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Investigation of Wrinkling in Hydrodynamic Deep Drawing assisted by Radial Pressure with Inward Flowing Liquid

Maziar Khademi[a], Abdolhamid Gorji[b,*], Mohammad Bakhshi[c], Milad Sadegh Yazdi[d]

[a]*MSc student, Metal Forming Research Center, Babol Noshirvani University of Technology, Babol, 48187-1167, Iran.*
[b]*Associate Professor, Metal Forming Research Center, Babol Noshirvani University of Technology, Babol,48187-1167, Iran*
[c]*Professor, Metal Forming Research Center, Babol Noshirvani University of Technology, Babol,48187-1167, Iran*
[d]*PhD student, Metal Forming Research Center, Babol Noshirvani University of Technology, Babol, 48187-1167, Iran*

Abstract

The formation of wrinkling in deep drawing processes generally occurs in the two area of flange and cup wall. In this paper, a geometric method based on FEM simulation has been developed to investigate the wrinkling in the wall area of conical cups. Wrinkling wave variation was considered as the criterion of wrinkle defect. The forming process in this study is hydrodynamic deep drawing assisted by radial pressure with inward flowing liquid. The effects of radial pressure and cavity pressure on wrinkle phenomenon have been investigated. To verify the results of the simulation, experiments were performed on the steel sheets. Good agreement between the simulation and experimental results shows the reliability of this method in the wrinkling study. Results showed that radial pressure and cavity pressure have significant impacts on creation or prevention of wrinkling in the side wall.

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Keywords: Wrinkling; Radial hydroforming; Conical cup

1. Introduction

Hydroforming is a technology that has gained an increasing interest in industries [1]. In Hydrodynamic Deep Drawing assisted by Radial Pressure (HDDRP), the die cavity is filled with a type of liquid. When the punch goes down and the blank is forced into the die cavity, the pressurized liquid will push the blank tightly onto the punch surface. Because of the small value of the gap between the die and blank holder, a liquid pressure exists around the blank rim. Researchers [2, 3] showed that the radial pressure can increase limiting drawing ratio (LDR) and reduce

* Corresponding author. Tel. and Fax: +98-11-32334205.
E-mail address: hamidgorji@nit.ac.ir

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forming load. They stated that in HDDRP, it is not possible to obtain a radial pressure greater than that of the die cavity. In order to obtain this, a new process was proposed, called HDDRP with Inward Flowing Liquid [3].

In automotive pressings, about egighty percent of the part failure can be attributed to wrinkling [4]. In HDDRP with inward flowing liquid, wrinkles can appear in the flange region or in the wall area (of the conical cups). Investigation of wrinkles in the wall area is more important than the flange area. By adopting energy criterion, Wang and Cao [5] studied wrinkling in deep drawing processes of an aluminum conical cup. The critical wrinkling stresses on the walls were analytically calculated. In this research, a geometric method was developed to study the wrinkle formation in the wall area of conical parts formed in the modified process proposed by Wang et al. [3] (Fig. 1).

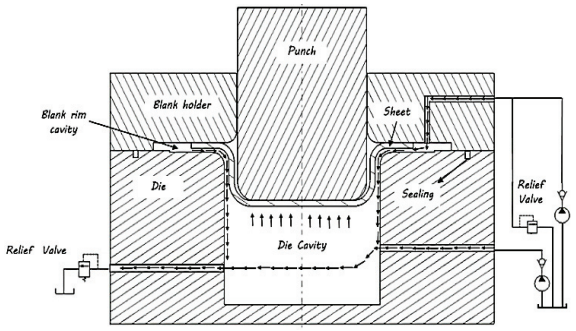

Fig. 1. The proposed modified Hydrodynamic Deep Drawing assisted by Radial Pressure with Inward Flowing Liquid.

2. Experimental procedure

The assembled die set and the hydraulic pressure unit are shown in Fig. 2-a. A universal testing machine with 600 kN capacity was used. All experiments were performed at the speed of 20 mm per minute .For the supply of process pressure, a variable flow rate hydraulic pump with the maximum pressure of 50MPa and a constant flow rate hydraulic pump with a maximum pressure of 100MPa were used, Fig .2-b. SAE10 hydraulic oil with a viscosity of 5.6 CST was used as the pressure medium that provides necessary pressure for forming process.

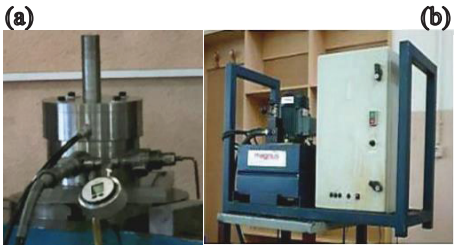

Fig. 2. (a) Hydrodynamic Deep Drawing assisted by Radial Pressure with Inward Flowing Liquid setup, and (b) hydraulic unit.

Table 1 shows the properties of St13 sheets used in the experiments. The sheets have a diameter of 100 mm and a thickness of 1 mm. The determined flow stress could be expressed by the power law as $\sigma=K\varepsilon^n$. Also, as shown in Fig. 3, the simplified loading path for the cavity pressure and radial pressure were determined. In this process, a small pre-bulging can be created on the sheet to improve the drawing process. In this research, 1 MPa pre-bulging pressure was applied (path AB) [1].The pressure was linearly increased to a maximum value (path BC). The slope of this path depends on the punch velocity and sheet thickness [6]. The pressure path was recorded by a computer connected to a digital manometer. In order to control the maximum pressure of the chamber and radial direction, pressure control valves were used. When the pressure in the chamber and rim area reached the predetermined maximum values, the pressure control valves were opened and the process continued with the constant pressure (path CD). Based on the nature of the HDDRP with inward flowing liquid, an O-ring was used for sealing to prevent fluid leakage.