

SIMPLE METHOD FOR MICRO FLOW GENERATION USING MAGNETIC FLUID AND SMALL CUBIC PERMANENT MAGNET

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Abstract. This paper proposes a simple method to generate some water micro flows. The method is a wireless energy supply system composed of a magnetic fluid and a cubic permanent magnet. The magnet—magnetic fluid element was submerged in the water. Immiscible magnetic fluid was adsorbed on the small permanent magnet in water. The system was driven by the external alternating magnetic field created by the coil. The interface of magnetic fluid responded to the alternating magnetic field with harmonic oscillation. The interfacial oscillation of magnetic fluid generated micro water flows. The generation of micro water flows was confirmed by visualization technique. The details of micro water flow and magnetic fluid interface response to the alternating magnetic field were revealed experimentally.

1. Introduction

Extensive studies on the flows induced by the vibration have been conducted for a long time. Such flows are especially of interest in fields such as acoustic streaming, acoustic levitation, heat exchanger, naval architecture, aerospace engineering, and civil engineering. For example, the vortex flows formed around a solid sphere or a cylinder in vibrating air were observed using smoke particles experimentally [1]. The flows around an oscillating cylinder in a fluid at rest were investigated by the visualization method [2]. Flow fields from transversely oscillating circular cylinders in water at rest were studied by numerical solution of Navier-Stokes equations [3]. Quantitative measurements on streaming flows forced by mechanical vibrations within a two-dimensionally confined geometry were presented [4]. In these studies, however, mechanical vibration generators such as electrodynamic shakers and diaphragms were used for excitation vibration. Wireless energy supply system for micro flow generation is important in microsystem applications such as μ -TAS, lab-on-a-chip, micro-mixer, and micro-reactor.

In this paper, a new simple method to generate micro water flows using wireless energy supply system was proposed. Water micro flows were driven by the interfacial oscillation of immiscible magnetic fluid adsorbed on a small permanent magnet in water. The interfacial oscillation of magnetic fluid was actuated by the alternating magnetic field with small intensity amplitude. Micro water flows around the magnetic fluid were visualized and the flow properties were revealed experimentally.

2. Principle of the proposed method

Schematic diagram of the proposed simple method for generation of micro water flow is shown in Fig.1. The flow generation system consist of small cubic NdFeB permanent magnet and hydrocarbon-based magnetic fluid. The permanent magnet is adhered to an acrylic resin flat plate. Magnetic fluid is adsorbed on the permanent magnet and it is immiscible with water. This magnet-magnetic fluid element is submerged in water. When the element is subjected to alternating magnetic field along the direction of magnetic pole of the permanent magnet, the interface of magnetic fluid responds in elongation and contraction [5]. This interface oscillation of magnetic fluid induces flows in the surrounding liquid (water).

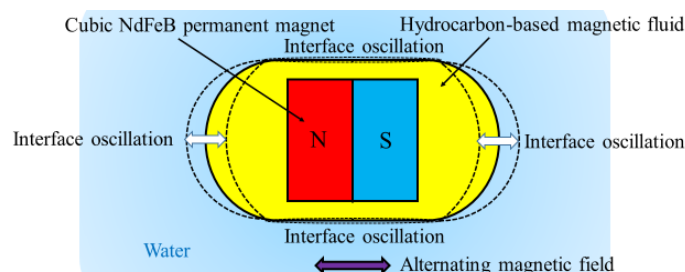


Fig. 1 Principle schematics of a simple method for generation of micro water flow

3. Experimental apparatus

The experimental apparatus was composed of magnet-magnetic fluid element, external alternating magnetic field generation system, and high-speed video camera analysis system. The NdFeB permanent magnet used in the experiment was a cube 5mm on each side. The sample magnetic fluid was synthetic hydrocarbon-based MSG P50 (Ferrotec Co.). The alternating magnetic field was generated by the Helmholtz

coil. The high-speed video camera analysis system was used to observe the flow phenomena. Fig.2 shows the photograph of the experimental apparatus.

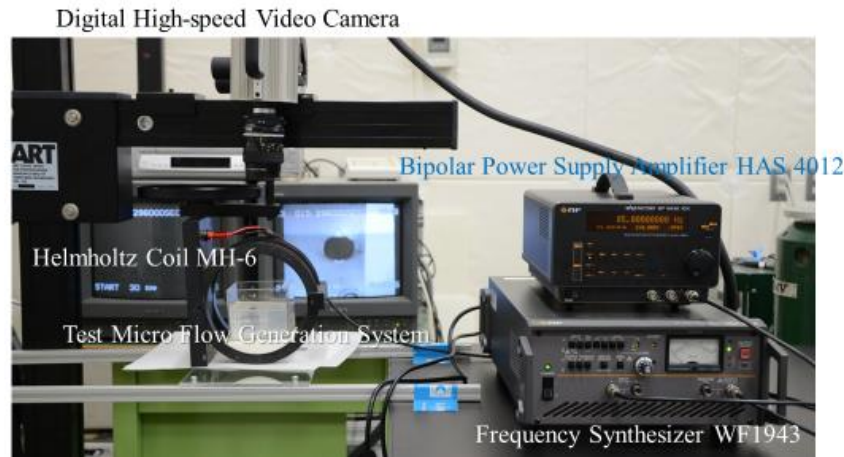


Fig. 2 Photograph of experimental apparatus

4. Experimental results and discussion

When the alternating magnetic field was applied to the magnet-magnetic fluid system in water, the interfacial oscillation of magnetic fluid was generated. The interface of magnetic fluid adsorbed on the permanent magnet showed a harmonic response to the external magnetic field. The interfacial oscillation generated flows around the magnetic fluid. A flow visualization picture is shown in Fig.3. In Fig.3, the volume of magnetic fluid is $V_m=300\mu\text{l}$, the frequency of alternating magnetic field is $f_0=75\text{ Hz}$, and the total amplitude of applied voltage to the Helmholtz coil is $E_0=90\text{ V}$. In Fig.3, the symbol t is the elapsed time after applying the external alternating magnetic field. It can be seen from Fig.3 that four flows are flowing out of the magnet-magnetic fluid element. The velocity of the water flow depends on the amplitude of magnetic field strength.

Fig. 3 A series of photographs indicating the progress of four flows produced around magnetic fluid element

Conclusion

Micro water flows were generated by the proposed system. The tip of flows grew with the elapsed time after applying the external alternating magnetic field.

References

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