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Procedia Engineering 207 (2017) 311–316

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on the Technology of Plasticity, ICTP 2017, 17-22 September 2017, Cambridge, United Kingdom

Numerical and experimental study on electrohydraulic forming process

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Abstract

Electrohydraulic forming (EHF) is one of the high-speed forming process that uses high-voltage discharge in liquid. Shockwave resulting from the discharge is generated between two electrodes in liquid and it deforms the blank into the die. When the blank is deformed in a very short time, the formability is enhanced and springback can be reduced. Furthermore, in electrohydraulic forming, the blank has no bouncing effect that happens in other high-speed forming process. Therefore, it is possible to deform the blank into a complex shape with only one operation. In this paper, numerical and experimental study of electrohydraulic forming was performed using an Al 6061-T6 sheet material. Numerical model was formulated in LS-DYNA program. ALE (Arbitrary Lagrange-Eulerian) scheme was applied to create the elements of the fluid parts and structural parts were modelled using shell elements. From the results of the numerical simulation, it was observed that the pressure of the fluid parts was increased by the electric energy and the movement of the water part could deform the blank into the die. In addition, electrohydraulic forming apparatus was developed and experiment was carried out using an equipment of 32 kJ capacity and conical die. Comparison of the numerical and experimental results was also conducted on the bulge height of the blank and it also showed similar tendency in relation to the deformed shape.

Keywords: Electrohydraulic forming, high-speed, high-voltage discharge, LS-DYNA, ALE

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10.1016/j.proeng.2017.10.780

1. Introduction

Electrohydraulic forming (EHF) is a high-speed forming method that uses a high-voltage discharge in liquid filled chamber. When the electric discharge occurs, high-pressure shock wave is generated between two electrodes and it accelerates the blank into the die. When a material is deformed in 1 ms, forming limit can be extended for several materials due to greatly high forming velocity and strain rates, and the springback is significantly reduced compared to conventional static forming process [1-4].

EHF has many advantages such as reducing experimental costs and bouncing phenomenon. In EHF process, additional forming tool, such as a punch, is not necessary and only one rigid tool to deform the blank is required, so the experimental cost can be reduced. In addition, according to [5], bouncing does not occur in EHF due to the existence of the liquid that plays the role of a medium retaining the forming pressure on one side of the blank.

The object of this paper is to conduct a feasibility study of EHF process by designing and manufacturing experimental apparatus to confirm the electrohydraulic effect. A numerical simulation was carried out in advance using ALE method in LS-DYNA commercial code to observe deformation behavior of the blank and to validate the design of the apparatus. From the results of the numerical simulation, it is confirmed that the apparatus used in the simulation was designed well to deform the blank into the die. Therefore, an EHF apparatus of 32 kJ was developed and experiment was conducted based upon the magnitude of the input voltages. Additionally, the results of the simulation and experiment were compared, so the reliability of the simulation was verified.

Nomenclature

P	pressure of the plasma
ρ_0	initial density
ρ	current density
γ	adiabatic coefficient for plasma
E	energy deposition rate

2. Numerical simulation

2.1. Numerical model

In order to examine the procedure of deformation in EHF process and confirm the applicability of designed equipment, numerical study was conducted using LS-DYNA program. As shown in Fig. 1, numerical models are composed of fluid parts (plasma, water and vacuum) and structural parts (chamber, die and blank). When modelling the fluid parts, Arbitrary Lagrange-Eulerian (ALE) scheme was used. ALE mesh has no mesh distortion and it also enables user to define the interaction between fluid parts simply by merging the nodes.

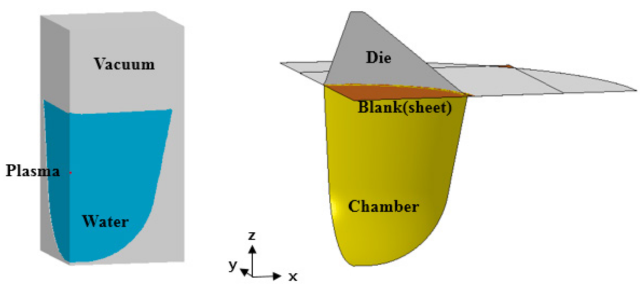

Fig. 1 Numerical models of electrohydraulic forming.