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Fabrication of Bipolar Plates of the Fuel Cell from Stainless Steel 304 by Hot Metal Gas Forming Process

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ABSTRACT: The hot forming of a sheet metal with gas blowing is a novel method in metal forming processes. It has the ability to manufacture products with complex shapes due to high formability and a low flow stress at high temperature. In this research, the forming of bipolar plates with a slotted serpentine pattern by hot metal gas forming process has been investigated experimentally. To this end, 304 stainless steel sheets with 0.12 mm thickness have been used. In order to evaluate the geometric and process parameters effect on forming trend, a convex die that includes three slotted serpentine channel with different widths has been manufactured. Then experiments were carried out at different temperatures, pressures and periods of time. The sheet thinning percentage, the thickness distribution and the depth of die filling have been considered as evaluation criteria of experiments results. The results indicated that the temperature and the forming time have respectively the most and the least effect on the formability. Among three slots with widths of 1, 1.5 and 2 mm, despite slot with 2mm width has the most die filling percentage, the sheet thinning percentage is less than the slot with 1.5 mm width. The most filling percentage of die channel with the amount of %88.8 was observed in the slot with the width of 2 mm at a temperature of 1000 oC, the pressure of 40 bar and forming the time of 30 min.

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1- Introduction

Fuel cells are capable of producing electrical energy from the chemical energy which is one of the sources of clean energy with very low emissions [1]. Bipolar plates are one of the important components of a fuel cell. They account for most weight, volume, and cost of a cell. Therefore, the use of thinner and lighter plates while maintaining their strength can have a significant impact on the cost and operation of the cell [2]. The low thickness and high draw ratio are the major challenges, which has led to the extensive research in recent years in the field of forming metallic bipolar plates by different methods [3]. One of the novel metal forming processes is hot metal gas forming. In this method, applying a high temperature during the process causes an increase in forming limit, decrease in residual stress, reduction of the required pressure and improvement of formability [4]. This study aims to investigate the forming of bipolar plates with a slotted serpentine pattern by hot metal gas forming process in the convex die.

2- Research Method

The material of the sheet used in the experiment was 304 stainless steel with 0.12 mm thickness. The overview of experiments setup is shown in Fig. 1. In Fig. 2, the schematic design of die set with parameters is displayed. Chosen temperatures for experiments are 800, 900 and 1000 °C. Also, the pressures of 15, 25 and 35 bar were applied. As can be seen in Fig.3, after deformation the different regions of specimens were selected and cut for thickness distribution analysis

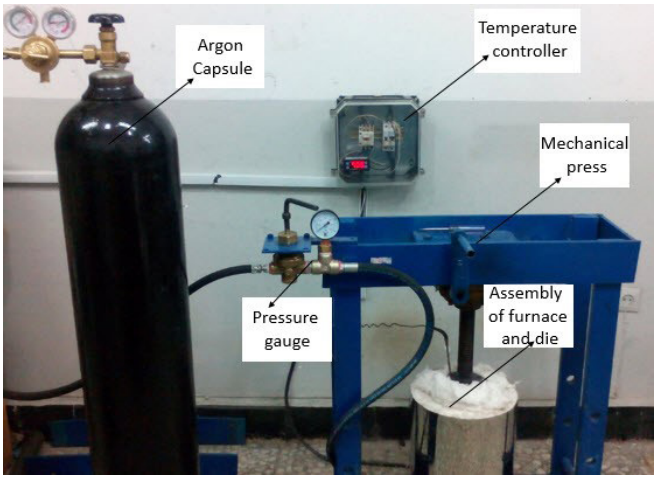

Fig. 1. Overview of experiments setup

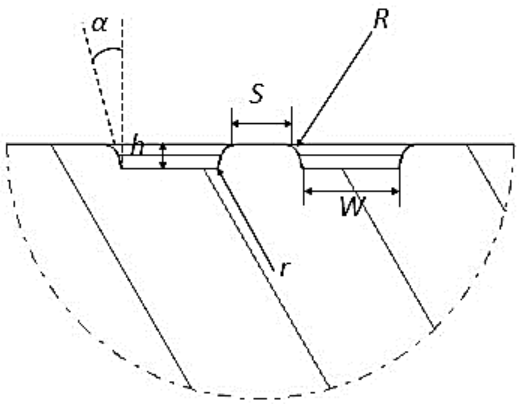

Fig. 2. Geometrical parameters of die

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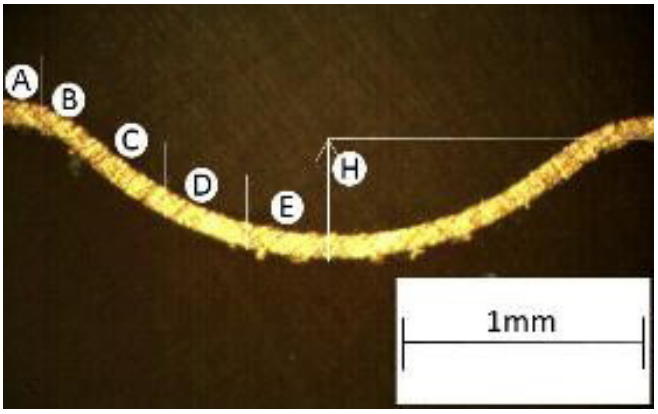

Fig. 3. Regions of the cross section

3- Results and Discussion

The thickness distribution of specimens with different slots width is shown in Fig. 4. As can be seen, as slot width increases, the sheet thickness distribution gets desired. Results indicate that the most thickness decreasing in all samples belongs to region B. The most desirable thickness distribution was determined by comparing the charts of thickness distribution with respect to the amount of slot filling in process conditions at a temperature of 1000 °C, the pressure of 35 bar and 20 min for slot width 2 mm. In Fig. 5 a sheet filling profile at different slots width in 1000 °C, 10 min, and 35 bar is shown. It was found that by increasing slot width up to 1.5 millimeters, the sheet leads to contact with the bottom of the slot and after reaching to the slot bottom, it moves to increase the filling percentage. Filling percentage of slots in 1000 °C, 35 bar, and 10 min is displayed in Fig.6. According to the curves, filling percentage in both sections increases with the increase of slot width. Increase in a section perpendicular to the slot is more than the increase in a section perpendicular to the end turn of the slot. In Fig. 7, the sheet thinning percentage of slots with different widths in 35 bar pressure, 1000 °C, and 10 min is shown. As can be seen, thinning percentage increases with the increase of the slot width. After examining the thinning percentage of all samples, it was determined that the highest percentage of thinning with the value of 18% occurred at a temperature of 1000 °C, the pressure of 40 bar, 30 min and slot with a width of 2 mm.

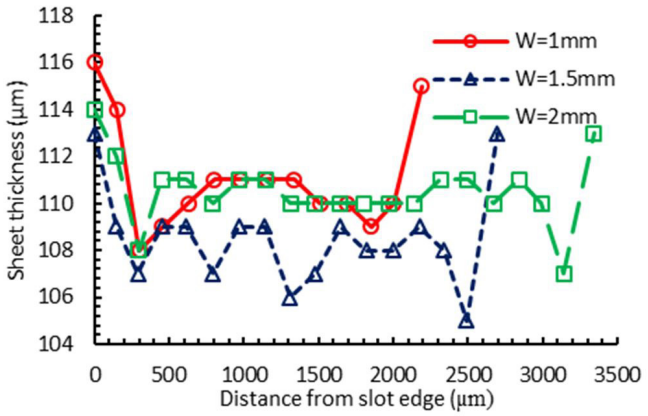

Fig. 4. Comparison of sheet thickness distribution at 1000 °C, 10 min and 35 bar

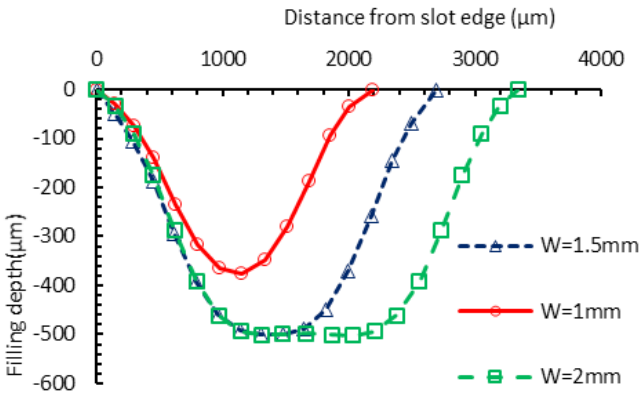

Fig. 5. Comparison of sheet filling profile at 1000 °C, 10 min and 35 bar

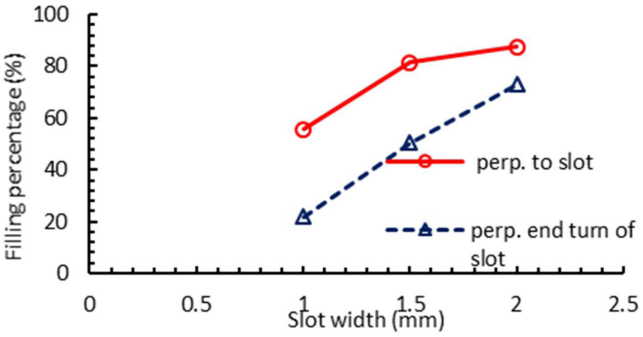

Fig. 6. Filling percentage of different widths of the slot at 1000 °C, 35 bar and 10 min

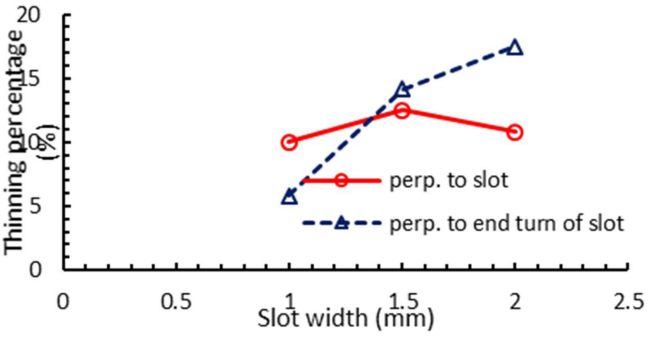

Fig. 7. Comparison of sheet thinning percentage of different widths of the slot in 35 bar, 1000 °C and 10 min

4- Conclusion

Comparing filling profile of different specimens, showed that the temperature has the greatest impact on the deformation of the sheet in the fabrication of bipolar plates. As slot width increases, sheet thinning in critical region increases. The pressure and time have the same effect on thinning; their increase leads to the increase in thinning percentage of the sheet. An increase in temperature from 900 to 1000 °C, the filling percentage increases two times and from 800 to 1000 °C, this increase is 5 times. The highest groove filling percentage (88.8 %) belongs to grooves with a width of 2 mm, the temperature of 1000 °C, the pressure of 40 bar, and time of 30 min.

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