Validation of a CFX Code for Helical-Type MHD Power Generator

Jong-Pil Park [a*], Doo Hee Chang [b]
[a]*KiJang Research Reactor Design & Construction Agency, Korea Atomic Energy Research Institute, Daejeon, Korea*
[b]*Nuclear Physics Application Research Division, Korea Atomic Energy Research Institute, Daejeon, Korea*
[*]*Corresponding author: pjp3381@kaeri.re.kr*

1. Introduction

MHD power generator is a magnetohydrodynamic converter that transforms thermal energy and kinetic energy directly into electricity. The MHD power generators can be used to increase the total efficiencies of fossil and nuclear power plants [1, 2].

The present work aimed to validate the utilization of a commercial CFD code, CFX, for analyzing MHD flow. The validation in this study involves comparing the results obtained from present CFD analysis with the experimental, theoretical, and numerical data from previous studies [3-5].

2. Numerical Method

2.1 Numerical model

The helical-type MHD power generator suggested by Takeda [3-5] is shown in Fig. 1. Takeda's helical-type MHD power generator consists of a cylindrical cathode pipe, an anode rod, and a helical partition board with a pitch number 2.5. As shown in Fig. 1, when fluid rotates around an anode in the presence of magnetic field, B_{ex}, parallel to the coaxial direction, electromotive force is generated according to Fleming's right-hand rule.

The computational domain used in the present work was modeled to be nearly identical to Takeda's helical-type MHD power generator (Fig. 1). The computational meshes were generated about 1,700,000 in the numerical model.

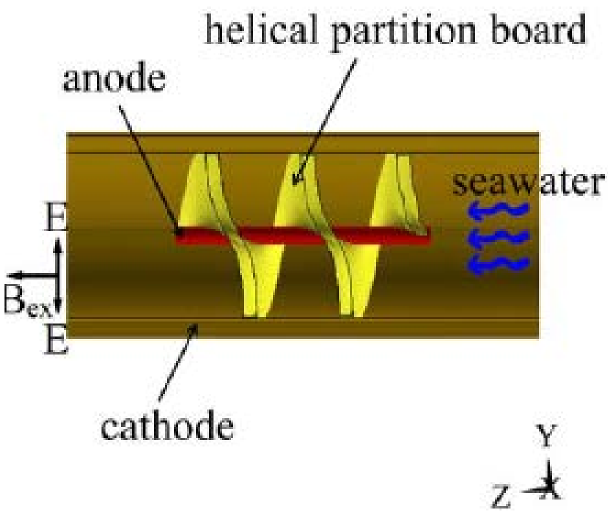

Fig. 1. Schematic of the helical-type MHD power generator [3-5]

2.2 Numerical Method

Two-types of steady-state simulation including fluid analysis without considering an external magnetic field and fluid-electromagnetic analysis were performed using a CFX 19.2.

For fluid analysis, the flow field of water flowing through the helical-type MHD power generator was solved using RANS equation for incompressible flow. The k-w SST model was selected to solve the turbulent flow. For fluid-electromagnetic analysis, the fluid flow field and the electromagnetic field in the helical-type MHD power generator were simultaneously solved using RANS equation together with Maxwell equation, Ohm's law.

The inlet boundary condition was set specific pressure obtained by experimental data at the entrance of the computational domain and the outlet boundary condition was modeled as a relative pressure of 0 Pa at the end of computational domain. Dirichlet boundary condition was specified on the electrodes (electric potential = 0 [V] on the anode wall, electric potential = V_{MHD} on the cathode wall) and Neumann boundary condition was specified on the helical insulation wall.

3. Results

3.1 Fluid Analysis

Fig. 2 and 3 show the velocity vector and pressure distribution along flow direction (from right to left) in the helical-type MHD power generator, respectively. The calculated velocity vector and pressure distribution are nearly identical to Takeda's simulation data using ANASYS multiphysic. The calculated pressure drops in the helical-type MHD power generator are compared with the experimental and numerical data in Fig. 4. The calculated pressure drops show a good agreement with the experimental and numerical data with error of + 7% and + 6%, respectively.

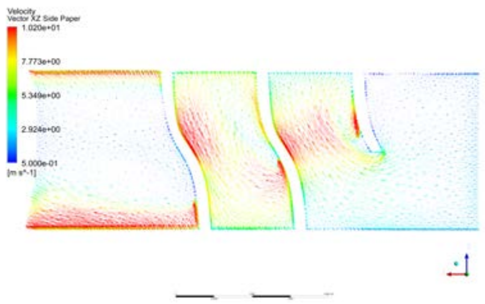

Fig. 2. Velocity vector

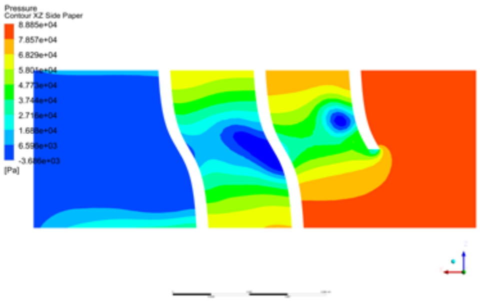

Fig. 3. Pressure distribution

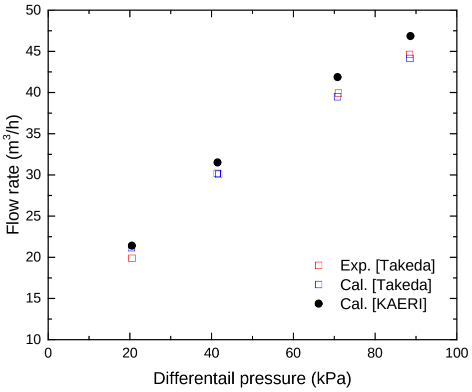

Fig. 4. Pressure drop curve with flow rate

3.2 Fluid-Electromagnetic Analysis

The important variables, such as the electric potential and current density, of MHD flow were directly obtained from the fluid-electromagnetic analysis. The performance parameters, such as electromotive force and output power of the MHD power generator can be calculated from these important variables. Fig. 5 shows the calculated electromotive force, which is defined as the electric potential difference between the anode and cathode, with flow rates in the various external magnetic fields based on present CFD results. The calculated electromotive forces show a good agreement with the experimental, theoretical (dot-line), and numerical data.

4. Conclusions

Based on the CFD results and comparison with previous data, it can be concluded that the CFX code is applicable for MHD flow analysis, and the validated numerical model can be used to further investigate and optimize the design of MHD power generators.

Acknowledgement

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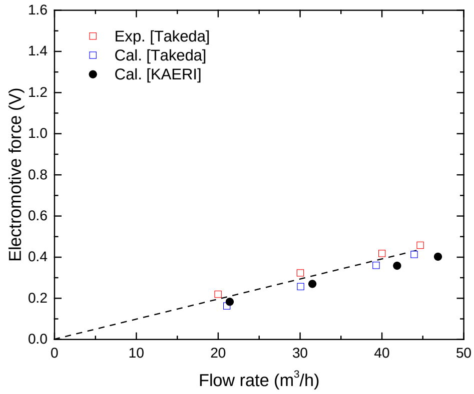
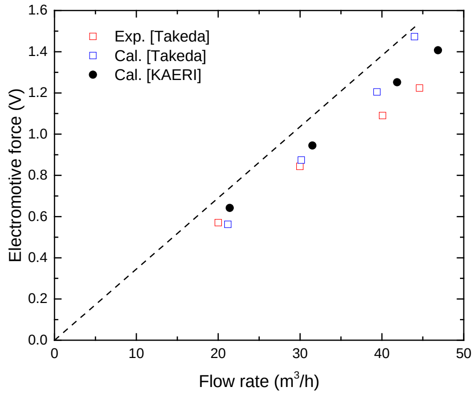


(a) External magnetic field, [2T]



(b) External magnetic field, [7T]

Fig. 5. Relationship between electromotive force and flow rate

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