Influence of Fluid Concentration and Channel Height on Heat Transfer Phenomena of Magnetic Fluid in Mini-channel

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Abstract

Influence of channel height, magnetic fluid concentration, Reynolds number and magnetic field intensity on heat transfer of magnetic fluid flow in a mini-channel was investigated experimentally. Two mini-channels which has 1 mm and 5 mm of channel height and 1.6 vol% and 3.2 vol% of magnetic fluid are prepared in this study. Reynolds numbers are set to 100, 200 and 300, and magnetic field intensity is varied 100, 300 and 500 mT. The results show that heat transfer is enhanced for 5 mm of channel height by applying strong magnetic field, while heat transfer is slightly suppressed for 1 mm of channel height.

1 Introduction

A magnetic fluid, which is a dispersion of surfactant-coated magnetic nanoparticles in base liquid, has a function of changing thermal-hydraulic properties such as viscosity, heat conduction and so on by applying a magnetic field. As a new application, magnetic fluid is expected to be used as a working fluid for cooling device in mini-scale electronic devices, semiconductors etc. Several studies on heat transfer of magnetic fluid flow under the influence of magnetic field have been performed, and many of them reported the heat transfer enhancement by applying magnetic field. However, in case of mini-scale flow such as mini-channel, there is a possibility that the heat transfer characteristics is different from the larger scale flow. In previous studies, Ghasemian et al.[1] reported heat transfer enhancement by applying magnetic field in 1 mm high of mini-channel, but some studies [2] including our previous study[3] have confirmed heat transfer suppression. Therefore, it is necessary to discuss heat transfer characteristics of magnetic fluid flow in mini-scale flow further more. In this study, we investigated the influence of channel height, magnetic fluid concentration, Reynolds number and magnetic field intensity on heat transfer of magnetic fluid flow in a mini-channel.

2 Experiment

Figure 1 shows the cross-sectional view of the mini-channel used in this study. Two mini-channels which have 1 mm and 5 mm of height are prepared. These channels have 10 mm of width and 100 mm of flow developing region at upstream of the test section. The mini-channel is made by copper plate for bottom wall and acrylic resin for other parts, the heater is attached under the bottom copper plate. Heat transfer coefficient can be calculated by flow temperature at inlet and outlet of the mini-channel and wall temperature measured by 5 thermocouples installed in the bottom plate with 20 mm of intervals (i.e. x = 120, 140 160 180 and 200 mm in Fig. 1) in the test section. Magnetic field is applied to magnetic fluid flow between x = 140 and 180 mm by electromagnet whose iron core has 30 mm of diameter. Magnetic field intensity is varied 100, 300 and 500 mT, and Reynolds number is set to 100, 200 and 300. Water-based magnetic fluid MSG-W10 produced by Ferrotec Material Technologies Co. is used. The volume fraction of original magnetic fluid is 3.2 vol%, and 1.6 vol % of magnetic fluid is prepared by diluting original one by water.

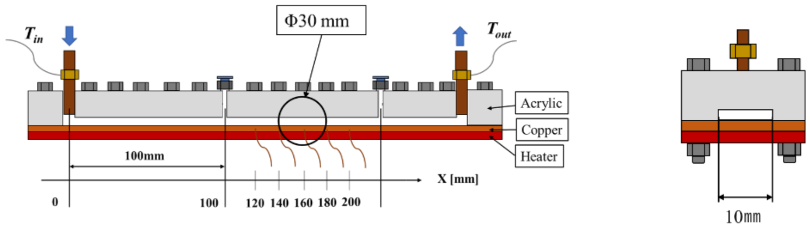

Fig. 1　Detailed structure of mini-channel.

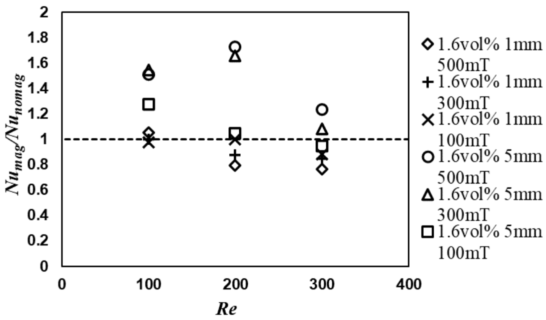

Fig. 2 Influence of channel height on heat transfer

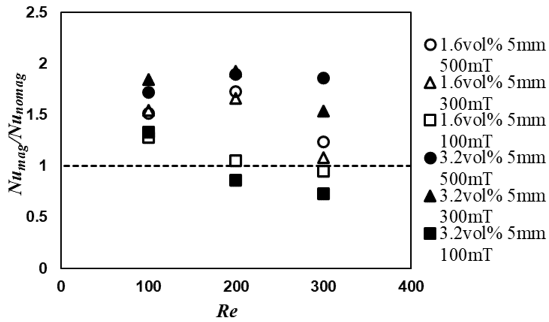

Fig.3 Influence of magnetic fluid concentration on heat transfer

3 Result and discussions

Figure 2 shows the influence of channel height on heat transfer of 1.6 vol% magnetic fluid. The vertical axes is Nusselt number ratio of magnetic fluid flow with to without magnetic field Nu_{mag} / Nu_{nomag}. This figure indicates that heat transfer is suppressed at Re=200 and 300 for 1 mm of channel height, while heat transfer is significantly enhanced at Re = 100 and 200 for 5 mm of channel height. Both suppression and enhancement level tend to increase with increasing magnetic field intensity at these Reynolds numbers. This seems that the relationship between inertia force of magnetic fluid flow and magnetic body force has important role of heat transfer phenomena in mini-channel. In the case of 1 mm of channel height, flow velocity is larger than that for 5 mm of channel height, but magnetic body force is much smaller than that for 5 mm of channel height because magnetic field area in flow is quite small. This means that the inertia force of magnetic flow is dominant comparing with magnetic body force. Therefore, it seems that this leads to constrict the development of thermal boundary layer and result in heat transfer suppression for 1 mm of channel height. Moreover, the magnetic body forces become dominant with increasing magnetic field intensity, the thermal boundary layer develops and the heat transfer turns to be enhanced between 100 mT and 300 mT of applied magnetic field. Influence of magnetic fluid concentration on heat transfer for 5 mm of channel height is shown in Fig. 3. This figure clearly indicates that the tredency of heat transfer variation is almost same both 1.6 vol% and 3.2 vol% of magnetic fuid, but the change becomes remarkable in larger concentration of magnetic fluid.

4 Conclusion

Heat transfer phenomenon of magnetic fluid flow in mini-channel is investigated experimentally. Heat transfer is largely enhanced for 5 mm of channel height by applying strong magnetic field, while heat transfer is slightly suppressed for 1 mm of channel height. The heat transfer change becomes remarkable by using condensed magnetic fluid.

References

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[3] Y. Mizuno et al., *Proc. SEAD33* (in Japanese), Online, (2021).