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Hydrodynamic deep drawing process assisted by radial pressure with inward flowing liquid

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ABSTRACT

A radial pressure can reduce drawing force and increase drawing ratio in hydrodynamic deep drawing. However, conventional hydrodynamic deep drawing cannot attain a radial pressure higher than the pressure in the die cavity. In this research, a modified method, named hydrodynamic deep drawing assisted by radial pressure with inward flowing liquid, was proposed and investigated using both primarily experimental and numerical simulation analysis. A radial pressure higher than the pressure in the die cavity was realized by means of the inward flowing of the liquid during this process. After preliminary experimental validation, FEM was used to explore the forming process. The results from the simulation were compared with those from the experiment. The effects of the radial pressure on the wall thickness distribution, punch force, and compressive stress in the blank flange were studied with assistance of numerical simulation. The process window for radial pressures versus drawing ratios was established in 2Al2O alloy experimentally and cups with drawing ratio of 2.85 were successfully formed.

1. Introduction

Hydrodynamic deep drawing (HDD) [1–4], as illustrated in Fig. 1(A), is one type of sheet hydroforming, which can be used in automobile and aerospace industries. In HDD process, the liquid in die cavity leaks dynamically through the gap between the blank and the die, when the blank moves along with the punch into the die cavity filled with oil. Meanwhile, the pressure of the liquid around the blank rim P_R is null. As shown in Fig. 1(B), a die rim block is set around the blank rim in HDD assisted by radial pressure [5]. The small gap between the blank holder and the die rim block increases the liquid pressure around the blank rim P_R, when the liquid flows. The liquid pressure around the blank rim P_R is greater than zero and less than that in the die cavity P_C, due to the pressure loss along the liquid flows path. It has been proved that the radial pressure applied onto the blank rim could reduce the drawing force and increase the limiting drawing ratios (LDR) [6–11], but it is impossible to obtain radial pressure higher than the pressure in the die cavity in the conventional HDD and in HDD assisted radial pressure.

In this study, an innovative method named as hydrodynamic deep drawing assisted by radial pressure with inward flowing liquid was proposed in order to obtain a radial pressure higher than the pressure in the die cavity during the HDD process. Fig. 1(C) shows the sketch of the proposed method. The idea is that a radial pressure higher than the pressure in the die cavity will be realized if the liquid flees inward from the rim cavity to the die cavity; meanwhile, the fluid presses the blank onto the blank holder to such an extent that no leak flow occurs between the blank and the blank holder.

The gap between the blank holder and the die is fixed in the proposed process. Pressure is applied to the liquid in the die cavity at the beginning of the process. This pressure lifts the blank from the draw die and presses the flange of the blank onto the blank holder. Thus, a seal is formed between the blank flange and the blank holder, while a gap between the blank and the die appears. The exchange valve turns and the pump supplies oil to the blank rim cavity when the liquid pressure in the die cavity reaches the preset value. Then, the liquid pressure in the blank rim cavity increases and the liquid flows through the gap to the die cavity, which means an inward flow is initiated. Owing to pressure loss along the flowing path, the liquid pressure in the rim cavity is higher than that in the die cavity because the gap between the blank holder and the die is very small. A higher radial pressure can help to push the blank to draw into the die cavity in the proposed process, compared with the conventional

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