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Hydrodynamic deep drawing of double layered conical cups

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Abstract: Hydrodynamic deep drawing assisted by radial pressure is an advanced sheet forming technology with great advantages such as higher drawing ratio, good surface quality and higher dimensional accuracy. In this process, both the bottom surface and the peripheral edge of sheets are under hydrodynamic pressure, so that the forming procedure is more uniform with low failure probability. Multi-layered sheets with complex geometries could be formed more easily with this technique compared with other traditional methods. Rupture is the main irrecoverable failure form in sheet forming processes. Prediction of rupture occurrence is of great importance for determining and optimizing the proper process parameters. In this research, a theoretical model was proposed to calculate the critical rupture pressure in production of double layered conical parts with hydrodynamic deep drawing process assisted by radial pressure. The effects of other process parameters on critical rupture pressure, such as punch tip radius, drawing ratio, coefficient of friction, sheet thickness and material properties were also discussed. The proposed model was compared with finite element simulation and validated by experiments on Al1050/St13 double layered sheets, where a good agreement was found with analytical results.

Key words: hydrodynamic deep drawing; radial pressure; double layered sheet; conical cup; critical pressure

1 Introduction

Industrial application of conical products has a wide variety [1]. Multi-layered sheets have several advantages over single layered sheets. Advantages such as improved formability, favorite corrosion and wear resistance, noise and vibration damping, favorite temperature distribution and less spring-back and wrinkling that result in weight and cost reduction [2]. Besides, non-defective forming of tapered sheet metal parts is one of the most complex areas in the sheet metal forming industry. Small contact area between the punch and the sheet at the beginning of deformation and high shear stresses exerted on the sheet will cause premature rupture. Wrinkles are also very likely to occur on the conical wall.

Hydrodynamic deep drawing process assisted by radial pressure (HDDRP) is a new technology in producing conical/cylindrical cups. This technique applies a uniform loading on the surface of the sheet and its peripheral edge [3]. The circumferential loading highly improves the flow of material into the die, increases the formability and reduces the defects. Thus, higher limiting drawing ratio (LDR), surface quality and dimensional accuracy of the final product are several advantages of this method [4]. In recent years, a few research works have been conducted to study the hydroforming of bilayer sheets and tubes. LANG et al [5] studied the hydroforming of multi-layer sheets with a thin middle-layer numerically and experimentally. They found a better distribution of wall thickness with steel/steel/aluminium combination than aluminium/aluminium/steel. They also observed that the forming limit of a bilayer sheet lies between the forming limits of its constituent layers. MOROVVATI et al [6] investigated the effect of blank−holder force on plastic wrinkling of aluminium/steel sheets in traditional deep drawing process. They used the energy method in their analytical model to predict the wrinkling, and studied the influential parameters on the formation of wrinkles using finite element simulations. BAGHERZADEH et al [7] studied the plastic instability of bimetallic sheets for using in hydromechanical deep drawing of cylindrical cups with emphasis on safe pressure range, stress and strain distribution, thickness of layers, location of layers, drawing ratio and frictional condition. MOHAMMADI et al [8] analyzed the bending of two and three layered

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sandwich sheets using the genetic algorithm. They studied the effect of setting conditions and thickness distribution on the spring-back during the bending process. SERROR [9] offered an analytical model for determining the formability of bilayer sheets under plastic instability conditions based on the effect of work hardening and relative toughness of the constituent layers.

The aim of this work is to propose a simple theoretical model for estimation of maximum (critical) pressure for HDDRP of conical cups. The obtained critical rupture pressure can provide useful guide for the optimal processing of hydrodynamic deep drawing. In engineering manufacture, this theoretical estimation could be used as the initial input data to be optimized by further finite element simulations or optimization techniques. Hence, a new theoretical model is proposed to determine the critical fluid pressure in HDDRP of double layered conical cups. Experiments have been conducted to verify the analytical results which are in agreement with each other. The effects of main process parameters such as strain hardening exponent, punch tip radius, sheet thickness and anisotropy values, drawing ratio and coefficient of friction in the flange area on critical rupture pressure are thoroughly discussed.

2 Process analysis

Figure 1 shows a schematic representation of radial pressure assisted hydrodynamic deep drawing process, which is fulfilled in two stages. At first, die cavity is filled with hydraulic fluid (usually oil or water, oil in this case) and a pre-bulging pressure is applied to forcing the sheet to the bottom of the punch. Then, punch moves downward to reshape the sheet. In this work, the second stage of forming is analyzed. Sheet is divided into three zones I, II and III during the forming process. Figure 2 shows the deformation model of a conical cup. Zone I

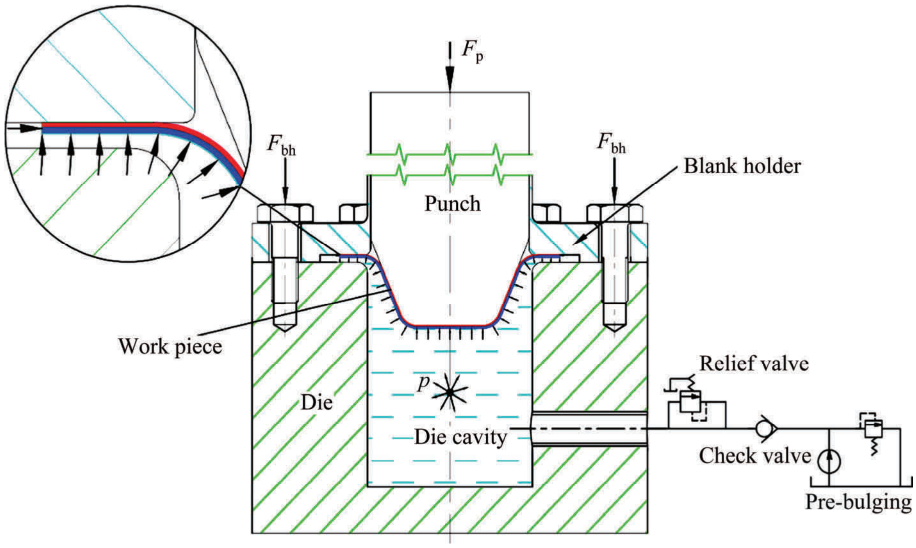

Fig. 1 Hydrodynamic deep drawing process assisted by radial pressure

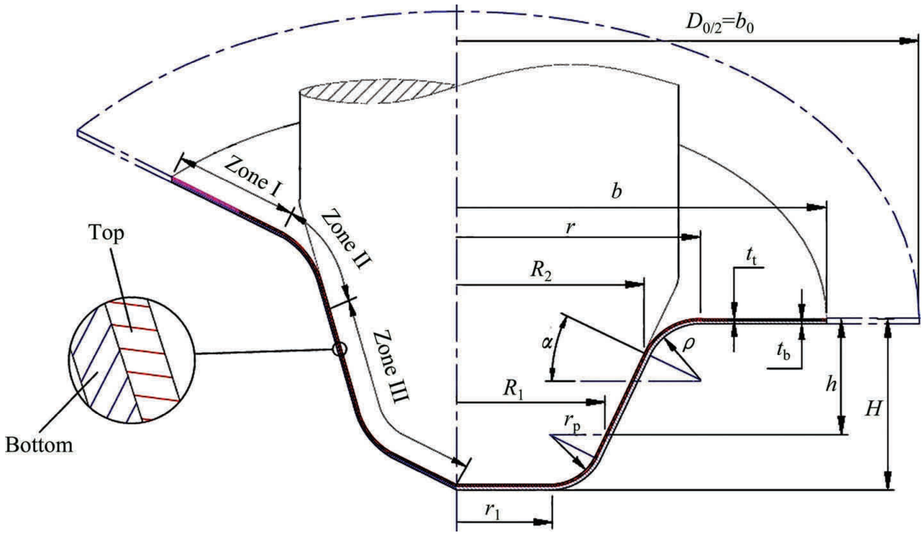

Fig. 2 Forming area during hydrodynamic deep drawing process