Research on deformation and stress in hydroforming process of an ellipsoidal shell without constraint

Wei-wei Zhang · Bu-gang Teng · Shi-jian Yuan

Abstract In order to study the deformation of die-less hydroforming of ellipsoidal shell under the condition of without restricting the elongation of short axis, experimental research on hydroforming of an ellipsoidal shell with the initial axis length ratio 1.8 was carried out to analyze the effect of internal pressure on the variation of shell shape, volume, and wrinkling. The results show that as the internal pressure increases at the early stage of deformation, the short axis elongates; correspondingly, the volume varies slightly; wrinkling occurs on the equatorial plane when the internal pressure is up to 1.0 MPa, and it becomes severe when the internal pressure increases to 2.2 MPa; as the internal pressure continuously increases, the long axis begins to shrink rapidly, but the shell volume has a very tiny change within the range of internal pressure 2.2–3.5 MPa; when the internal pressure is 3.8 MPa, the wrinkling is eliminated completely, and the shell volume suddenly increases; when the internal pressure is up to 5.5 MPa, the equatorial plane is no longer shrinking but expanding and the out-of-roundness approaches zero; finally, when the internal pressure is 6.8 MPa, the ellipsoidal shell with the axis length ratio 1.06 is obtained, and the variation of long axis, short axis, and volume are −2.9, 64.6, and 52.7 %, respectively. Simulation was also carried out simultaneously to analyze the stress locus of typical points. It has indicated that the compressive stress in the circumferential direction is the reason of wrinkling occurring; accordingly, the tensile stress in the circumferential direction is the reason of wrinkling disappearing.

Keywords Ellipsoidal shell · Hydroforming · Variation of volume · Variation of axis length · Stress locus

1 Introduction

The ellipsoidal shells have been widely used as pressure vessels, water containers, artistic buildings, and components of ellipsoidal structures due to the advantages of the small wind area, the large capacity, and the attractive outline [1–3]. Traditional method of manufacturing ellipsoidal shell is first stamping lateral petals, then assembling and welding into an ellipsoidal shell. So the press and dies are needed, and higher investment and longer production cycle are inevitable. In order to overcome the shortcoming mentioned above, the die-less hydroforming of ellipsoidal shell provided an easier, economic, and flexible method to manufacture ellipsoidal shell with advantages of lower investment and higher forming accuracy [4]. The so-called die-less hydroforming process first uses a single curvature shell to assemble an ellipsoidal shell, then fills the shell with liquid media and finally bulges the shell into the desired shape [5].

During hydroforming process of ellipsoidal shell, when the initial axis length ratio exceeds $\sqrt{2}$, there is a strong possibility of wrinkling occurring on the equatorial plane due to the continuously increasing compressive stress in the circumferential direction at the early stage of hydroforming [6, 7]. In order to manufacture the ellipsoidal shell with the axis length ratio exceeding $\sqrt{2}$, some measure should be carried out during experiments. The ellipsoidal shell with initial axis length ratio 1.67 was hydroformed [8]. In the experiment, the short axis was restricted by hydraulic press after the wrinkling occurred seriously. Hence, the wrinkling would be eliminated as the internal pressure further increased. However, it is not suitable for hydroforming of large-size ellipsoidal shell due to the area constraint of work table in hydraulic press. Similarly, the ellipsoidal shell restricted in short axis direction by welding a central tube in the initial state was also researched [9]. Simultaneously, in order to overcome wrinkling occurring, the diameter of central tube should be much...
larger. But the method is also not suitable for hydroforming of large-size ellipsoidal shell because it is hard to resist the instability caused by external pressure applying on central tube. However, hydroforming of an ellipsoidal shell without any constraints with the initial axis length ratio exceeding $\sqrt{2}$ has not been researched.

In this paper, hydroforming process of an ellipsoidal shell with the initial axis length ratio 1.8 was studied. Under condition of without any constraints, the variation of shell shape, shell volume, wrinkling, and stress locus as the internal pressure increased has been studied by experimental research along with simulation. Based on the deformation influence,