Flow properties of EHD fluid in a simple flow channel

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Abstract The flow of the EHD(Electro-hydro-dynamics) fluid is induced under the application of the electric field and the flow properties of the EHD flow such as pressure, flow velocity and flow rate can be controlled by the electric fields. The devices such as pump using those characteristics of the EHD flow are developed in the various fields. However, the influence of the configuration and arrangement of the electrodes on the flow properties is not clear now and the influence should be known to design and develop the efficient device using EHD fluid. In the present study the CFD (Computational Fluid Dynamics) analysis is conducted to investigate the behavior of EHD flow near the electrodes. The influence of the number and layout of the electrodes on the flow mechanism and flow velocity distributions in a two-dimensional flow is investigated. As a result, it is found that the present CFD method is very useful to predict the velocity distribution of the EHD fluid near the electrode and the influence of the electrode layout on the flow properties is understood.

Keywords: Fluid Engineering, EHD fluid, CFD, Numerical Flow Visualization

1 Introduction

The researches about the development of the devices such as pump using the EHD fluid are conducted because those devices have a simple structure, no moving part and low noise [1]. The small pump based on cylindrical electrodes were developed [2] and we produced the pumps in which the electrode contains multiple holes to increase the load pressure [3]. However, the influence of the configuration and arrangement of the electrodes on the pump property such as a flow velocity is not clear and the influence should be known to design and develop the efficient pump using EHD fluid. In the present study the two-dimensional CFD analysis is conducted to investigate the behavior of EHD flow near the electrodes. The influence of the number and layout of the electrodes on the flow mechanism and flow velocity distributions is investigated.

2 CFD method

The two-dimensional numerical simulation of EHD fluid flow in the simple flow channel is conducted when steady electric fields are generated through a direct current by two plate electrodes at the bottom of the flow channel. The governing equations used in the present calculation are (1) Continuous equation, (2) Navier-Stokes equation, (3) Gauss’ law and (4) Charge conservation law. Velocity vector, pressure, charge density and electric potential are unknown variables to solve the equations. The influence of the electric field on the flow is considered by the body force term in Navier-Stokes equation. We regard the coulomb force as the principal body force that generates the flow in the electric fields. HSMAC (Highly Simplified Marker and Cell method) is used to derive the velocity and Poisson equation is used to derive the pressure.

3 Calculated results and discussion

The calculated results are shown in the case of 1.5kV at t=5.23×10⁻⁵s below. The distribution of the electric potential is shown in Fig.1(a). The electrode GB’ is applied high voltage and the electrode A’F is ground. The free boundary condition is given at the boundaries B’C’, C’D’ and D’A’. Therefore the physical values such as velocity on the free boundaries are calculated from the internal values of the region A’B’C’D’A’. The no slip condition is applied at the boundary A’B’ including the electrodes because the boundary A’B’ is wall. The distribution of the electric potential is almost symmetry. The velocity distribution is shown in Fig.1(b). The magnitude of the velocity near the points F, G is large. The sketched stream lines to show the flow direction clearly are also shown in Fig.1(b). The vortex flows are indicated by the dotted lines and one directional flow from the boundary B’C’ to the boundary A’D’ is indicated by the straight line. It is recognized that the one directional flow is generated.
The velocity distribution under condition of the three electrodes is shown in Fig.2 at $t=5.33\times10^{-5}$ s. The distribution is almost symmetric for the symmetric axis of the region A’B’C’D’. The one directional flow seen in the case of the two electrodes can not been seen for the three electrodes.

4 Conclusions

(1) The two-dimensional numerical solver to simulate two dimensional EHD flow is completed for the kV order electric potential.
(2) One-way flow of EHD fluid is simulated under application of the direct voltage by two plate electrodes at the bottom of the simple flow channel using the present numerical method.
(3) It is found that the one-way flow generated for two electrodes is not generated for the three electrodes.

References

