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Design and Simulation of Pulsed Loading Parameters in Tube Hydroforming

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Abstract. In order to determine the pulsating loading parameters in the hydroforming of the reducer, an austenitic 304 stainless steel reducer is taken as an example. The simulation model is established by using finite element analysis software. The hydraulic loading speed is 2 MPa · s-1 and the amplitude 3MPa and 5MPa, frequency 1Hz and 0.5Hz. Based on the comparison of the simulation results of the wall thickness distribution of the formed parts, it was found that the maximum thinning rate and the maximum thickening rate of the composite parts were 5MPa and 1Hz respectively and the distribution of wall thickness is more uniform. The result of the actual machining proves the feasibility of the above computer aided design method.

1. Introduction

Tube Hydraulic Forming (THF) refers to the use of liquid pressure to make the workpiece forming a plastic processing technology, widely used in the manufacture of various cross-section along the axial changes in the hollow parts [1]. With the rapid development of high precision hydraulic computer control technology, RIKIMARU et al [2] proposed pulsating loading pipe hydraulic forming method, that is, in the process of forming the hydraulic pressure at the same time a certain frequency and amplitude of the sine or cosine wave. At home and abroad, it has been found that the pulsating load can promote the feeding of the pipe during hydraulic forming and reduce the obstruction of the friction and make use of the appearance and disappearance of the small folds in the forming process. On the other hand, for the austenitic stainless steel, The pulsating load can enhance the transformation process of the phase change plasticizing effect, thereby enhancing its formability [3 ~ 9].

As with other processing methods, the quality of the pulsating loading pipe hydraulically depends on the processing parameters such as forming pressure, forming time, axial feed volume, amplitude and frequency of pulsation. Considering the double influence of the external force and the microstructure evolution of the internal material, it is very important to study the influence of the specific process parameters on the forming performance, and to optimize the process parameters and realize the control of the final organization and performance of the material [3, 8]. The pulsed waveforms can be combined by a general linear loading curve function with a trigonometric function. Therefore, the forming pressure, the forming time, the amplitude and frequency of the pulsation load, and the axial feed quantity become important process parameters. In this paper, the simulation model is established by Dynaform-based finite element analysis. The forming pressure, axial feed and forming time are calculated. The effects of different pulse loading amplitude and frequency on the wall thickness of the parts are studied by pulsating loading simulation. And finally get the process parameters of pulsating loading, which can provide reference for the determination of other parameters.

2. Simulation Model Established

The tube is made of austenitic 304 stainless steel with a density of 7.85 g / cm3, a tensile strength σb = 520 MPa, a conditional yield strength σ0.2 = 205 MPa, and a minimum fillet radius rc = 5 mm. The diameter of the diameter of the reducer is 50 mm, the total length of the part is ll = 220 mm, the outer diameter of the pipe is d = 65 mm, and the transition half cone angle is α = 20 °.

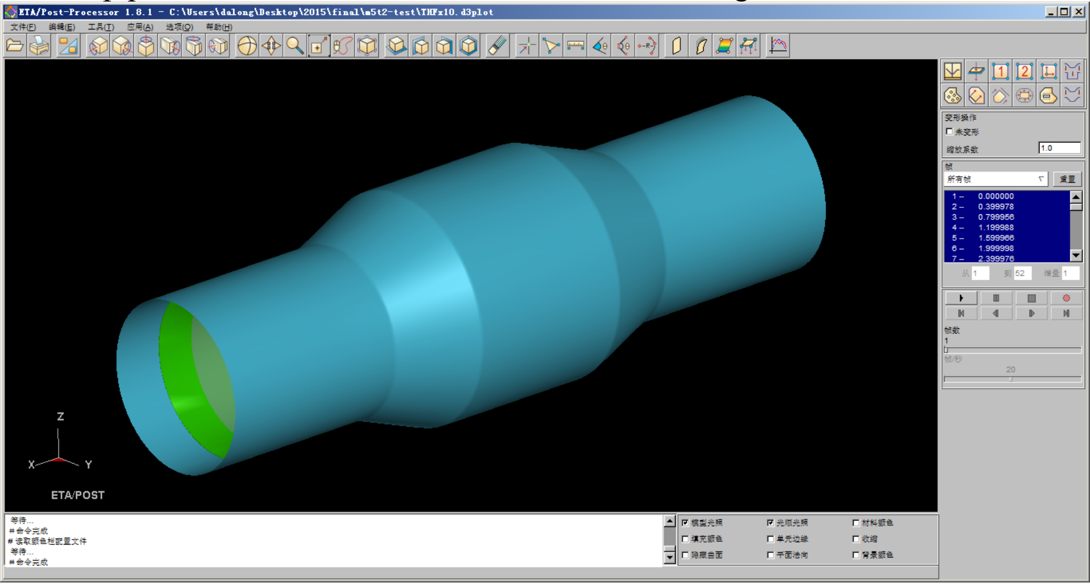

Fig.1 Simulation Model Established

First determine the plastic pressure, taking into account the material forming process of work hardening, the estimated plastic pressure using the formula 1:

$$P_c = \frac{t}{r_c}\sigma_s = \frac{0.6}{5} \times \frac{\sigma_{0.2} + \sigma_b}{2} = 43.5MPa \tag{1}$$

After a large number of simulation experiments, the length of the blank is 240 mm, the axial feed is 16 mm, the forming pressure is 40 MPa, and the forming time is set to 20 s, then the hydraulic loading speed is 2 MPa · s-1.

Dynaform is able to simulate the entire mold development process, greatly reducing mold commissioning time and reducing the cost of producing high quality covers and other stamping parts [2,9]. In order to study the pulsation loading scheme in the hydroforming of austenitic 304 stainless steel reducer, Dynaform finite element analysis software was used to establish the simulation model of the variable pipe, as shown in Fig. Its size parameters are as follows: tube thickness t = 0.6 mm, diameter D = 65 mm, tube length L = 240 mm. Hydraulic bulging of the external mold size parameters shown in Figure 2:

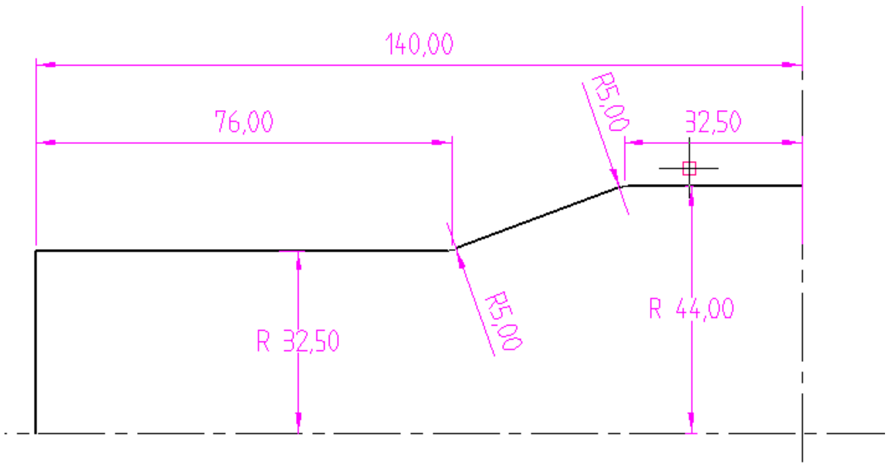

Fig.2 Mold size parameter

After defining the parameters of the model, create a three-dimensional slice model with UG, set the Boolean value to 0 and save it as an IGS file. In order to reduce the calculation time and increase the efficiency of the study, we only take the 1/4 of each model, divide the grid, mold, and left and right of the parts. In order to reduce the calculation time and increase the efficiency of the study, the IGES file is imported into the sheet metal forming technology Dynaform. The head is divided by the Tool mesh, which is fully geometrically characterized. The billet uses the Part mesh for the blank to obtain a uniform and high quality mesh. The finite element model after meshing is shown in Fig.3:

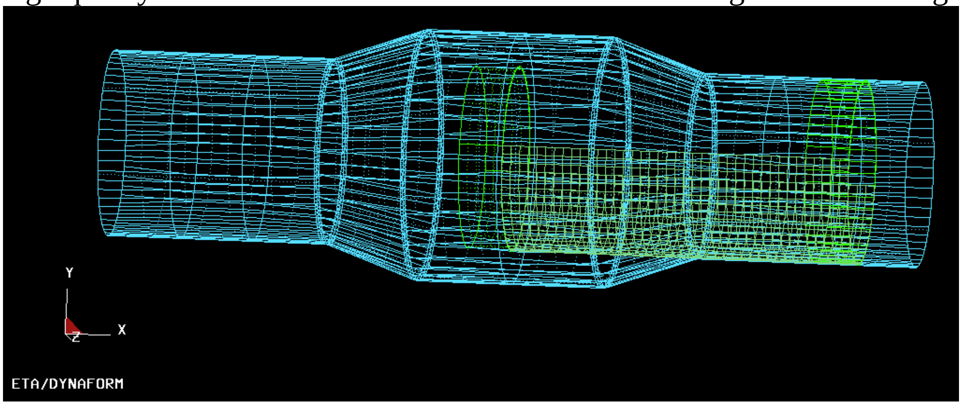

Fig.3 The division of finite element meshes of tubes, molds and punches

3. Pulsation Loading Simulation

The forming pressure was 40 MPa, the forming time was 20 s, and the pulsation treatment was carried out. The sinusoidal curves of different amplitudes and different frequencies (as shown in Equation 2) were used to load the pulsation and observe the results.

$$p(t) = p_0(t) + p_p(t) = \frac{P}{T}t + \Delta p \sin(2\pi f t) \quad (2)$$

Where $p(t)$ is the instantaneous loading pressure, $p_0(t)$ is the linear loading, $p_p(t)$ is the pulsating load, they are a function of t, P is the molding pressure, T is the molding time, Δp is the pulsating wave amplitude, f is the pulse frequency.

According to the information [2 ~ 7] and through the repeated simulation test to get the load amplitude to take 3 MPa, 5 MPa, pulsation frequency take 1 Hz, 0.5 Hz effect is good, so the design as shown in Table 1 is more than the hydraulic pulsation loading simulation Experimental program, get the data shown in Figure 4.

Tab.1 Simulation scheme of hydraulic pulsation loading

NO.	Amplitude(MPa)	Frequency (Hz)
1	3	0.5
2	3	1
3	5	0.5
4	5	1

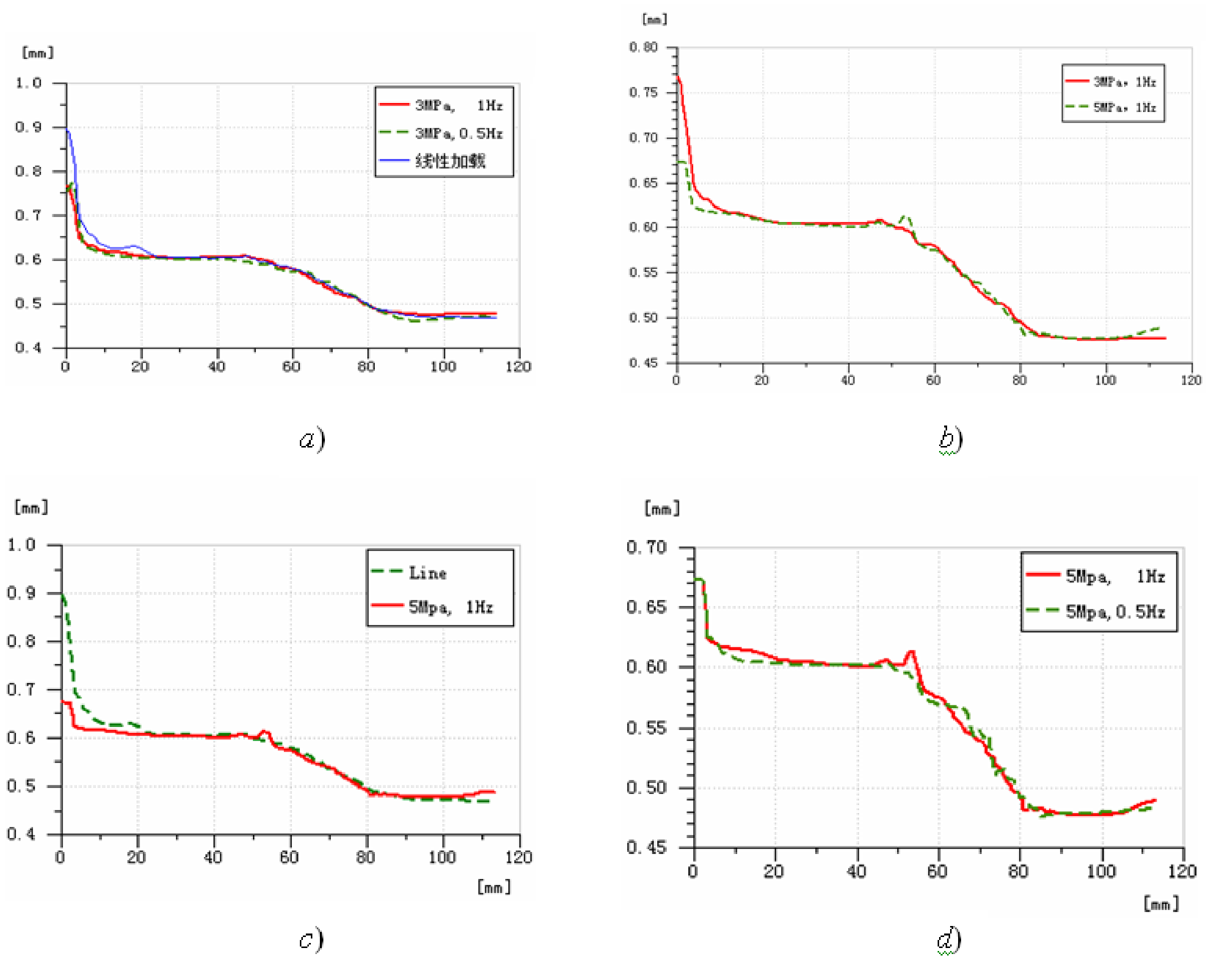

Fig.4 Wall thickness of the parts obtained under different hydraulic loading curves

It can be seen from Figure 4, in the 3MPa hydraulic loading, relative to the linear loading, pulsating load on the uniformity of the distribution of parts of the uniformity of the larger; compared to 1Hz frequency and 0.5Hz frequency, 1Hz fluctuation loading part molding Quality is relatively suitable.

Compared with the amplitude of 5MPa frequency 1Hz and the amplitude of 3Mpa frequency 1Hz pulsating load obtained when the part of the wall thickness distribution data, to significantly observe the former parts of the forming wall thickness distribution was significantly better than the latter. The results show that the maximum thickness reduction is reduced and the maximum thickness is reduced, and the wall thickness distribution is more uniform than that obtained by linear loading of hydraulic pressure. The maximum reduction rate decreases, the maximum thickness is significantly reduced, and the wall thickness distribution is more uniform than the linearly loaded hydraulic pressure.

4. Simulation Results

Based on the Equation 2 Load curve (shown in Figure 5) to simulate, the results shown in Figure 6 (the right side of the data for the wall thickness, the unit is mm). The wall thickness distribution data curve shown in Figure 7.

$$p(t) = p_0(t) + p_p(t) = \frac{P}{T}t + \Delta p \sin(2\pi ft) = 2t + 5\sin(2\pi t) \tag{3}$$

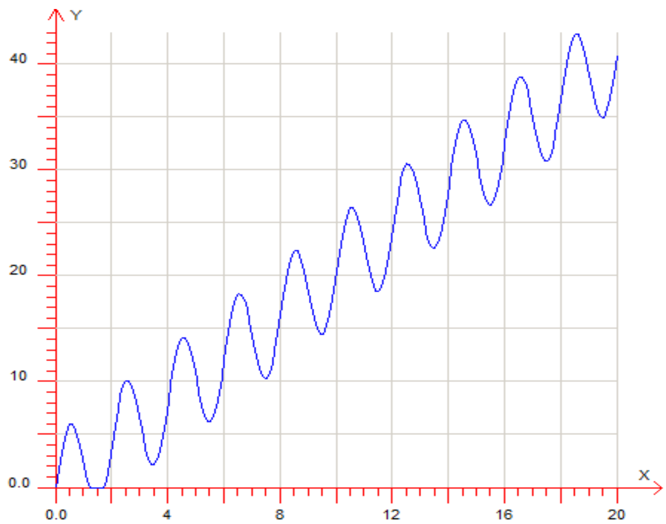

Fig 5 Composite amplitude 5MPa frequency of 1Hz sinusoidal pulse pressure hydraulic loading curve

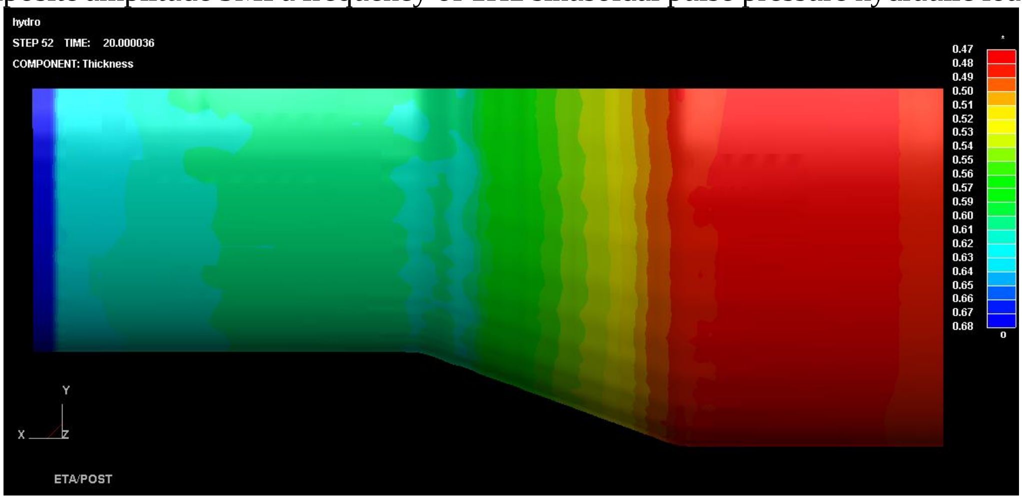

Fig.6 Based on Dynaform finite element analysis results (the right side of the data for the wall thickness, the unit is mm)

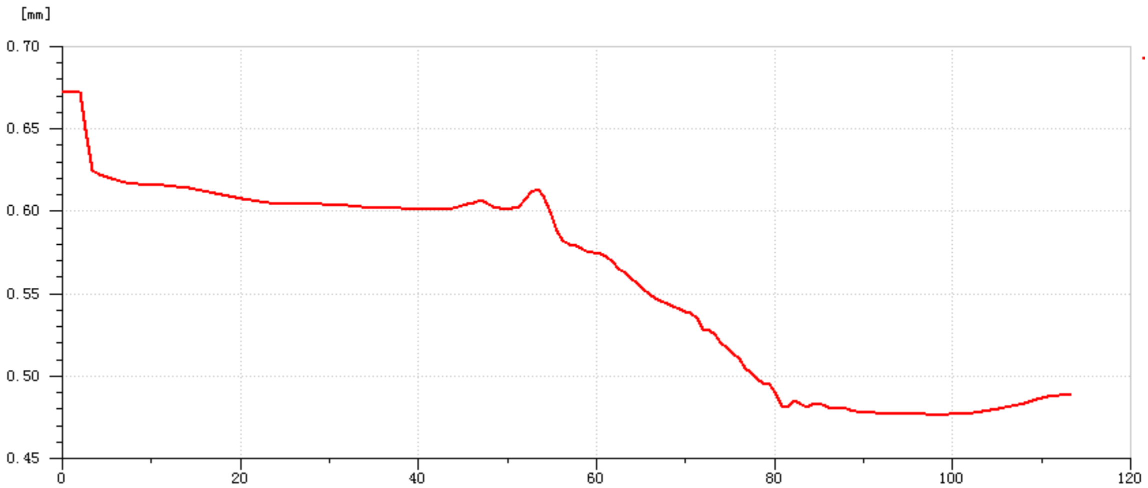

Fig.7 Data distribution data curve (origin for the part of the axial symmetry center position)

5. Conclusion

From the above data can be observed using 2 MPa · s-1 as the baseline, the composite amplitude of 5 MPa frequency of 1 Hz sinusoidal curve of the load simulation results, the wall thickness distribution is better, the maximum reduction rate of About 20%, and the maximum thickening rate is only about 13% lower, forming a higher quality, fillet film in good condition, paste a higher rate.

Acknowledgements

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