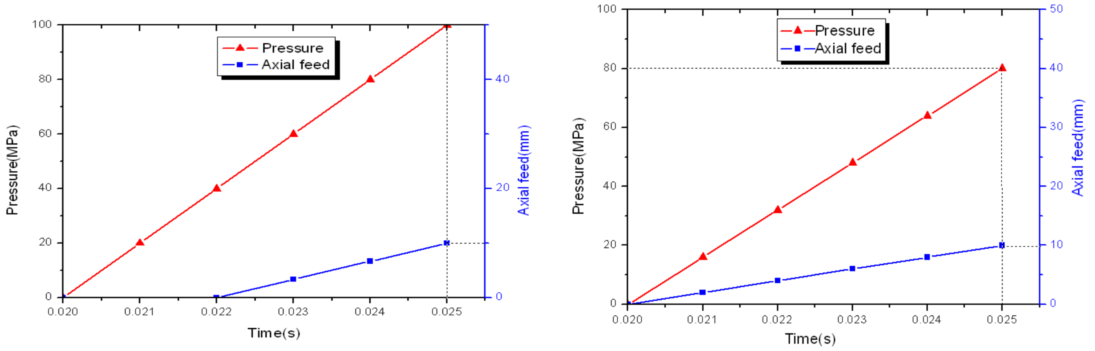
3.2 The influences of the loading paths to the formability of tube

As an innovative manufacturing process, the tube hydroforming process has some key technical issues to be studied. The formability of tube is affected by a large number of parameters, among which the process loading paths is a remarkable. In the process of finite element analysis, we selected 4 loading paths, shown in Fig 3



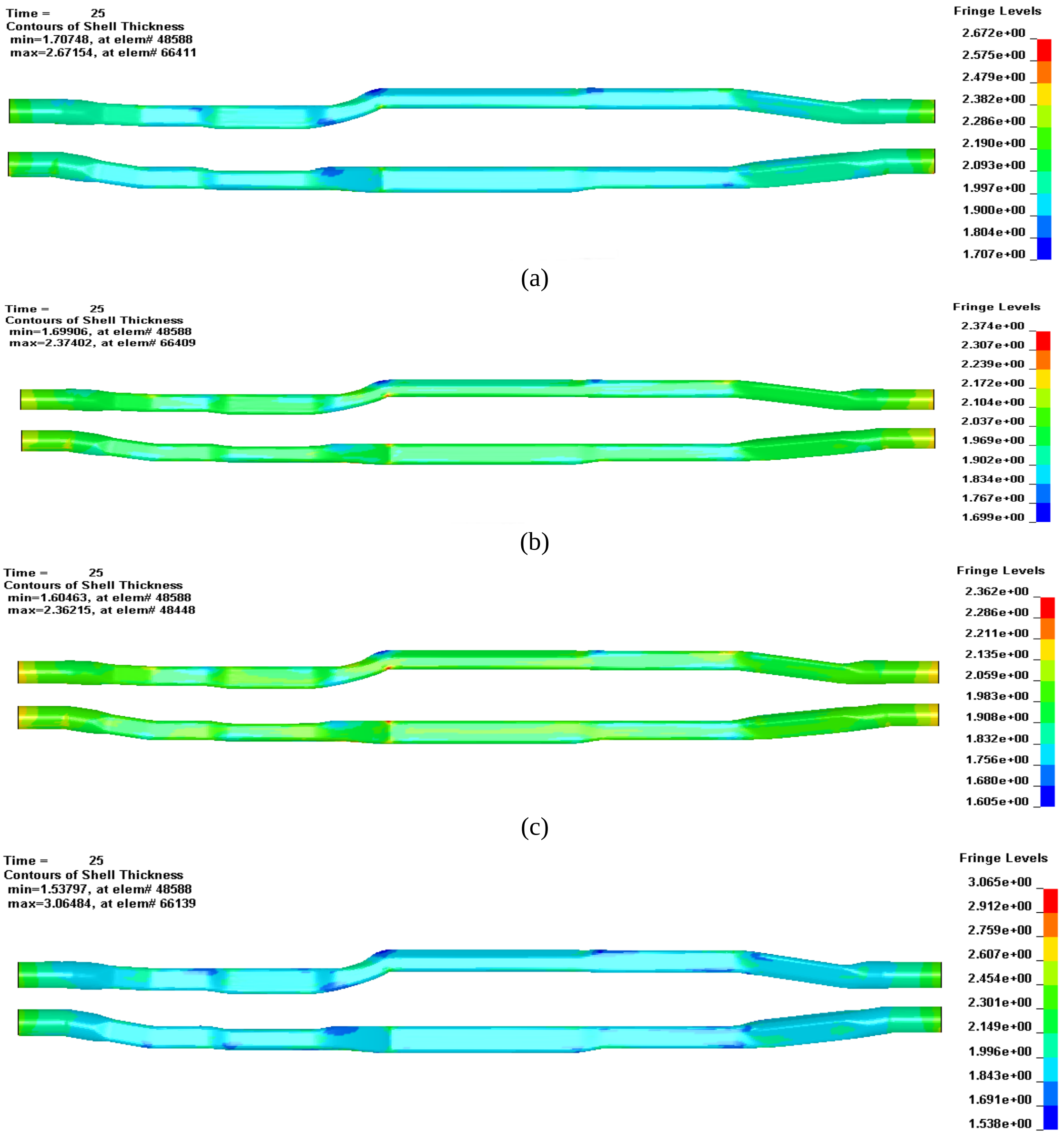
(a)

(b)



(c) (d)

Fig 3.2 The simulation results of the model of different loading paths are as follow (Fig 4.7) that shows the shell thickness with different loading paths.



(a)

(b)

(c)

(d)

Fig 4.6 The thickness reduction of different loading paths

From the figures, we knew that the thickness of tube ends wall increased lightly because of being fixed.

The thickness of the tube wall is not distributed uniformly at the forming area, and the wall thickness thinned more seriously at the corner.

In terms of the thinning velocity of the wall thickness of the 4 different loading paths, the corner of the forming area thinned most seriously. By comparison we can found that the thickness reduction distribution is most uniform when applying the loading path (b)($\Delta t = 0.675mm$). The different loading paths have significant influences on the thickness reduction distribution. On condition of the same ultimate internal pressure and displacement, adding the displacement at high pressure ends is benefit for improving the uniform of the thickness reduction distribution of the part wall.

Table 4.3 Summary table of all the simulations conducted with different loading path

	Max pressure (Mpa)	Left Axial Feed(mm)	Right Axial Feed(mm)	Maximum thinning %	Wrinkles
Case 1	60	15	15	14.62	Small
Case 2	60	12	12	15.05	no
Case 3	80	10	10	19.77	no
Case 4	100	10	10	23.10	no

By applying different loading paths, light wrinkle emerged in the path (a) and didn't appear in the other three conditions. In conclusion, application of large internal pressure and adding displacement at high pressure range benefit in reducing the emergence of wrinkle.

Fig 4.8 Shows the thinning of the thickness of the most thinned element in different paths.

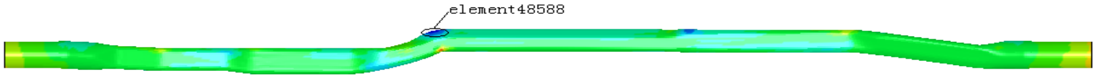


Fig 4.8 Thin part of the tube at a corner

Fig 4.9 The thickness of the most thinned element in different paths

Thought the thickness curve (thickness verves time) of thinnest area of the mesh, we found that the thinning of tube wall is interrelated with loading paths intimately, By the increase of internal pressure, the thickness of the thinnest area on the tube wall is thinner. Seen from the Fig 4.10 and Fig 4.11 we concluded that adding the displacement at high pressure ends is benefit for improving the uniform of the thickness of the part wall.

4.3.3 Defect analysis for tube hydroforming

Unreasonable process parameters will lead to some kinds of defects in the process of the tube hydroforming, such as wrinkle, folding and crushing and so on.

On the condition that the axial force is too lager and the internal pressure is not enough, the irreversible wrinkling will emerge.

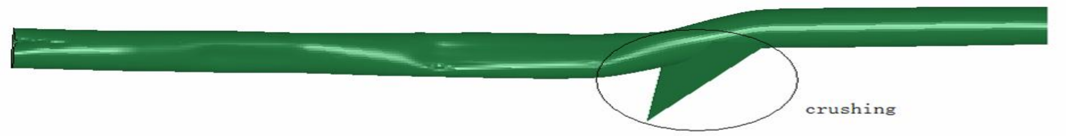


Fig 4.10 The failure of crushing

4.0 Conclusion

Tubular hydroforming has attracted increased attention in the automotive industry recently. This paper covers a complete hydroforming process design for an instrument panel beam of Chrysler 300C model by finite element simulation using the explicit code LS-DYNA. The manufacturing process for the instrument panel beam consisted of tube bending and final hydroforming. To accomplish successful hydroforming process design, four simulations with proper combination of process parameters such as internal hydraulic pressure and axial feeding is carried out by finite element analysis to predict the tube wall thickness and shape. Moreover, the influence of the axial feed and inner pressure on hydroforming has been discussed. On the base of the simulation, an optimized process parameter combination has obtained and has been verified by the instrument panel frame hydroforming experiment. The works show that:

a. The hydroforming of Chrysler 300C model instrument panel beam requires proper selection of process parameters, i.e. the internal pressure and axial feeds.

b. The combination of the internal pressure and axial feeds are crucial to the success of the hydroforming operation.

c. In order to reduce the trial-and-error effort in the designing of the process parameters, FEA simulations can help to determine the “optimum” process parameters and predict the forming results, such as % thickness reduction, buckle or wrinkle.

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