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Influence of process parameters on the quality of flexible forming of 316L bipolar plate

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Abstract. Bipolar plate is one of the most important components of proton exchange membrane fuel cells. In this paper, taking the micro channel flexible forming process of 316L stainless steel sheet as the research object, the influence of process parameters on the forming quality of micro flow channel is analysed, so as to provide guidance for the flexible forming of bipolar plate. The effect of equipment pressure and hardness of soft film on micro flow channel forming has been studied. In particular, the effect of different grain sizes on the forming quality was studied. The results show that the increase of equipment pressure and the decrease of soft film hardness are conducive to the improvement of the forming depth of bipolar plate. Under the same conditions, the increase of grain size reduces the difficulty of forming, and the larger the grain size, the larger the forming height and channel filling rate. However, with the increase of grain size, the surface roughness of the bipolar plate increases and the wall thickness of some parts of the runner is uneven.

Keywords: Bipolar plate; Flexible forming; Grain size; Surface roughness.

1 Introduction

The design and manufacture of bipolar plates is an important part of the process of producing proton exchange membrane cells. Metal bipolar plates have attracted much attention because of their excellent electrical conductivity, high mechanical strength, good processability and low cost [1]. Flexible film forming is a new type of forming method. It differs from the traditional press forming method in that a rigid punch is replaced by an elastic material [2]. This forming method greatly reduces the manufacturing cost of the mould and also avoids the coupling problem between rigid dies [3]. Many scholars at home and abroad have studied the soft film forming process of metal bipolar plates [4]. This paper analyses the influence of flexible forming process parameters on micro-channel forming quality, especially the influence of different grain sizes on forming quality, and provides process reference for ultra-thin metal bipolar plate soft film forming.

2 Research Objectives and Methods

The size parameters of the bipolar plate microchannel studied in this paper are shown in Fig. 1. Cold rolled annealed state 316L stainless steel with thicknesses of 0.075 mm was used. Different grain sizes are obtained by different heat treatment processes, and the metallographic structure and tensile curves are shown in Figure 2. The stretching is carried out in the RD direction, with little anisotropy due to full annealing. The experiments in this paper were done on a 3000t hydraulic press.

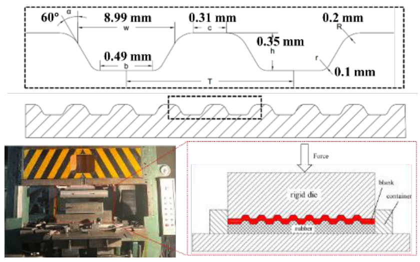

Fig. 1. Geometry of bipolar plate channel and experimental setup.

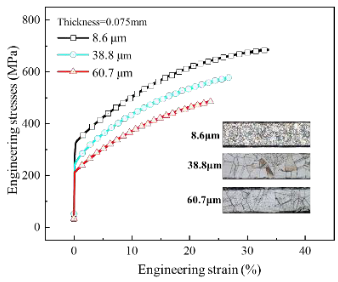

Fig. 2. Metallographic pictures and engineering stress-strain curve of 316L stainless steel.

3 Results and discussion

3.1 Influence of equipment pressure and soft film hardness on forming quality

The forming experiments with equipment pressure of 10, 15, 20, 25, 30, 35, 40 and 45 MPa were carried out.The hardness of the soft film was selected as 80 shore A. The cross section and the hight of the runner are shown in

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the Fig. 3. The runner depth increases with the increase of pressure, but the overall depth increase trend decreases, and in the second stage (35-45MPa) the depth has reached the maximum forming height, and the depth no longer increases with the increase of pressure. However, it can be seen from the runner profile and physical drawings of the second stage of the deformation mainly occurs in the bottom of the runner and the bottom rounded corners, so the runner filling rate appears to increase the trend, but the trend of increase relative to the first stage is much smaller.

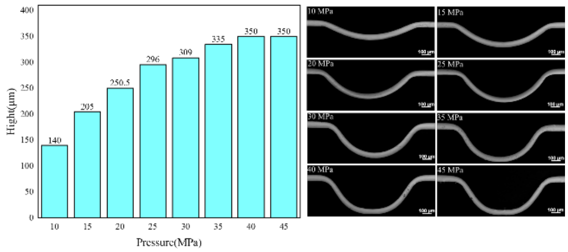

Fig. 3. Hight of runner with different pressures.

The forming experiments with three different hardnesses of rubber pads (75 shore A, 80 shore A and 90 shore A) were carried out.The equipment pressure was selected as 25 MPa. The cross section and the hight of the formed runner are shown in the Fig. 4. The soft film hardness has a slight effect on the forming quality, and the forming depth of the runner decreases as the soft film hardness increases. The reason for this phenomenon may be that, under the same pressure, the lower the hardness of the soft film, the greater the degree of elastic deformation of the soft film, the more conducive to the transfer of punch force to the sheet, so that the driving force of the sheet forming increased, more conducive to forming.

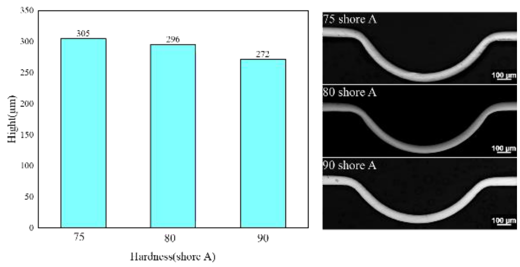

Fig. 4. Hight of runner with different soft film hardness.

3.2 Influence of grain size on forming quality

Forming experiments with three different grain sizes were carried out. It can be seen from Fig. 5, under the pressure of 45 MPa, the film height after forming of these three grain sizes reached 350 μm. The flow channel filling rates of the plates with grain sizes of 8.6 μm, 38.8 μm and 60.7 μm were 88.56%, 91.37% and 93.58%, respectively. It can be seen that after regulating the grain size of the plate material to make it grow, it is conducive to reducing the forming difficulty and improving the runner filling rate after forming. However, the thickness distribution fluctuates greatly when the grain size is large, the minimum wall thickness of the runners do not necessarily appear in the upper corner, there is a 'paradoxical thinning' phenomenon. From the surface roughness of the runners after forming with different grain sizes, it can be seen that the average surface roughness of the runners with grain sizes of 8.6 μm, 38.8 μm, and 60.7 μm is 0.541 μm, 1.008 μm, and 1.327 μm, respectively.

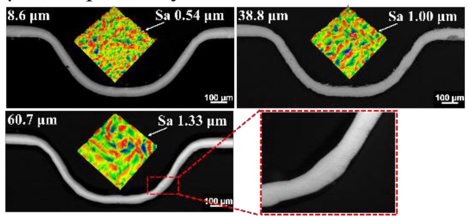

Fig. 5. Typical runner profile after forming with grain sizes

Fig. 6 shows the inverse pole figure (IPF) and Kernel average misorientation (KAM) of the organisation after forming at 45 MPa with grain sizes of 8.6 μm and 60.7 μm, reflecting the distribution of deformation. The EBSD results show that the straight wall of this runner has an 'anomalous thinning' phenomenon, where there is only one layer of grains in the thickness direction, and the grains are elongated after forming. From the KAM diagram, it can be seen that the KAM value of the anomalous thinning position is high, showing yellow-red colour, where a large dislocation density is gathered and a large degree of plastic deformation occurs.

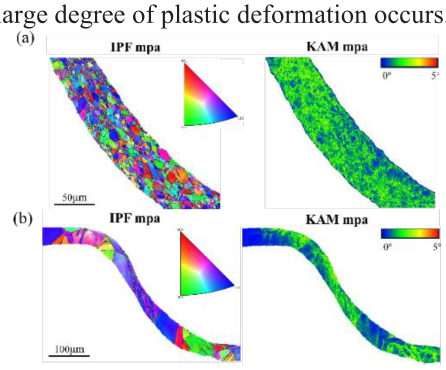

Fig. 6. EBSD for deformed runner: (a) 8.6 μm;(b) 60.7 μm

4 Conclusions

The increase of the equipment pressure and the decrease of the soft film hardness are all conducive to the improvement of the forming depth of the bipolar plate. Under the same conditions, the increase of grain size reduces the forming difficulty, the larger the grain size, the larger the forming height and channel filling rate. However, as the grain size increases, the surface roughness of the bipolar plate increases, and the wall thickness of the runner section is not uniform.

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