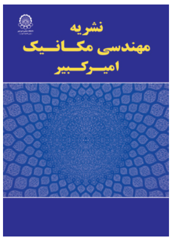

Amirkabir Journal of Mechanical Engineering

Amirkabir Journal of Mechanical Engineering, 49(4) (2018) 291-294
DOI: 10.22060/mej.2016.759

Investigation into Detection Criteria for Wrinkling in Tube Hydroforming

S. Navabi Nezhad, A. Jaamialahmadi*

Department of Mechanical Engineering, University of Mashhad, Mashhad, Iran

ABSTRACT: One of the most common non-traditional forming process, is the tube hydroforming, which is widely used for to form various tubular parts. To produce final product without any failure, tube hydroforming process is strictly dependent on load path, internal pressure-axial feed. Major modes of failure which may be occur in tube hydroforming process are necking, bursting, buckling and wrinkling. Predicting and preventing each of these failures are very important and leads to defects-free products. In this study, geometrical criteria for detecting wrinkling in numerical methods such as finite element analysis are reviewed. This type of identifying the wrinkling can be pointed out such as the first derivative or geometric slope and length to area indices criteria. In this paper, a new geometric method as a center of volume is introduced. In this case, the center of volume of wrinkled part is not equal with the wrinkled-free one. In order to verify, the results of this new criterion were compared with the results of previous measures and experimental tests in published articles.

Review History:

Received: 27 November 2015
Revised: 14 April 2016
Accepted: 9 May 2016
Available Online: 30 August 2016

Keywords:

Tube hydroforming
Wrinkling
Geometrical method
Center of volume criterion

1- Introduction

Tube hydroforming is an improved process for producing tubular parts with complex shapes and variable cross sections which is not possible to use traditional methods or needs a multi-stage production process. Tubular workpiece is bulged to contact with the internal surface of the complex die cavity to form into desirable shape, by applying internal pressure and axial feeding simultaneously. The hydroforming process is used commercially in many industries, among them a wide variety of automotive components such as camshafts, radiator frames, front and rear axial parts, engine cradles, crankshafts, etc. [1].

The major modes of failure in tube hydroforming process are necking, bursting, wrinkling and buckling. If the axial compressive forces acting on both ends of the tube are too large, excessive material will be accumulated into the middle area of the tube, which will result in the wrinkling failure [2]. In design and manufacture of parts to obtain an acceptable product, it is necessary to recognize the conditions lead to defects. In this regard, eliminating trial and error testing and reduce costs and design time of components, numerical methods such as finite element method are used, due to the predict ability. Including methods for determining the wrinkling in finite element analysis to be pointed geometric criteria.

The first method is the geometric slope or first derivative of wrinkles. In this criterion wrinkles are identified by considering changes of slopes of the tube profile. The slopes are calculated from the nodes along a prescribed line. The second is length to area wrinkle criterion. Since the first introduced criterion have not the ability to recognize the type of wrinkle and the ability to predict wrinkles in parts with complex shapes, the second criterion has been introduced in the paper [3]. Another measure of wrinkling occurrence, the tube surface to fluid volume ratio, is simple but its calculating and applicability is difficult [4].

In this article a new geometric criteria to predict wrinkling of the tube hydroforming process as the center of volume of wrinkled part is presented. In order to verify the accuracy of its predicting, a comparison with experimental results and other geometric criteria is carried out.

2- Methodology

In this section, a new criterion is introduced where the center of the tubular volume at any point in the process known as wrinkling indicator. So that in a tube hydroforming process, in one part with a specific volume, the center of volume of wrinkled part is not equal to the part without wrinkle.

On this criterion, the center of tubular volume determined in each time step of simulation by using the Eq. (1). Volume centers coordinates along the main axis of the tube for specified volumes are calculated as normalized variable.

$$\bar{x} = \frac{x_v - x_{v_0}}{x_d - x_{v_0}} \qquad \bar{y} = \frac{y_v - y_{v_0}}{y_d - y_{v_0}} \qquad \bar{z} = \frac{z_v - z_{v_0}}{z_d - z_{v_0}} \tag{1}$$

In the above equations:

x_d , y_d and z_d are the center of die volume in order to x, y and z direction.

x_v , y_v and z_v are the center of tubular volume in order to x, y

Corresponding author, E-mail: jaami-a@um.ac.ir

and z direction.
x_{v_0} ‘ y_{v_0} and z_{v_0} are the center of tube volume in order to x, y and z direction at V=0.
By using Eq. (1):

$$\Delta_v = \sqrt{\left(\bar{x}^2 + \bar{y}^2 + \bar{z}^2\right)} \quad (2)$$

In order to use it for the detection and prediction of wrinkles, it is necessary to track and compare its evolution with a known unwrinkled deformation history. In most cases, a practical way to obtain an unwrinkled deformation history is to run one ideal FEM[1] analysis under self feeding conditions. Using the Eq. (1) at any time step in the process, the center of volume under self feeding condition is achieved. Then put each of the obtained values in the Eq. (3) and changes in the center of tube volume under self feeding condition will be calculated.

$$\Delta_v^{self} = \sqrt{\left(\bar{x}_{self}^2 + \bar{y}_{self}^2 + \bar{z}_{self}^2\right)} \quad (3)$$

By introducing W as an indicator of wrinkling, Eq. (4) can be used:

$$w = \Delta_{[v]} - \Delta_{[v]}^{self} \quad (4)$$

3- Results and Discussion

In order to evaluate the performance of this detection criterion for wrinkling, its results have been compared with experimental data of Strano [4], Yuan [5] and other geometrical criteria.

As shown in Fig. 1, variations of wrinkling indicator are plotted as a function of the non-dimensional volume at 12 points where the amounts of the self-feeding and axial feeding processes volumes are equal. The greater the value of W, the higher the wrinkling occurrence probability during the real FEM simulation. At the end of the process part is wrinkled and by referring to Fig. 2, the results obtained from Yuan's experiment is in good agreement with FEM simulation.

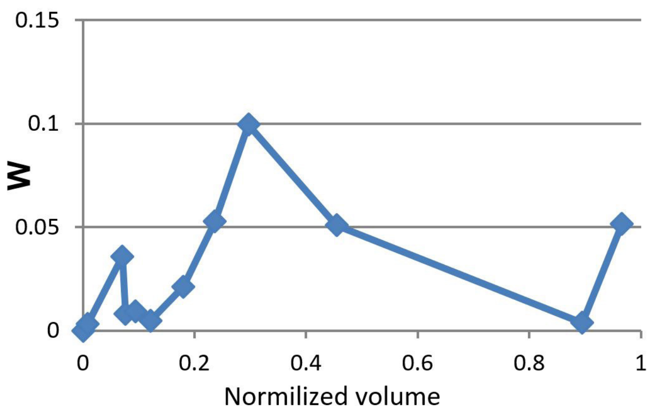

Figure 1. The new geometrical wrinkle indicator results as a function of volume for considered model by Yuan

Fig. 3 shows results of the new geometrical indicator for two load case of Strano [4] experiments which only case 2 is shown in Fig. 4. By comparison with Fig. 5, It is obvious the good agreement between experiment and FE simulation too. In addition, this situation is repeated for load case 1 more clear which are not shown here.

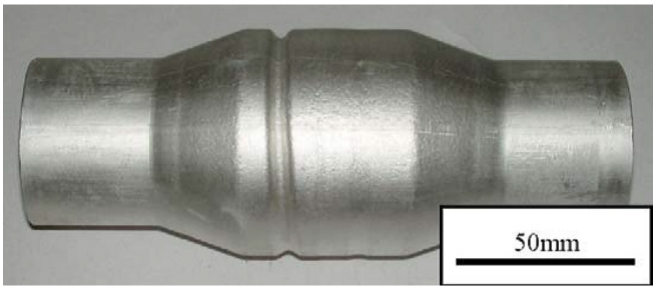

Figure 2. Wrinkled part at the end of the process[4]

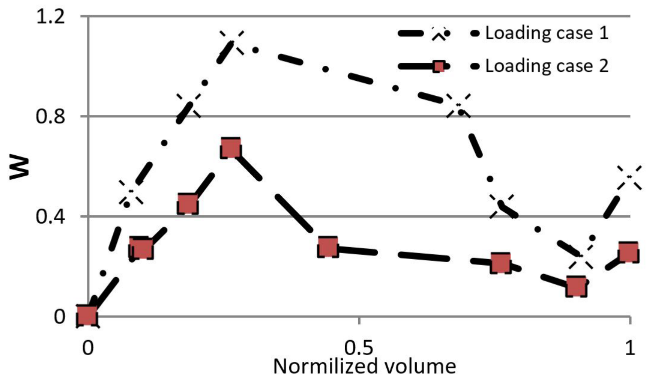

Figure 3. The new geometrical wrinkle indicator results as a function of volume for considered model by Strano [5].

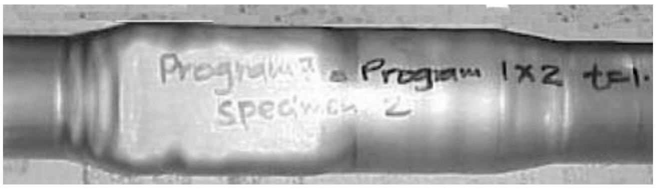

Figure 4. Detail of final part –case 2; slight wrinkling is visible at the corners of the square shaped bulge [5]

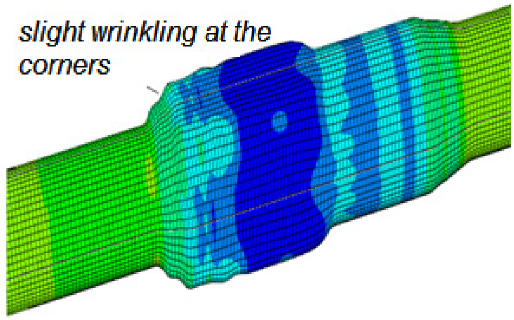

Figure 5. Final part, FEM detailed plot -case 2; slight wrinkling is visible at the corners of the square shaped bulge

1 Finite element method

4- Conclusions

In this article, geometric criteria to predict wrinkling in the finite element methods have been investigated and a new geometrical wrinkle indicator is proposed and evaluated. By comparing the data obtained from this new model with other criteria and experiments data that was introduced before. The results show that the proposed indicator is:

- Easy to implement and compute.
- Suitable for a wide range of die geometries.

References

[1] E. Chu, Y. Xu, Hydroforming of aluminum extrusion tubes for automotive applications. Part I: buckling, wrinkling and bursting analyses of aluminum tubes, *International Journal of Mechanical Sciences*, 46(2) (2004) 263-283.

[2] S. Yuan, Z. Tang, G. Liu, Prediction and analysis of wrinkling in tube hydroforming process, *International Journal of Materials and Product Technology*, 40(3-4) (2011) 296-310.

[3] M. Strano, S. Jirathearanat, S.-G. Shr, T. Altan, Virtual process development in tube hydroforming, *Journal of Materials Processing Technology*, 146(1) (2004) 130-136.

[4] M. Strano, S. Jirathearanat, T. Altan, Adaptive FEM simulation for tube hydroforming: a geometry-based approach for wrinkle detection, *CIRP Annals-Manufacturing Technology*, 50(1) (2001) 185-190.

[5] S. Yuan, W. Yuan, X. Wang, Effect of wrinkling behavior on formability and thickness distribution in tube hydroforming, *Journal of Materials Processing Technology*, 177(1-3) (2006) 668-671.

Please cite this article using:

S. Navabi Nezhad and A. Jaamialahmadi, Investigation into Detection Criteria for Wrinkling in Tube Hydroforming, *Amirkabir J. Mech. Eng.*, 49(4) (2018) 829-838.

DOI: 10.22060/mej.2016.759