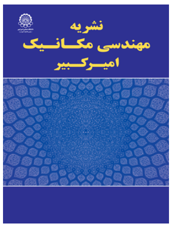

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Numerical and Empirical Investigation on Bending Behavior of Composite Bipolar Plates for Polymer Electrolyte Membrane Fuel Cells

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ABSTRACT: Polymer electrolyte membrane fuel cells, as an energy generator, convert the chemical energy of the fuel directly into electrical energy. An important component of polymer fuel cells is bipolar plates, which are responsible for the distribution of fuel and oxidants and facilitate the management of water inside the cell and the transmission of electric current. In this study, the fracture method of graphite-based composite bipolar plates of polymer fuel cells under bending loads was investigated experimentally and numerically. Simple and perforated composite bipolar plates were tested and simulated with the approach of determining flexural stability under static load. In numerical analysis, mechanical simulation using the finite element method and Abaqus software were used. Then, after making the laboratory samples, the experimental test of three-point bending was performed on them to validate the simulation results. Finally, the results of numerical and experimental analyses of the flexural behavior of composite bipolar plates were compared with each other. A comparison of the results of numerical and experimental analyses showed that the results of these two methods had an acceptable agreement with each other. In addition, the presence of a high percentage of graphite as well as high fragility weakens the body, and beams of this material increase the specimen of the sample, which occurs only due to the molecular bond of graphite, which causes the graphite to slip.

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1- Introduction

A fuel cell is an electrochemical generator that directly converts the chemical energy of fuel into energy. One of the important components of the electric energy production process in fuel cells is bipolar plates, which are responsible for collecting the output current from the anode and cathode of a fuel cell [1].

Afshari and Jazayeri [2], using numerical and two-phase simulations of polymer fuel cells, investigated different working conditions such as humidity percentage, flow rate, temperature, and pressure of inlet gases on fuel cell performance. Kakati et al. [3] conducted experiments to investigate the properties of graphite composite bipolar plates made by compression molding technology. They tried to find a way to achieve a lighter and more cost-effective bipolar plate and carried out their research based on this purpose. The results of their research showed that the cost of the polymer fuel cell is mainly dependent on the two components of the bipolar plate and the gas diffusion layer. Chen et al. [4] conducted research on the preparation of bipolar plates based on graphite/resin for polymer membrane fuel cells. Based on the results of numerical analysis, taking into account the strengthening of electrical, bending, and hydrophilic properties, three types of bipolar plates were obtained according to the properties of graphite and resin. They prepared plates with natural graphite and developed graphite as filler and epoxy resin and phenolic resin as substrate. In their research, it was found that composite plates containing epoxy resin have higher electrical conductivity.

2- Methodology

The main problem and goal of this research is to numerically and experimentally investigate the fracture behavior of composite bipolar plates of polymer fuel cells under the conditions and effects of tensile and bending loads by numerical and experimental methods. At first, numerical model design and finite element modeling were discussed, then the experimental model was tested, and finally, the results of numerical and experimental analyses were compared.

To predict the mechanical behavior and failure modes of studied sandwich structures, a 3D FEM was developed using commercial finite element software ABAQUS/Explicit, release 16.14.

In this experiment, samples with a rectangular cross-section were used as beams. The samples are placed on two supports with a specified distance. Then, with the help of a

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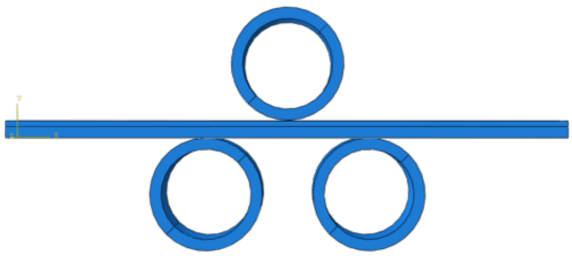

Fig. 1. Bending test simulation

Fig. 2. Bending test apparatus

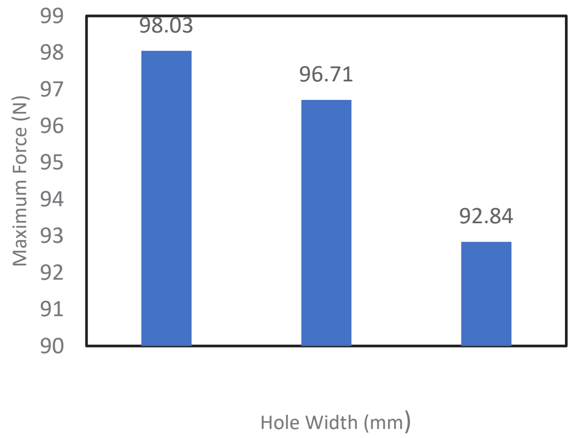

Fig.3. The diagram of the maximum force obtained from the numerical analysis of the hole with a width of 2 mm and different lengths.

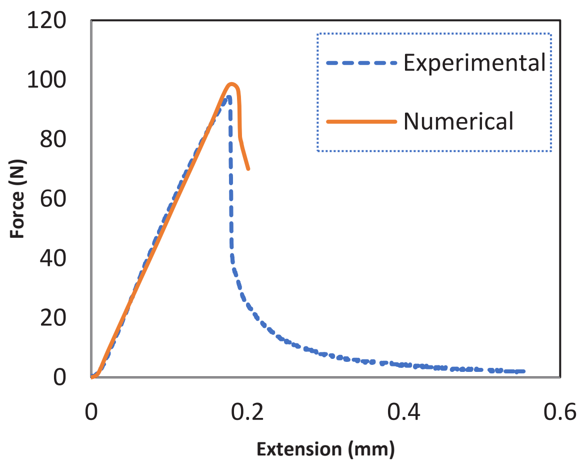

Fig. 4. Numerical and experimental comparison diagram of perforated beam

mandrel from above and in the middle of these two supports, the force was applied to the middle of the beam at a speed of 0.5 mm/min and the deflection of the beam was measured. The flexural strength and flexural modulus can be determined by simultaneously measuring the beam's elasticity and the force acting on it.

3- Results and discussion

Numerical investigations for the rectangular hole in the center of the beam have been carried out according to the test design. The results of numerical studies indicate that as the length of the hole increases, the piece becomes more weakened and the bending strength of the object decreases. Figure 3 shows the maximum force diagram for a beam with a width of 2 mm and lengths of 4, 12, and 20 mm resulting from the numerical analysis.

In this part of the research, the beam with dimensions of 100x3x10 mm was experimentally tested only by creating a hole in the middle of the beam with dimensions of 2x4 mm. The boundary conditions are the same as the previous examples and the speed of the upper jaw is 0.5 mm/min and the distance of the supports is 29 mm according to the D790 standard. Figure 4 shows the comparison of two numerical and experimental graphs of the perforated beam.

4- Conclusion

In this research, the analysis of composite bipolar plates was investigated and for the best possible bending analysis of these plates, they were investigated in the form of composite beams. In the case of holes, it was investigated with the approach of bending stability and determination of fracture strength. The presence of a high percentage of graphite as well as high brittleness causes the body to weaken, and therefore in the numerical and experimental analyses of beams of this type, it leads to an increase in the elasticity of the sample, which occurs only because of the molecular bonding of graphite, which causes graphite to slide.

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