A Study on the Shape deviation rate of Hydroforming of Seamed tubes Based on Two Different Velocity

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Abstract: Due to the low price, the seamed tubes are used more and more widely in various industrial fields in recent years. The difference in material properties between the weld zone of the parent metal zone of the thin-walled seamed tubes, the deformation of the hydraulic bulging under the same conditions will also be different, thus resulting in an inconsistency in the overall bulging of the seamed tubes. In this paper, the hydraulic bulging experiment of the seamed tubes at low and medium velocity, and the shape deviation law of the seamed tubes at different velocity are obtained. In the first half of the bulging, the seamed tubes at the medium velocity drops faster than the low velocity shape deviation rate, and the medium velocity is closer to circle; in the second half of the bulging, the medium velocity is go up faster than the low velocity. The shape deviation rate is higher before the tubes are burst, but the medium velocity’s radial average bulge height is smaller than the low velocity.

1. Introduction
Tube hydroforming (THF) technology is an advanced, net forming technology for the production of such components. It is a widely used non-traditional metal forming technology. [1] The materials used for tubes hydroforming are mainly divided into two types: seamless tubes and seamed tubes. Due to the advantages of low production cost and high production efficiency, seamed tubes have more and more applications in THF. Therefore, it is extremely important to study the influence of welds on the
hydroforming process of tubes. For the seamed tubes, according to the weld line of the tube axis parallel or perpendicular, the seamed tubes is divided into a straight seamed tubes and a welded tube.

The seamed tubes is greatly different in structure and preparation method from the seamless tubes. The non-uniformity of the heat transfer in the soldering process results in changes in the metallographic structure and grain size of the weld zone, which causes the mechanical properties of the material in the weld zone to be inconsistent with the parent metal zone [2], resulting in weld seams, HAZ (heat affected zone) and parent metal these three areas. The size and material properties of the three regions will be different, under the same conditions of hydraulic bulging, the deformation of the three materials will be different and will be uncoordinated, which will result in the contour of the seamed tubes to be different with the seamless tube.

Many scholars have talked about the unevenness of tube bulging. Guannan Chu [3], it was found that the bulging state of the welded tubes was affected by the length ratio and the thickness ratio. The deformation coordination of the thick and thick welded tubes increased with the increase of the length ratio and the deformation coordination decreased with the increase of the thickness ratio. At present, the most used and most studied seamed tubes is an electric resistance welding (ERW) straight seam tubes. Some scholars assume that the axial profile of the welded tube during the bulging process is a cosine function [4], ellipse [5] and circle [6]. There are few articles on the deviation rate of radial profile in the process of seamed tubes bulging, especially the comparison of the deviation rate of radial profile and the quantitative variation of the deviation rate under different bulging rates. Zhan Mei [7] and many other scholars have proposed that it is urgent to study the non-uniform deformation behavior.

This paper studies the free bulging of high-frequency resistance welded straight seam tubes at two different forming rates, obtained the real-time bulging height of the weld zone and the parent metal zone of the welded tubes, then obtained the shape deviation rate at different bulging rates.

2. **Welded tube bulging test**

2.1. **Test materials**

The material in this experiment is electric resistance welding (ERW) SS304 stainless steel seamed tubes. The nominal diameter is 25 mm, nominal wall thickness is 0.6 mm, length is 110 mm and bulging zone length of 50 mm. The maximum diameter is measured to be 25.02 mm, the minimum diameter is 24.83 mm, the shape deviation rate $\lambda$ is introduced to characterize the irregular shape of the tube:
The initial maximum shape deviation rate of the welded tube is measured to be 0.72%.

2.2. tube free bulging test platform
The low-rate bulging test device consists of a hydraulic oil supply system, bulging system and 3D strain measurement analysis system. The bulging rate is \(10^{-2} \text{s}^{-1} \sim 1.5 \times 10^{-2} \text{s}^{-1}\). The medium velocity bulging experimental device adds the deep drawing punch than the low velocity, so added an impact hydraulic generating system, as shown in Fig 1. The device produces a bulging rate of \(1 \text{s}^{-1} \sim 1.5 \text{s}^{-1}\).

The pressure supply system provides the hydraulic oil, which is transported to the inner part of the welded pipe through the pipe. Both ends of the welded tube are placed in the left and right locating rings, and two urethane plugs are placed inside the two ends. The tube, two locating rings, and two urethane plug are joined together by a long stud. The liquid enters the inside of the tube through the liquid filling hole at one end of the stud. With the increase of the hydraulic pressure, the urethane plug is expanded by the action of the hydraulic pressure to achieve the sealing of the tube end; since there is no other binding force at both ends and only by the frictional force, the tube can be relatively freely contracted along the axial direction, the tube gradually inflated, which is the free bulging of the tube.

![Figure 1: bulging device.](image)

A three-dimensional strain measurement analysis system was used to collect the deformation images in the hydraulic bulging. It consists of two CCD camera, two LED lamp, a control box, a computer and a tripod. During the bulging process, the weld is directly facing the center of the camera image, and the deformation data of the material is dynamically obtained by matching the grayscale distribution information of the speckle on the image before and after the deformation.

3. Data processing of bulging experiments
First, the mesh of the seamed tubes speckle area is divided, and the grid width is set to 0.72 mm. And the 3D coordinates of each grid in each deformation time are obtained. Secondly, the center origin of the radial direction of the tube is found by fitting. The highest point of axial bulging is found according to the data of the sheet before bulging. The origin of the system is moved to the center of the radial circle of the cross section of the highest point of axial bulging. The x axis is parallel to the weld axis. Finally, using the y and z coordinates of the output, can obtain the max and min radial radius of the weld zone and the parent metal zone during the bulging process. According to the calculation formula of the shape deviation rate \( \lambda \), the curve of the shape deviation rate with the radial average bulging amount during the bulging process is obtained.

4. Hydraulic bulging test results

In the experimental study, only the radial shape deviation rate at the highest point of the axial bulging shape was considered.

The initial shape deviation of the seamed tubes does not start from 0. As the bulging progresses, the shape deviation rate of the welded tube has a decreasing process, the low velocity bulging height reaches about 1.48 mm, the medium velocity bulging height reaches 1.16 mm, the shape deviation rate of the welded tube both are close to 0, indicating that the shape of the welded tube at this time is the closest to the circle. The larger the bulging rate, the closer the shape deviation rate of the welded tube is to 0.

![Shape deviation rate curve](image)

**Figure 2.** Shape deviation rate curve.

In the second half of the THF, the shape deviation rate of the medium velocity rises faster than the low velocity, and the shape deviation rate before the bursting is about 1% larger than the low velocity. Before bursting, the final bulging height of the medium velocity is about 0.34 mm smaller than the final bulging height of the low velocity. Because the metal deformation rate increase, the recrystallization cannot be overcome by the work hardening phenomenon, and the elongation index
and the area shrinkage of the metal are decreased, the deformation resistance is increased, and the plasticity is deteriorated.

![Graph showing bulging height curve](image)

**Figure 3.** Shows the bulging height curve of the weld zone and the base zone at medium velocity. 

Fig. 3 is the curve of the bulging height with time in the welding zone and the base zone under medium velocity. The reason why abscissa is not uniform is that the time interval of data acquisition is the same, but the bulging of welded pipe is not uniform. In the bulging front half, the cross-sectional profile of the tubular member is greater in the weld direction than in the direction of the parent metal, but in the bulging second half is opposite. The degree of work hardening in the weld zone is higher than the parent metal zone, so the deformation resistance of the weld zone is relatively large, and the amount of deformation generated in the same hydraulic environment is small. This explains and verifies the variation of the shape deviation rate in Fig. 2.

5. Conclusions

The regularity of the contour shape reflects the geometric accuracy of the bulging member and the geometric accuracy is one of the important forming quality control indicators for THF high-precision parts. In this study, the deformation data in the hydraulic test of the welded tube is obtained by DIC technology, and the deformation Radial radius of curvature is obtained. Research indicates:

1. The bulging shape of the medium and low velocity decreases in the early stage, but the shape deviation rate decreases faster at the medium velocity, and the shape deviation rate of the medium velocity increases faster than the low velocity in the late bulging.

2. The final shape deviation rate is about 1.3% at low velocity, and the final shape deviation rate is about 2.26 % at medium velocity. The bulging height of the medium velocity is smaller 0.34 mm than
that at the low velocity, indicating that the radial bulging profile of the welded tube at a lower velocity is more regular and the bulging height is higher.

3. When the radial bulging height does not exceed 2 mm, the shape deviation rate both close to the shape deviation rate of the initial welded tube. By properly controlling the bulging height, a cross-sectional shape closer to a circle can be obtained.

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