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A Developed Geometry for Endplate for Uniform Contact Pressure Distribution on the Polymer Exchange Membrane Fuel Cells Active Area

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ABSTRACT: The contact resistance between polymer exchange membrane fuel cell components has a crucial effect on cell performance. The geometry of the endplate, on the other hand, plays an essential role in the contact pressure distribution on the membrane electrode assembly and the amount of contact resistance between plates. In this paper, the effect of endplate geometry on the contact pressure distribution over the membrane electrode assembly is simulated using ABAQUS software. In the next part, a new geometry for the endplate is provided and compared to flat endplates. Geometrical parameters of an endplate with curvature (bomb-shaped endplate) are considered, and the effects of these parameters on the contact pressure distribution over the membrane electrode assembly are investigated. In this simulation, a 3D model of the fuel cell is developed. Our simulation results show good performances for the designed endplate and uniform contact pressure distribution on the fuel cell active area. Finally, a single fuel cell was manufactured and assembled using the simulation parameters, and experimental tests are conducted using pressure films to verify the design.

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1- Introduction

Nowadays using renewable energies as a suitable replacement of fossil fuels is one of the main challenging areas for researchers among new energy sources, fuel cells are more attractive compared to other sources. Many research works are devoted to investigating the effects of design and assembly parameters on the contact pressure distribution in recent years. Wang et al. [1] performed an experimental study on clamping pressure distribution in Polymer Exchange Membrane Fuel Cell (PEMFCs) using hydraulic assembly. Alizadeh et al. [2] examined the effects of thickness and material of the endplate, hardness of gasket and number of cells on the pressure distribution. Liu et al. [3] optimized the geometry of the endplate in a way that reduced the weight of the fuel cell and also increased the uniformity of contact pressure distribution. Habibnia et al. [4] discussed the design and assembly parameters in PEMFCs and effects of these parameters on the contact pressure distribution over Gas Diffusion Layer (GDL). Alizadeh et al. [5] proposed a novel clamping mechanism and its influence on contact pressure distribution over Membrane Electrode Assembly (MEA). In this paper, a new geometry is presented for the endplate of the PEMFCs and compared against flat endplates. In the next step, the geometrical parameters of the presented endplate are analyzed to reach uniform contact pressure. To study the effects of various parameters of endplate on the contact pressure distribution over the active area of the fuel cell, 3D finite element simulations are conducted on ABAQUS software. Finally, to validate the results, the fuel cell with the optimum parameters of the endplate geometry is assembled, and experimental tests are conducted to analyze the contact pressure distribution using pressure films.

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2- Methodology

ABAQUS commercial code is used to investigate the contact pressure over the MEA and the electrodes. The geometry of the model is shown in Fig. 1.

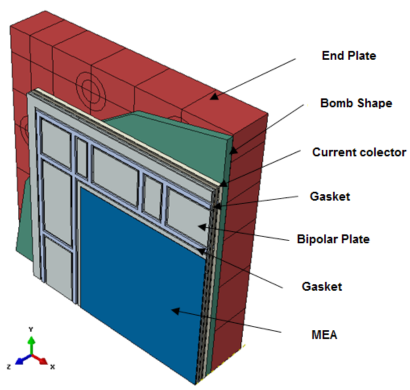


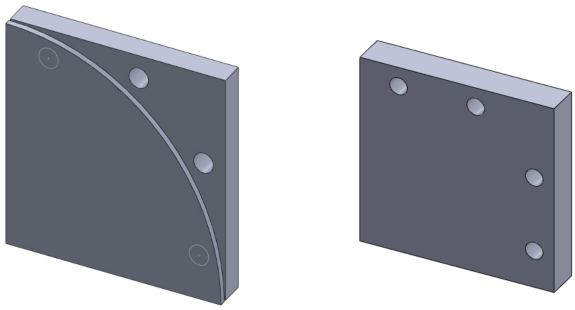
Fig. 1. The employed single fuel cell stack model

Due to the symmetry of the fuel cell and for computational cost purposes, the cell is divided into eight parts, and only one part is modeled. The modeled cell contains endplate, current collector, gasket, bipolar plate, GDL, and the membrane. To exert the clamping pressure bolts are used. In the simulation, for simplicity purposes, compressive stresses are exerted instead of bolts. Fig. 2 shows the positions of exerted stresses on the endplate. The exerted stress is equal to 15 MPa.

3- Results and Discussion

3- 1- Effects of endplate geometry:

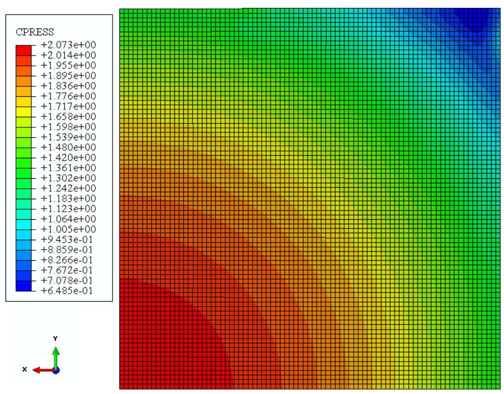
Two different endplates with conventional (flat) and curved geometries are shown in Fig. 2.



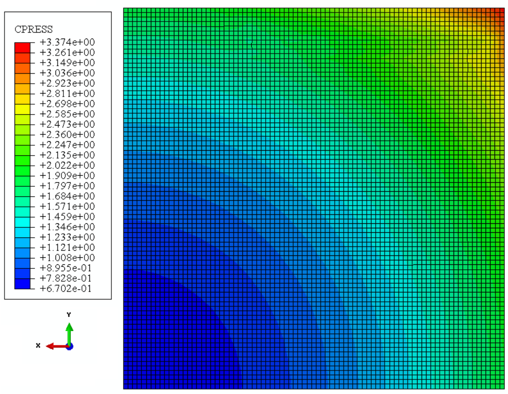
(a) (b)

Fig. 2. Geometries of the endplate; a) conventional, b) curved.

For comparison purposes, design and assembly parameters are considered identical in both models. The thicknesses of the endplate in both models are equal to 30 mm, and the material is Steel in the first step. Contact pressure distributions over MEA for both models are shown in Fig. 3.



(a)



(b)

Fig. 3. Effect of depth of channel on pressure distribution of GDL

As it is shown in Fig. 3, the contact pressure distribution differs from conventional to curved geometries. In the conventional, the compressive stress increases from the center toward the corner. On the other hand, in curved geometry, stress increases from the corner toward the center.

3- 2- Effect of curvature on the mean value and the deviation of stress over MEA:

For a uniform contact pressure distribution in a PEMFC with a curved endplate, different curvatures are investigated. First, the curvatures of 0 to 0.25 mm with 0.05 mm steps were tried for a PEMFC with 200 × 200 mm^2 active area. The distribution of contact pressure on the *x*-axis is shown in Fig. 4.

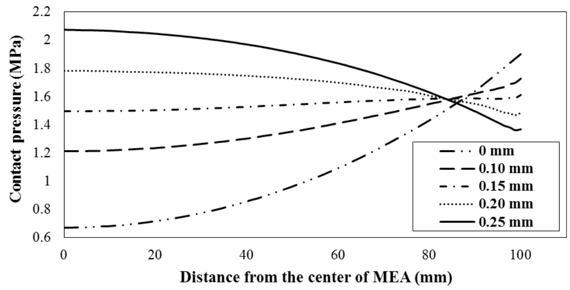


Fig. 4. Contact pressure distribution in x-direction over MEA for different curvatures (0 to 0.25 mm).

3- 3- Effect of endplate material on the contact pressure distribution

The endplate is one of the main components which increases the weight of a fuel cell. Thus, in this paper, the effects of the endplate material (Steel or Aluminum) are discussed to reduce the total weight of the fuel cells. The results of contact pressure as a function of distance from the center of MEA for both Aluminum and Steel endplate with 30mm of thickness are shown in Fig. 5. As can be concluded, in the case of same parameters, the steel endplate leads to more uniform contact pressures.

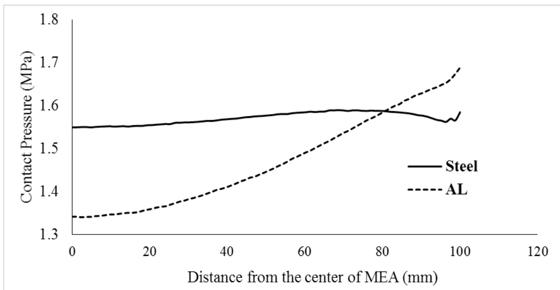


Fig. 5. The result of contact pressure on MEA for Aluminum and Steel endplate with the same thickness of 30mm.

4- Conclusion

In this research, a developed geometry for the endplate of PEMFCs is proposed and investigated. The geometrical parameters of the new endplate to reach a uniform contact pressure distribution are investigated in the next part of the research. Indeed the effects of endplate material are simulated. Comparing the weight of endplates made of Steel and Aluminum, it was concluded that the total weight of the endplate decreases by 50 % when using Aluminum endplates. The optimum geometry was obtained using finite element simulation. The simulation results showed that the optimum contact pressure distribution could be accomplished using

Aluminum endplate with 0.17 mm of curvature (bomb value) and 43 mm of thickness. This geometry results in 1.55 MPa of the mean value of stress and only a deviation of 0.017 MPa from the mean value. Finally, to validate the results of the simulation, a PEMFC was designed and assembled using the optimum geometry of the proposed endplate, and the uniformity of the contact pressure distribution was experimentally shown using pressure measurement films.

5- References

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