Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(3) (2018) 165-168
DOI: 10.22060/mej.2017.13097.5537

Experimental Investigation and Numerical Simulation of the Pressure Force on the Formation of Metallic Bipolar Plate in the Stamping Process

F. Ahmadi Khatir[1], E. Alizadeh[2*], M. Barzegari[2], M. Momenifar[2], H. Masroori Saadat[2]

[1] Mechanical engineering, Tarbiat Modares Tehran, Tehran, Iran
[2] Fuel cell Technology Research laboratory, Malek Ashtar University of Technology, Fereydoonkenar, Iran

ABSTRACT: Bipolar plates are one of the most important parts of the fuel cell which have the highest production cost for the system. In this study, the formability of SS 316L bipolar plates with an active area of 100 cm2 by the stamping process is investigated. With respect to various types of the forming process, stamping process has the advantages of simplicity, higher production speed, and lower production. In this process, the sheet is considered to be between two rigid die slabs, and applying force to the die set results in forming the plates. The important issue of bipolar plates is the dimension accuracy of the channels. In this paper, the width and flatness of the channels and ribs of the produced plates are investigated. If the tolerances of the formed channels are not in the desirable range, the performance of the fuel cell is disturbed and the fuel cell efficiency is considerably decreased. The results of this study demonstrate that increasing the stamping force results in an increase of the width of channel and rib. Moreover, the flatness due to the spring-back of the sheet is in the desired tolerance range and these plates can be utilized as metallic bipolar plates in the fuel cell stacks.

Review History:

Received: 3 July 2017
Revised: 19 October 2017
Accepted: 28 November 2017
Available Online: 4 December 2017

Keywords:

PEM fuel cell
Metallic bipolar plate
Stamping process
Flatness
Forming force

1- Introduction

Fuel cells are kind of electrochemical energy converters that directly convert chemical energy into electrical energy. Fuel cells can be used in various applications. A fuel cell system consists of several components, of which the bipolar plates are very important in terms of volume and weight (about 60 to 80 percent), as well as cost (about 30 to 45 percent) [1]. Fast penetration of reactive gases and high electrical conductivity are two important parameters to achieve the proper performance of the fuel cell. Increasing the cross-sectional area of the bipolar plates will increase the penetration rate of the reactive gases as well as the better discharge of the reaction products [2]. In addition, the increasing surface of the ribs results in an improvement of electrical conductivity. Therefore, rib width and its flatness are also effective on the fuel cell performance [3]. For this reason, the width of the rib and the channel should be optimized in the design step.

The main objective of this paper is to perform an experimental study and simulation of the effect of forming forces on the dimensional accuracy of the channels of the produced plates from the modified stamp formation process that has not been studied in any research yet. Contrary to the study of other researchers who have examined several channels from a bipolar plate, this study examines the formulation of a bipolar plate taken from an industrial sample. Investigation of multi-channel formation alone is not sufficient and the necessity of studying the plasticity of the bipolar plate is necessary. In this study, the modified stamp process is used to form metal bipolar plates with an active surface area of 100 cm2. Parameters such as channel and rib widths as well as flatness of the channel and the ribs using simulation and laboratory results have been investigated.

Corresponding author, E-mail: fccenter@mut.ac.ir

2- Experimental Stages

In this study, the cascade flow field pattern is used. The main advantage of this research is the formation of a metal bipolar sheet that examines the interactions of channels in the vicinity of each other as a very important issue. This is rarely investigated in previous research. Fig. 1 shows an initial plan of flow field pattern and a sectional view of it along with the parameters of the channel width (W), the width of the rib (S), the depth of filling (channel height), the internal filtration radius (R), the external filament radius (r) and the wall angle (α). Table 1 shows the dimensions of the bipolar plate. In this paper, the flatness of the channel and the rib, as well as the effect of forming force on the width of the channel and the rib, is investigated.

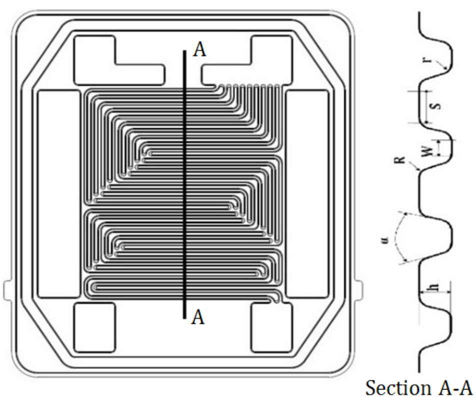


Fig. 1. Groove design and its dimensions and sizes

Table 1. Dimensional geometry of die-set and sheet

Geometry parameters	Dimension, mm
Channel height, *h*	0.85
Channel angle, *α*	20°
Fillet radius, *R*	0.2
Fillet radius, *r*	0.2
Channel width, *W*	1
Rib width, *S*	1.3
Sheet thickness, *t*	0.1

3- Simulation

In this study, the ABAQUS 6.14.1 finite element software is used to simulate the stamping process. Since the flow field of the metal bipolar plate is not symmetric, the finite element is used to simulate the full 3D model. Fig. 2 shows the meshed model of the set.

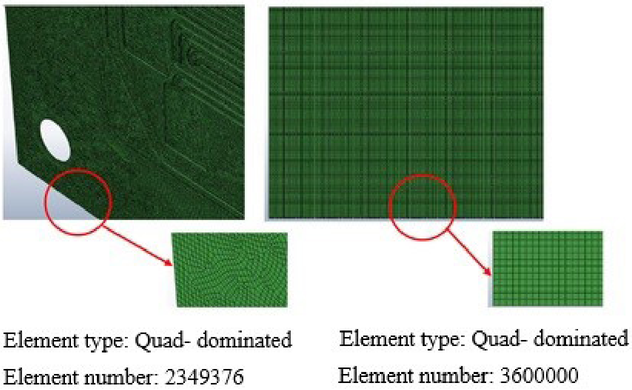


Fig. 2. Sheet, die & punch element sizes

4- Results and Discussion

4- 1- Validation of finite element model

In order to validate the finite element model of forming metal bipolar plates, the shaped plates of the critical region are cut through the wire cutting machine, and after the mantle and polishing surface, the dimensions of the channels are observed with an optical microscope.

In accordance with Eq.(1), the thinning percentage for the critical region (central channel) of the plate formed with the highest filling rate is 22% in the experiment and 19% in the simulation. As shown, there is a good agreement between experimental results and simulation and the maximum error is 3%.

$$Thinning\ percentage = ((t0 - tf)/t0) \times 100 \qquad (1)$$

4- 2- The flatness of channel and rib

Based on the simulation results, experiments are carried out at a maximum force of 160 tons. Fig. 3 shows the lack of flatness for the channel and the rib. As it is clear from the figure, the mean flatness for the ribs is about 10 microns and for the channel is about 12 microns.

4- 3- Strain distribution on metallic bipolar plates

As shown in Fig. 4(a), a force of 100 tons is able to bring the sheet to the bottom of the mold, and in effect to form the action. The advantage of increasing force in the stamping method is that when the sheet is placed between the two molds under the force, the sheet is flowing and actually increases the channel and the rib width. In other words, as shown by the comparison of (a) and (b), by increasing force, the strain rate is increased and the thickness of the sheet decreases.

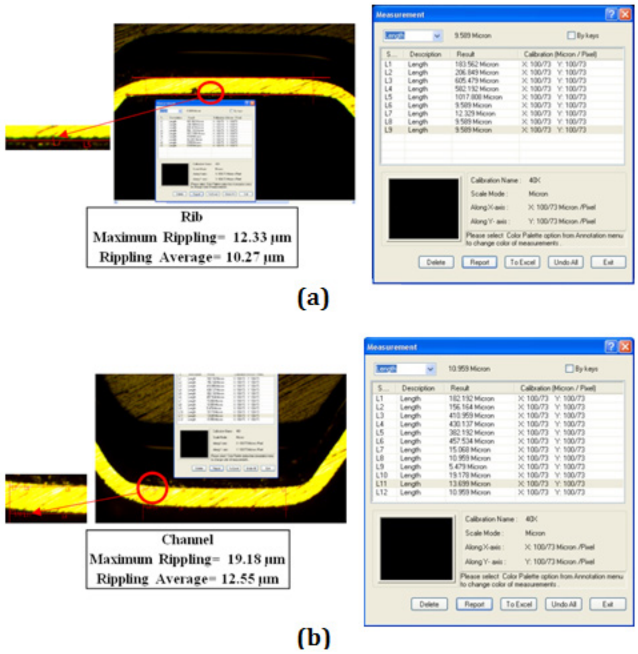


Fig. 3. Measurement of flatness. (a) rib (b) channel

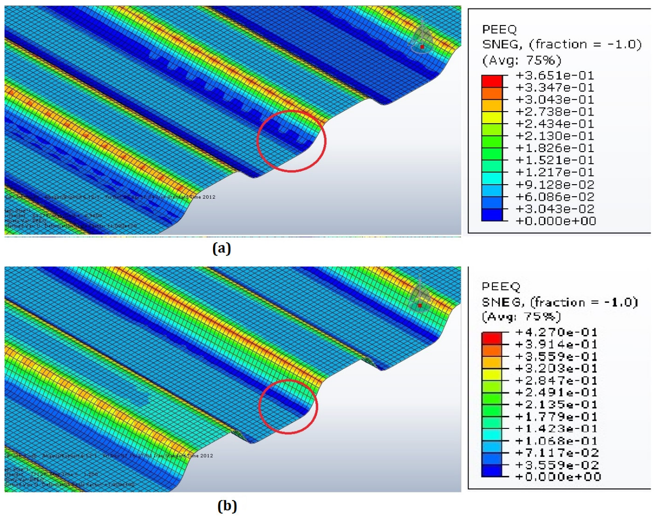
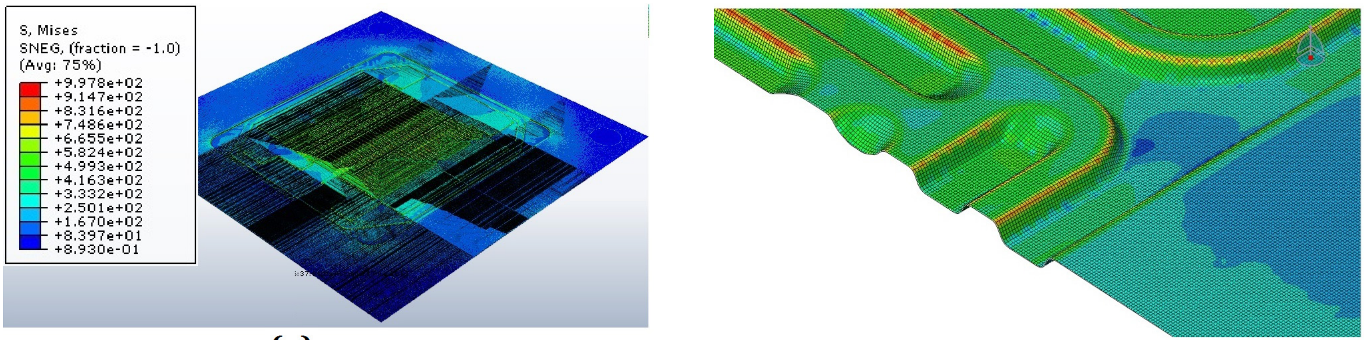


Fig. 4. Strain distribution on shaped metal bipolar plates (a) 100 ton (b) 160 ton

4- 4- Distribution of stress on metallic bipolar plates

One of the advantages of the process of stamping in the production of metallic bipolar plates is the application of uniform force per unit area, which distributes uniform stress over the entire surface of these plates. Fig.5 shows the stress distribution values at the maximum force forming. The applied tensions in the modified stamp process to the surface of these plates are such that when the two molded slabs reach each other and the sheet between the two sheaths do not rupture the sheet. Or, in other words, the maximum stresses applied are less than the sheet failure stress.



(a)

(b)

Fig. 5. Stress distribution values at the maximum force forming (a) 160 ton. (b) view of other section

5- Conclusion

The results of this study showed that increasing shaping force in the modified stamping process, unlike the flexible forming processes, causes the filling of the corners of the mold and thus increases the width of the channel and the rib. Also, the lack of flatness rate resulting from the spring back of the sheet is also in this process in the desired tolerance interval and these sheets can be used as metal bipolar plates in the fuel cell.

References

[1] V. Mehta, J.S. Cooper, Review and analysis of PEM fuel cell design and manufacturing, *Journal of Power Sources*, 114(1) (2003) 32-53.

[2] Y.-G. Yoon, W.-Y. Lee, G.-G. Park, T.-H. Yang, C.-S. Kim, Effects of channel configurations of flow field plates on the performance of a PEMFC, *Electrochimica Acta*, 50(2) (2004) 709-712.

[3] P. Zhou, C. Wu, G. Ma, Contact resistance prediction and structure optimization of bipolar plates, *Journal of Power Sources*, 159(2) (2006) 1115-1122.

Please cite this article using:

F. Ahmadi Khatir, E. Alizadeh, M. Barzegari, M. Momenifar, H. Masroori Saadat, Experimental Investigation and Numerical Simulation of the Pressure Force on the Formation of Metallic Bipolar Plate in the Stamping Process, *Amirkabir J. Mech. Eng.*, 50(3) (2018) 505-516.

DOI: 10.22060/mej.2017.13097.5537