Experimental Research of Hydroforming Square Hollow Component

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Abstract—Tube hydroforming is attracting more and more attention in many industrial fields, especially in automotive industries and aircraft industry. In this paper, aiming at the problem of the match of axial force and internal pressure, the results of experimental research on the influence of loading path on hydroforming square hollow component was presented. The detail experimental procedure and material property was introduced firstly and the effect of loading path on the thickness distribution of the component was discussed in detail. Finally, the difference of four loading path was presented and analyzed with experimental results. It is demonstrated that the forming of blank is under the effect of tension stress and compression stress, the tension stress come from the force of punch and the compression stress come from the internal pressure, the loading path plays an important role in tube hydorforming process which was the key technology of hydroforming and it is benefit to optimize the load path with hydroforming different hollow component.

Keywords-tube; hydorforming; loading path; thickness distribution; experiment

I. INTRODUCTION

In the past few years, because of the advantages of saving money, weight reduction, quality improvement and higher accuracy, the process of tube hydroforming developed very rapidly. It has become an economic alternative to various stamping processes and has been wildly used in aircraft industry and automotive industry, especially in the field of lightweight or complicated construction of automobiles[1]. Fig .1 shows some typical components of this process.

As a comparatively new process, the core of tube hydroforming process is using the hardness and stiffness of blank fully, replacing the clavate blank with tubular blank and forming tubular components by internal hydraulic pressure[2]. The fundamental principles of tube hydroforming processes can be described as Fig .2. A precut and performed tubular blank is inserted into an axially- or radically-split die. Then the die closes, crushing the tube, and the blank is sealed at each end. Finally, hydraulic liquid fills the tube and hydraulic pressure is applied inside the tube whilst simultaneous axial loading is applied at the ends of the tube, pushing it into the die. After the rejection of the workpiece next cycle time can start [3-8].

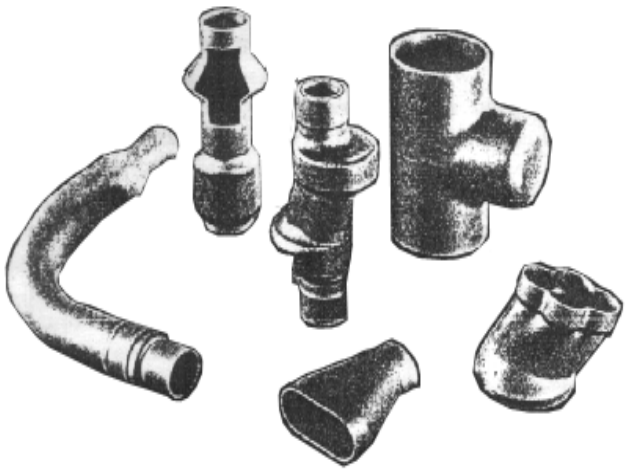


Figure 1. Some typical components of tube hydroforming process

Although it developed rapidly and receiving greatest attraction in many industry fields, there are also some problems have not been solved absolutely. Which included the problem of sealing, match of punch displacement and internal pressure, distribution of strain and stress of component, the metallic flowing model, deformation behavior and character and so on[9-12].

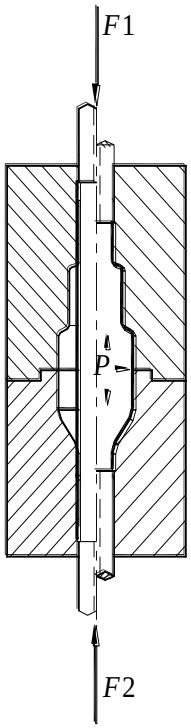


Figure 2. The process of tube hydroforming

These problems are blocks of tube hydroforming process, and how to solve them is the hinge of the developing of tube hydroforming not only in the field of theory study but also in the field of engineering practice. Among all the blocks, the match of punch displacement and internal hydraulic pressure is the key problem for the tube hydroforming process[13-16]. In this paper, aiming at the problem of the match of punch displacement and internal hydraulic presser, by means of the experiment of forming the square component from tubular blank, the result of experiment is presented and the influence of loading path on tube hydroforming is discussed in the condition of same punch displacement and similar final internal pressure.

II. EXPERIMENTAL PROCEDURE

Loading path plays an important role in tube hydroforming process. To analyze the influence of loading path on tube hydroforming, four different typical loading paths were chosen. By the way of measuring the transformation of gridding on component of different loading path, the influence of loading path on hydroforming is illustrated.

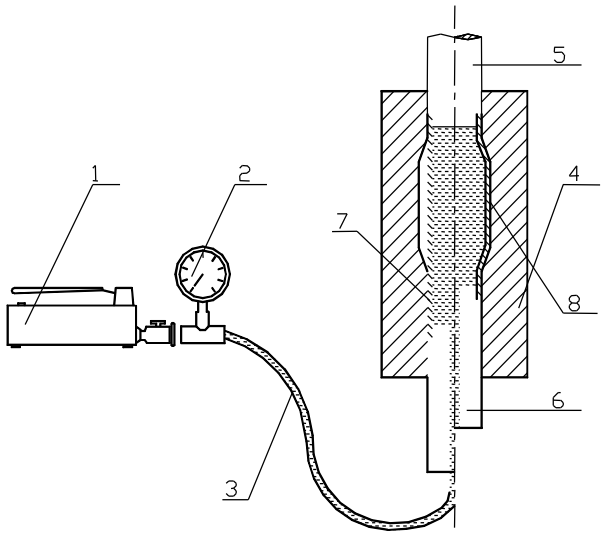
A. Tube material and experimental setup

In the paper, stainless steel seamless tubes (1Cr18Ni9Ti) with 40mm in diameter D and 1.7mm in thickness T are used for the technology experiment. The main mechanical properties of the material are shown in Table 1.

TABLE I. MECHANICAL PROPERTIES OF TUBE MATERIAL

E MPa	n	Yield stress MPa	Tensile strength MPa	Elongation %
2.08×10^5	0.3	338	628	50

The main parts of the experimental setup for tube hydroforming are shown in Fig .3. Through high-pressure hose hand pump provided internal pressure which is up to 63MPa.



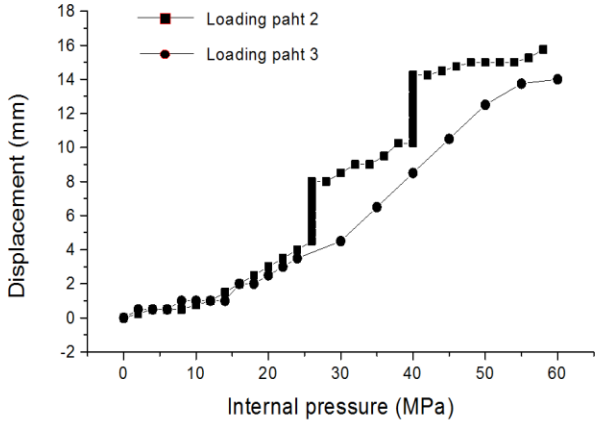
1-pump 2-hydraulic pressure gauge 3-high-pressure hose 4-die 5-upper punch 6-lower punch 7-blank 8-component

Figure 3. Figure 3. Experimental setup

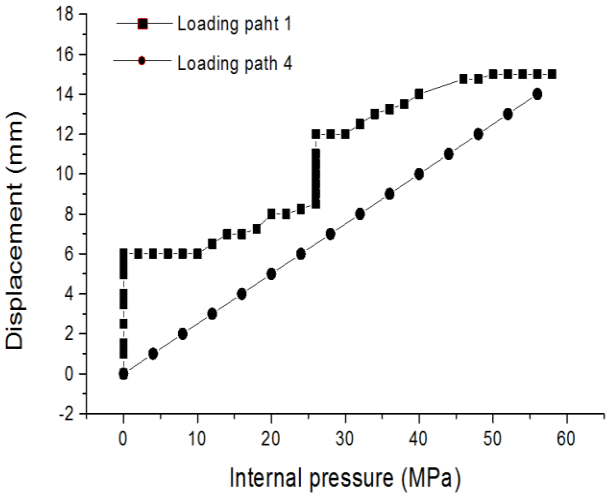
B. Choose of loading path

Although MoS_2 was used as grease in the experiment, the frictional force is still very high and can't be ignored. For the convenience for controlling, experiment choose punch displacement and internal pressure as controlled

parameter. The loading paths are shown in Fig .3. The four loading path with the same initial and final pressure and punch displacement, but the procedure was different, which will show how loading path influence the thickness distribution of the component.



(a)



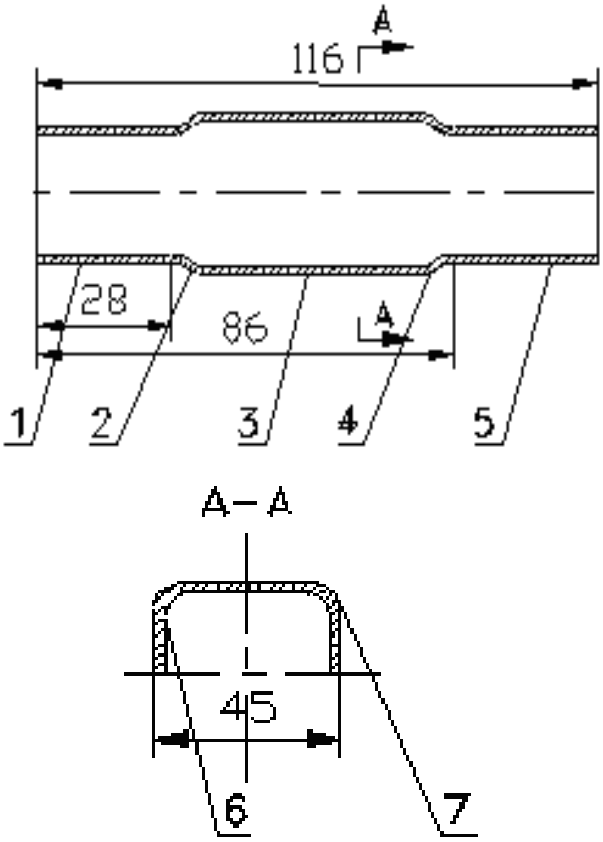
(b)

Figure 4. Loading paths

(a) Path 2and path 3 (b)Path 1 and path 4

C. *Date acquisition*

Because the die and blank are all symmetry, in the experiment only quarter of the component was analyzed as subject investigated. The part name of component was shown in Fig .5.



1-fixed end 2-fixed end's intermediate zone 3-shapping zone 4-feeding end's intermediate zone 5-feeding end
6-edge of component 7-coner of component

Figure 5. The part name of component

D. *Strain distributions*

By measuring the gridding of components of different loading paths, the strain was calculated. The strain distribution shows that, the forming of blank is under the effect of tension stress and compression stress, tension stress come from the force of punch and the compression stress come from the internal pressure. The tangential stress of fixed end's intermediate zone is lager than that of feeding end's intermediate zone. That was because of the friction force, which cause the compression stress of fixed end 's intermediate zone smaller than that of feeding end 's intermediate zone. According to the yielding criterion, the tangential stress is different definitely. The shaping zone being a plane, the difference of stress condition dose's change remarkably, so tangential strain and axial strain of shaping zone is uniform. The tangential strain of different loading paths is different. Which of loading path 1 is the smallest and loading path 3 has the largest tangential strain. That was because of there was no punch displacement in the last stage of loading path 1, it is a process of bulging .The displacement of loading path 3 is the largest of all these path. According to yielding criterion, compression stress is beneficial to the forming of component. The component of loading path 3 is under a stress condition of larger compression stress, so the strain is the largest. The tangential strain of the coner is larger than that of edge of the component. That was because of the forming of corner is a process of bulging.

E. Analysing of formability

As showing in table 2, the corner radius of component of different loading paths is also different. The corner radius of loading path 3 is the smallest, the component is the most close to the contour of die .According to radius of components, the turn of path is 3, 4, 2, 1. Comparing with other path, the rate of slope of path 3 is the largest in the stage of higher pressure. It shows the increasement of displacement of punch in the stage of higher pressure can make component formed in optimized stress condition, it is beneficial to the forming of component. Optimized stress condition which determined the strain condition and material flow of the tube and was the key technology for hydroforming.

At the same time, there are interseting lines between the shaping zone and intermediated zone. The interseting line of path 3 is unconspicuous, it also proved that path 3 is better than other path. Comparing the two interseting lines of fixed end and feeding end, the fixed end's is clearer. It shows that feeding on both end is better than feeding on one end. Fig . 6 is the photo of components of different loading path, all the difference of different loading path can be seen clearly on the picture with was numbered with loading path 1 to 4 and the size can also be seen with compared ruler.

TABLE II. LOADING PATH AND IT'S CORRESPONDING RADIUS

Loading path	1	2	3	4
Radius (mm)	16	14	10	12

Figure 6. The Photograph of component with different loading path

III. CONCLUSIONS

The influence of loading path on tube hydroforming process was investigated in the condition of same punch displacement and similar final internal hydraulic pressure by means of forming the square component from tubular blank, and the following conclusion can be drawn.

1. The forming of blank is under the effect of tension stress and compression stress, tension stress come from the force of punch and the compression stress come from the internal pressure

2. Loading path plays an important role in the influence of formability and strain distribution of component, for the 4 loading path the thickness distribution was different greatly.

3. The increasement of punch displacement in the stage of high pressure is beneficial to the forming of component, which optimized the stress state of the material of deformation.

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