



Process window diagram of conical cups in hydrodynamic deep drawing assisted by radial pressure



Abbas HASHEMI¹, Mohammad HOSEINPOUR GOLLO¹, S. M. Hossein SEYEDKASHI²

1. Faculty of Mechanical Engineering, Shahid Rajaee Teacher Training University, Tehran 16785-136, Iran;

2. School of Mechanical Engineering, University of Birjand, Birjand 97175-376, Iran

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Abstract: Major defects in forming of conical cups are wrinkles and rupture. Hydrodynamic deep drawing assisted by radial pressure (HDDRP) is a sheet hydroforming process for production of shell cups in one step. In this work, process window diagrams (PWDs) for Al1050-O, pure copper and DIN 1623 St14 steel are obtained for HDDRP process. The PWD is determined to provide a quick assessment of part producibility for sheet hydroforming process. Finite element method is used for this purpose considering the process parameters including pressure path, and the blank material and its thickness. Numerical results are validated by experiments. It is shown that the sheets with less initial thickness and higher strength show better formability and uniformity of thickness distribution on final product. The results demonstrate that the obtained PWD can predict appropriate forming area and probability of rupture or wrinkling occurrence under different pressure loading paths.

Key words: conical cups; hydrodynamic deep drawing; finite element simulation; process window diagram

1 Introduction

Hydrodynamic deep drawing (HDD) is a sheet hydroforming process which is a combination of conventional deep drawing and hydroforming, comprising the advantages of both technologies. HDD is known by different titles such as hydraulic counter pressure deep drawing, fluid former, aquadraw and hydromech [1]. HDD is categorized as a flexible forming process, and has a wide range of applications in different industries due to its capability of forming complex parabolic and conical shapes with high limiting drawing ratio (LDR) in a single step. In HDD process, a shaped punch forces the blank into the liquid-filled die cavity, so that the liquid is pressurized and forms the blank around the punch [2,3]. The created frictional force between the blank and the punch allows to apply higher pressures, thus stress concentration is reduced on the blank at the punch tip area and the formability will be improved. On the other hand, the exerted pressure provides a bed for the free portion of the blank between the punch and the die shoulder, pushing the blank upward to create the tensile circumferential stresses that assist in preventing

from wrinkles. In this flexible process, the same die can be used in forming of various geometries using different punches.

Hydrodynamic deep drawing assisted by radial pressure (HDDRP) is a special application of HDD, in which the pressurized forming liquid is applied also to the outer edge of the blank at flange area to improve the material flow during the forming process [4]. There is no sealing in the flange area in HDDRP and the gap between the die and blank-holder is slightly bigger than the blank thickness. When the punch moves down and the liquid is pressurized, the sheet is drawn into the die cavity while stuck to the punch surface and the blank-holder. At this time, the pressurized liquid can flow into the gap between the blank-holder and the die. This gap causes a uniform radial pressure around the sheet edge in the flange area assisting in more efficient flow of material into the die cavity [5]. HDDRP has a lot of advantages compared with conventional deep drawing such as higher drawing ratio and dimensional accuracy, uniform thickness distribution, better surface quality and more complex products. The radial pressure can be created around the blank with a little modification in the HDD die set. Figure 1 shows a schematic of this process.

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