

Abstract

Currently this is very preliminary. This is an attempt to design a pump that can efficiently pump ferrofluid with no moving parts except the ferrofluid and two blobs of an immiscible, incompressible fluid, such as water. Eliminating moving parts allows miniaturization and potentially fabrication as a chip. A miniature pump could be used for cooling a chip and for “lab on a chip” applications. The proposed design uses two permanent magnets and seven controllable electromagnets. The design was developed from considering the minimal topological connection of fixed chambers. It has four distinct phases, each phase having a distinct magnetic configuration.

Keywords: ferrofluid pump

1 Introduction

Ferrofluid can be manipulated by electronically controlled magnetic fields to exert force on fluids[1, 2, 3]. This makes it possible to build pneumatic or hydraulic devices, perhaps on very small scales, such as a single chip[4, 5], to miniaturize fluid handling. This has been proposed for biomedical purposes[6] that would use water or body fluids, although this paper reports only on experiments done with air. Miniature pumps and valves could be used to make a “lab on a chip” (LOC) or even to heat or cool different chip areas.

2 Related Research

A number of papers report on ferrofluid pumps, focusing in particular on micropump and lab-on-a-chip applications[3, 7]. Many of these papers use a version of mechanical valve not based on passive ferrofluid, even though they move a ferrofluid bolus with a magnetic field. For example, a corrugated silicone micro valve[4, 8] has been reported. Other researchers use active valves, which require synchronization with the ferrofluid plug to form a pump, such as [9], which describes an active *T-Valve* with a moving ferrofluid plug, and [10] describes a complete fluid pump with valves that use active control

of a ferrofluid bolus. At least two additional kinds of active valves, a *well valve* and *Y-valve*, have been described[11]. Active control is possible because the action of the plunger or bolus may be synchronized with the opening and closing of the valves. Nonetheless a passive valve would be simpler and less expensive, and would not require knowledge of the timing of the plunger.

An interesting functional micropump in which the moving ferrofluid bolus merges with a fixed ferrofluid valve and then separates on each pumping cycle has been described[5].

An interesting devices induces a flow directly in ferrofluid with no moving parts, presumable based on the rotation of clumps of ferrofluid [12].

3 The Idea

There is no known way to directly move a mass of ferrofluid which is immersed in ferrofluid. The idea of moving a ferrofluid plug or bolus which is bounded by air or water via electromagnets turned on or off is well known. A slight inversion of this idea is to use two boluses to trap a blob of water. The water thus remains a separator. In the diagrams below it is represented as a “W”, and the ferrofluid as an “F”. The separator allows us to move the bolus slightly. In order to create a pump, we need to recycle this separator, rather than moving it once, as in a piston.

If we combine this with the idea of a moving bolus “picking up” some ferrofluid and then dropping some of that ferrofluid, we can have a two circulating water blobs and two circulating ferrofluid plugs. One ferrofluid plug, which is moving from the inlet to the outlet, is larger. The other plug is smaller, and merely separating the water plugs as it is returned.

If we reduce this to a minimal configuration, we have a circle of seven regions of equal size. The inlet and the outlet prevent the water blobs from escaping by having permanent magnets in place. The water blobs can never displace these locks, represented by “L” in our diagram. The inlet of the pump has an inexhaustible supply of ferrofluid represented as a source (“S”). The outlet is represented as a drain “D”.

The water plugs must always be kept separated by ferrofluid plugs. However, these plugs can pull fluid from the source and push it into the drain if so driven by the changing magnets in the seven dynamic regions. By cycling through four configurations as depicted, we can move ferrofluid from the source to the drain.

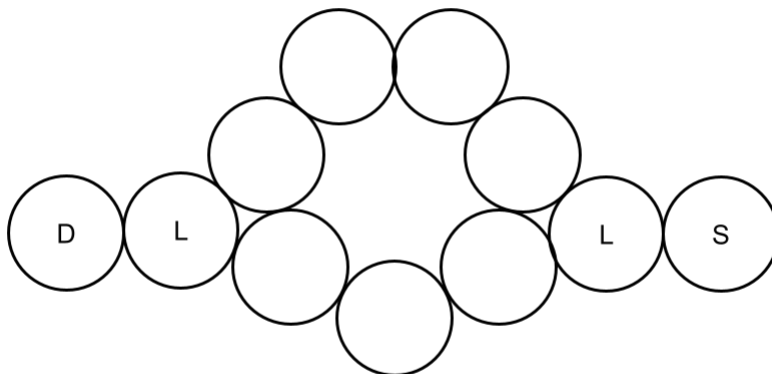


Figure 1: The Pump Schematic

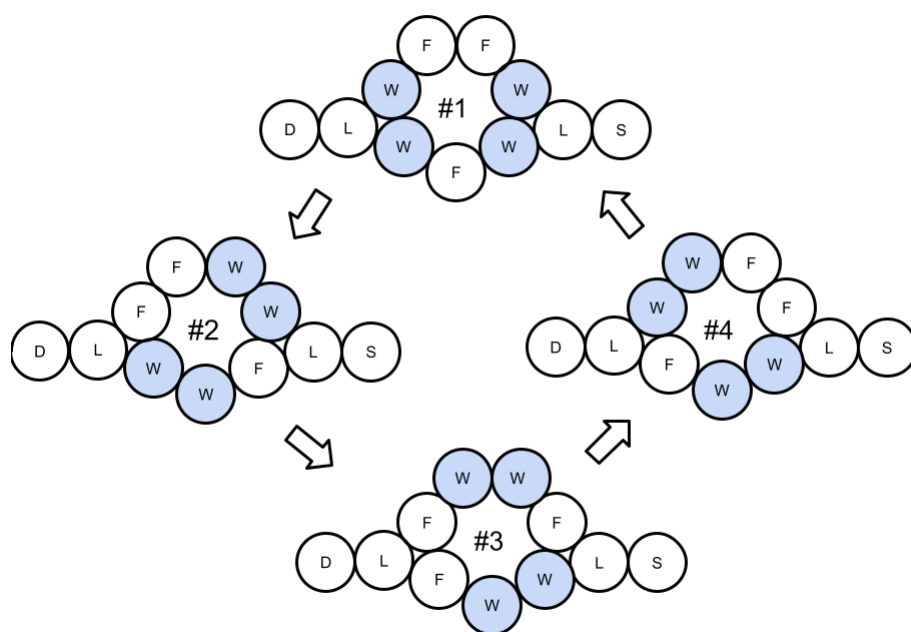


Figure 2: The Pump Schematic

4 Conclusions

5 TODO

Study this: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.719.4343&rep=rep1&type=pdf>

6 Acknowledgements

This paper was an outgrowth the the Passive Ferrofluid Check Valve (PFCV) [13] reported by Veronica Stuckey and Robert L. Read. Veronica Stuckery 3D printed some of the apparatus.

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