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The Study of Effective Process Parameters in the Warm Sheet Hydroforming

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ABSTRACT: Nowadays, in different industries, especially in the automotive industry, the use of lightweight materials such as aluminum alloys has been increased in order to reduce the weight of parts and fuel consumption. These alloys have low formability at room temperature. To overcome this problem, forming at elevated temperatures is proposed. In this paper, formability of 5052 aluminum alloy sheet under hydrodynamic deep drawing assisted by radial pressure process has been studied at the warm condition. Initially, after analyzing the effect of geometric parameters on thickness distribution and punch force, the effects of temperature, fluid pressure and punch speed on thickness distribution, punch force and limiting drawing ratio have been investigated. Also, the effects of forming temperature and punch speed on the minimum thickness of the workpiece have been studied using the Taguchi method. Based on the obtained results, higher temperature in warm isothermal and non-isothermal states leads to a decrease and increase in the part thickness, respectively, while higher punch speed helps in thickness improvement. It was found that the limiting drawing ratio increases with increasing temperature in non-isothermal state and with decreasing temperature in an isothermal condition. In addition, an increase in fluid pressure leads to a higher limiting drawing ratio.

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1- Introduction

In industries such as the automotive industry, the use of lightweight alloys has been increased in order to reduce the weight of the parts and consequently to reduce fuel consumption and pollution. Aluminum and magnesium alloys (as two known lightweight alloys) have low formability at room temperature. This drawback could be eliminated by forming at high temperatures. Sheet hydroforming is one of the relatively new forming method for producing complex and integrated parts [1] which could be classified into aqua draw deep drawing, hydromechanical deep drawing, Hydrodynamic Deep Drawing (HDD), hydraulic deep drawing with counter pressure, twin-bulging, sheet hydroforming with a movable die, hydro-form, Hydrodynamic Deep Drawing Assisted By Radial Pressure (HDDRP) and hydromechanical deep drawing with uniform pressure on the blank [2]. Groche et al. [3] examined the effect of temperature in both conventional and hydromechanical deep drawing processes. They found that elevating forming temperature enhances part formability in both methods. In the present paper, formability of aluminum 5052 sheet alloy in isothermal and non-isothermal warm HDDRP has been studied. This forming method has not been studied well.

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2- Methodology

2- 1- Experiments

The die set-ups used for executing the experiments in non-isothermal and isothermal states are shown in Fig. 1 (a) and (b), respectively. In a non-isothermal state the punch is cooled with water and no such cooling is implemented on the isothermal state. The sample is 2 mm thick circular 5052 aluminum alloy sheet.

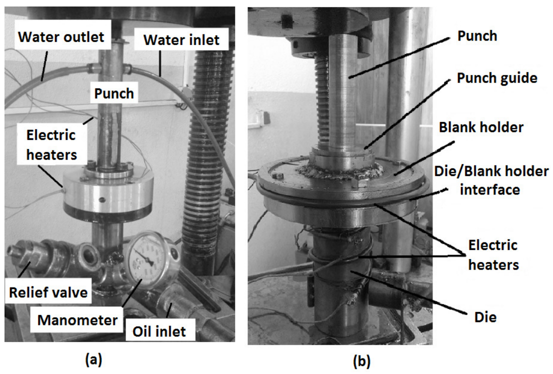

Fig. 1: Die set up for (a) non-isothermal and (b) isothermal state

2- 2- Finite element analysis

The axisymmetric model has been used to simulate the process via ABAQUS 6.10 software. The sheet and the die set-up parts were meshed using CAX4RT elements. Plastic data is taken from Ref. [4] and other simulation inputs are listed in Table 1.

Table 1: Mechanical and thermal specifications of sheet and die (at room temperature)

Specification	Value	Unit
Yield strength	89.6	MPa
Density	2680	kg/m^3
Elasticity modulus	70.3	GPa
Poisson's ratio	0.33	-
Ultimate tensile strength	250	MPa
Maximum elongation (%)	11	-
Sheet (Die) thermal conductivity	220 (70)	W/mK
Sheet (Die) specific thermal capacity	904 (450)	J/kg.K

2- 3- 2.3. Taguchi method

The effect of temperature (T) and punch speed (PS) on the minimum part thickness was investigated using the Taguchi method. The parameters levels were set according to Table 2.

Table 2: Parameters levels for Taguchi method

Parameter	Unit	Level (-2)	Level (-1)	Level (+1)	Level (+2)
T	°C	30	120	210	300
PS	mm/min	50	-	-	200

3- Results and Discussion

Before conducting the Taguchi method, optimal corner radius of the punch and the die were found and both were adjusted to 6 mm. The increase of these geometric parameters beyond 6 mm does not change the thickness and punch force significantly. The result of the Taguchi method is shown in Fig. 2.

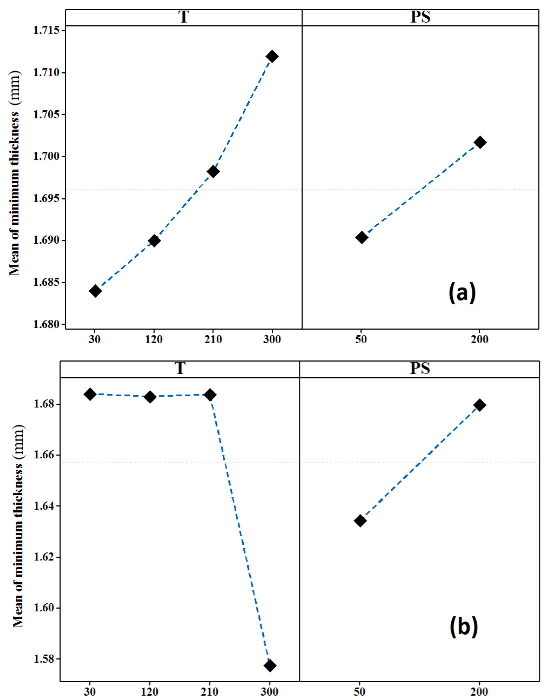

Fig. 2: Effect of temperature and punch speed on the minimum part thickness in (a) non-isothermal and (b) isothermal state

The amount of Limiting Drawing Ratio (LDR) obtained from the finite element analysis is depicted in Fig. 3. Similar to Fig. 2, it shows that elevating temperature improves sheet formability in non-isothermal condition, while it has an adverse effect in the isothermal state.

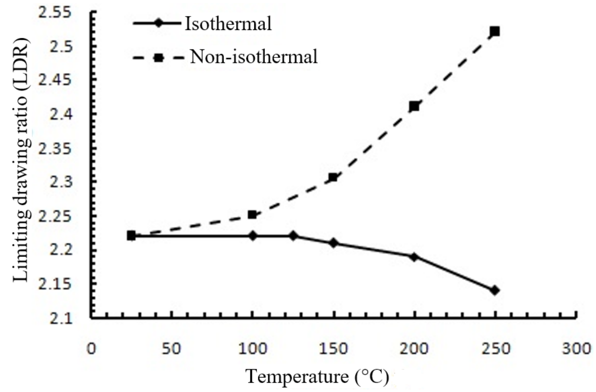

Fig. 3: Limiting the drawing ratio as a function of temperature

The experimental and numerical investigation also reveals that the more the forming temperature the lower the amount of maximum punch force (Fig. 4). The increase of the temperature from 25 to 250 °C reduces the maximum punch force for about 21%.

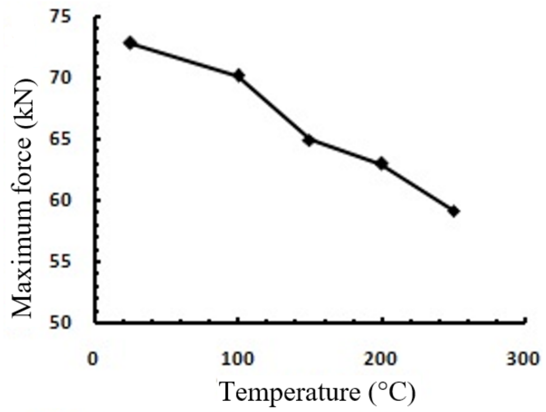

Fig. 4: Maximum punch force at different temperatures in the isothermal state

4- Conclusion

In this paper, the effect of temperature and punch speed on part thickness, punch force and LDR in non-isothermal and isothermal states of HDDRP process were studied. It was found that the increase in forming temperature improves the sheet formability in non-isothermal condition, while deteriorates thickness and LDR in an isothermal state. Adjusting the punch speed on 200 mm/min instead of 50 mm/min has a positive effect on both forming methods. Punch force remarkably decrease with increasing temperature especially in isothermal warm hydroforming.

5- References

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