The Flow of Magnetic Particles in Viscous Fluids

Rabia Siddiqui[1], Austin Myers[2] and Eric Strom[1]

[1] Department of Electrical and Computer Engineering, [2]Department of Mechanical Engineering,

z1828726@students.niu.edu, z1754583@students.niu.edu, z1820538@students.niu.edu

Northern Illinois University, DeKalb, IL., USA

***Abstract*— the research, development and results presented in this paper describe a user-friendly apparatus exploiting electromagnetic forces to control the motion of a ferrofluid. The project uses a matrix of Electromagnets and a Graphical User Interface (GUI) scheme which prompts a user to select specific sections of this matrix to enable and disable specific electromagnets. The design itself employs a system of voltage and current controlled relays in order to bridge the gap between hardware and software via an Arduino Mega 2560 microcontroller.**

I. INTRODUCTION

Modern treatments of cancer include operations that are both invasive and costly to patients. Surgical treatments are second only to chemotherapy, and leaves little to be desired as it is an ongoing, expensive procedure that doses patients with large sums of chemicals that seek out and destroy everything from hair cells to cancer cells. The idea was to mitigate these treatment options in favor of one that was much easier to implement. This entails the research, design and implementation of the prototype built by our team.

II. METHODS AND MATERIALS

A schematic of the relay board is displayed in Figure 1. This design utilizes a series of voltage and current relays that process and manipulate incoming electrical signals by toggling switches within the relays in order to allow for the passage of electrical current when closed. Excited by current, electromagnets generate a magnetic field exerting a guiding force on the magnetic nanoparticles.

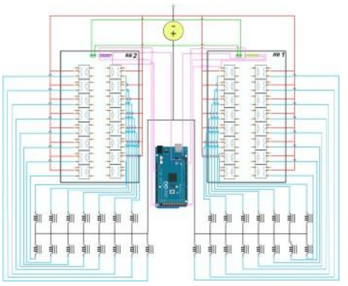

Fig. 1, Schematic of the Relay Board

This design is intended to conform to the user via a flexible Thermoplastic Elastomer Filament (TPE) These cylindrical electromagnets were chosen due to their field distribution, ease of use in designing a comfortable and viable device for patients and the size of the electromagnets themselves. With a height of 1.2" and a diameter of 0.8" they are versatile in their ability to mount on various devices. Pictured in Fig., 2, this filament allows any interconnecting wiring to be routed without compromising the proximity to the users target area of treatment.

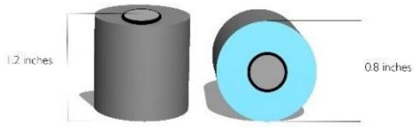

Fig. 2, Electromagnet Topology

This filament also has a heat resistance that enables it to absorb excess energy generated by the internal resistance of the electromagnets while maintaining its desired size and shape. This protects the user first and foremost. Had we used a rigid design, the electromagnets would need to be remounted onto a different surface for every different application costing even more time and money, making this form of treatment highly inefficient. The novelty in our design is attributed, partially, to the aspect of conformability to the user.

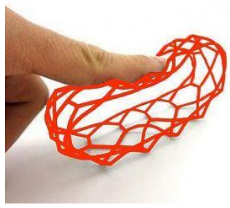

Fig. 3, TPE Filament Mesh

III. SOFTWARE, INTERFACING AND POWER SOURCING

In the design and testing phase of the prototype we encountered relentless struggles in being able to easily control the matrix of electromagnets both physically and electronically. The GUI was designed and implemented using the arduino IDE and allows a fully hands off approach in the implementation of the prototype. The central idea is that multiple electromagnets would need to be triggered in specific locations at specific instances of time and manually connecting a variable power supply to multiple electromagnets created a serious issue in the rapid deployment of, and real time control in, the motion of a ferrofluid. Once the relay control board was designed and built the only problem remaining was that of interfacing with peripherals in order to toggle the magnetic fields for absolute control of the ferrofluid to and at a desired region of the patients body. Electrical power is supplied by an Ever Glow 120 Volt AC (VAC) Power Adapter. This power adapter converts the AC input into a 7V DC output sufficient enough to drive the electromagnets in order to generate a magnetic force capable of producing the desired effects on the stream of ferrofluid. This was crucial as too small of a voltage would generate an insufficient magnetic force and would not grant the full control needed for successful treatment. Too large of a voltage creates the opposite problem, too strong of a magnetic force makes it nearly impossible to successfully navigate the ferrofluid but is absolutely essential in more direct applications such as thermal ablation where a stream of ferrofluid is rapidly oscillated back and forth over a specific site in order to collapse unwanted growths attached to musculature and organs that may be otherwise damaged in an operation where they would be physically excised. These obstacles were overcome by using a step down AC to DC buck converter in addition to the voltage and current relays.

IV. DESIGN

The design for this project consists of 30 electromagnets attached to a 3D printed TPE Filament with a bag of oil placed on top. The bag of oil will have a droplet of magnetic fluid which will be used to demonstrate the flow of the magnetic particles in a viscous fluid. The electromagnets are attached to a 12 V power supply and some are selectively chosen to turn on and off to have the magnetic fluid flow to a specific spot to illustrate magnetic drug delivery. This is represented in the Figure 3.

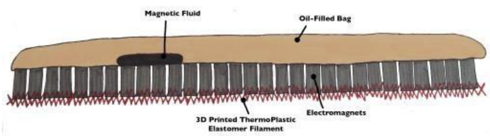

Fig. 4, Electromagnetic Placement Grid with Oil Bag containing Magnetic Fluid – 2D

This project will explore the limitations of guidance in current procedures where magnet drug delivery/hyperthermia is achieved by either passive and/or active targeting. Through this design, the user will be able to guide the magnetic particles to whatever complex direction of choosing. This will be accomplished via a code that incorporates Arduino Mega and code to turn on and off specific electromagnets. For this design purpose the 30 electromagnets will be arranged in a 5 by 6 fashion as seen in Figure 4, bolted to a 3D printed thermoplastic elastomer filament mesh.

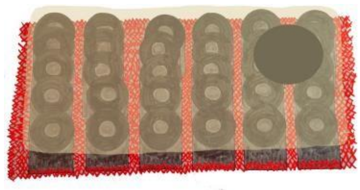

Fig. 5, Electromagnetic Placement Grid with Oil Bag containing Magnetic Fluid – 3D

V. RESULTS AND DISCUSSION

The performance of the prototype designed is as desired in its ability to systematically and algorithmically manipulate the flow of a ferrofluid bound with medicine to treat tumors. Testing of the prototype was successful in demonstrating the goal of our project and its extensive capabilities in customizability, user simplicity and effectiveness in its assigned tasks. Functionality of the prototype was recorded and displays the intended modes of operation. Future entails a device that is a flexible and safe to use on human beings for purpose of magnetic drug delivery as represented in Figure 5.

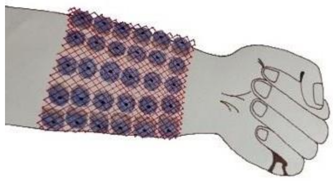

Fig. 6, Desired Conformity to a Patient

VI. CONCLUSION

The prototype design was modified in order to accommodate the impossibility of face to face interaction. This was an unfortunate setback as it forced us to alter our design using components that provide the visual representation of our intended functionality without the use of those we set out to use including the matrix of electromagnets and the TPE filament. In future iterations of this project, this can be achieved given the research and design considerations that our team has conducted on electromagnets, magnetic nanoparticles, the biological systems involved in thermal ablation and the treatment of parasitic tumors as well as the control system functionality of the prototype.

VII. REFERENCES

[1] Pinank K, Kaushik B, Shaym V, Amrutiya M, Faldu N, et al. (2016). Revolutionary therapies and manipulation of nanoparticles to cure cancer. J Bioelectron Nanotechnol 1: 1-5.

2] Springer. "Magnetic nanoparticles can 'burn' cancer cells: Magnetic hyperthermia is still a highly experimental cancer treatment, but…." ScienceDaily. ScienceDaily, 4 April 2019. <www.sciencedail[y.com/releases/2019/04/190404114521.htm>.