EMBRY-RIDDLE Aeronautical University

Mechanical Engineering

# MAGNETIC HYDRODYNAMIC PROPULSION OF BLOOD

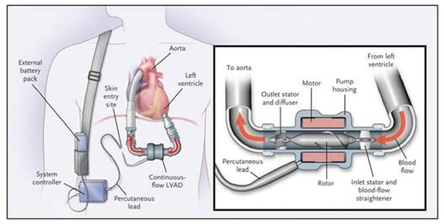

**Harvey Lee Waters Jr**
watersh1@my.erau.edu

**Daniel Flores**
floresd9@my.erau.edu


## BACKGROUND

**Left Ventricular Assist Device issues**

- ❑ Axial Fan
- ❑ Many moving parts
- ❑ Imposes unnatural behavior to the flow of the blood
- ❑ Stagnation points
- ❑ Impingement regions
- ❑ **Can induce Thrombosis**




## DEFINITIONS

- ❑ **Thrombosis:** Local coagulation or clotting in the blood in a part of the circulatory system.
- ❑ **Electromagnetic flowmeter principle**: Faraday's law of electromagnetic induction
- ❑ When a conductive medium pass through a magnetic field B, a voltage E is generated which is proportional to the velocity v of the medium.
- ❑ **Magneto-hydrodynamic drive principle**: Lorentz force
- ❑ The force experienced by an enclosed charge q moving with a velocity v under an applied electric field E that is orthogonal to a magnetic field B [F= q(E + v x B)]
- ❑ Inside the MHD VAD, the blood will act as the conductive fluid needed to flow through the device.

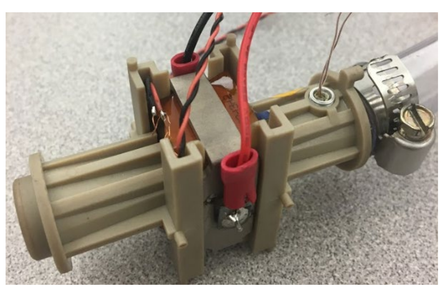
## INTRODUCTION

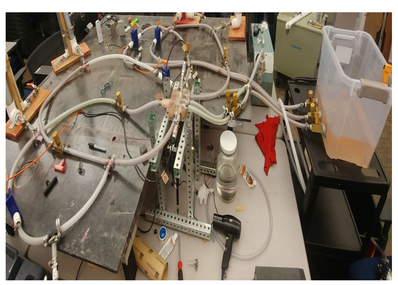
An electromagnetic flow meter and a Magneto-Hydrodynamic Drive have similar operation principals. Thanks to this, it is possible to first construct an experimental electromagnetic flow meter and then convert that flow meter into an MHD system

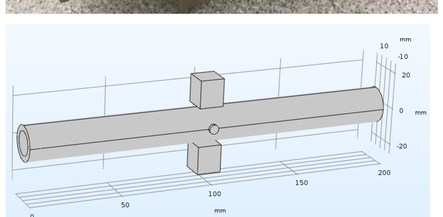
- ❑ Step 1: Create and calibrate electromagnetic flow meter
- ❑ Step 2: Design an ideal model of a Magneto Hydrodynamic drive
- ❑ Step 3: Create a Magneto-Hydrodynamic Drive
- ❑ Step 4: Create case specific designs of Magneto-Hydrodynamic Drives

## DESIGNS

Magnetic Flow Meter → Ideal Model of Magneto-Hydrodynamic drive → Magneto-Hydrodynamic Drive







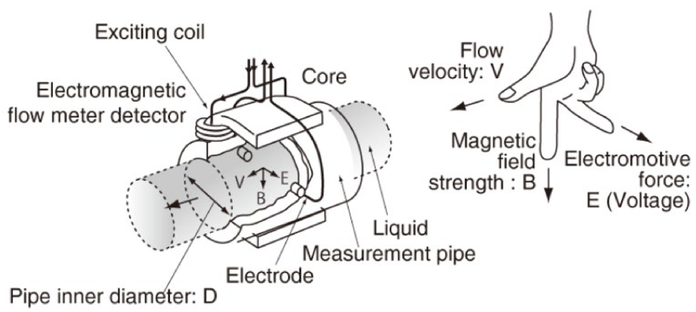

**Pictures from top to bottom**

- ❑ New Model of Electromagnetic Flow meter
- ❑ Mock flow loop to test the Flow meter
- ❑ The Ideal Model of the Magneto-Hydrodynamic Drive


## ABSTRACT

The pump component in a typical Ventricular Assist Device imposes unnatural behavior to the flow of the blood such as stagnation and impingement regions due to the many moving parts, thus promoting the formation of blood clots. To solve this problem, a magneto hydrodynamic drive or MHD could be implemented instead of a mechanical pump. MHD takes advantage of the Lorenz's force, which states that a magnetic field perpendicular to an electric field will add a force to a conducting particle moving through the two fields as long as they are orthogonal to each other. The result is a continuous flow that experiences a head gain from the MHD.

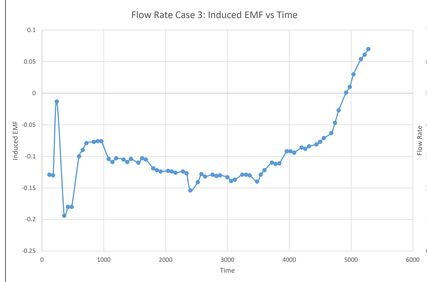
The first step is to design a simplistic and effective electromagnetic flow sensor. This sensor will operate on a bench-top flow loop built to model a circulatory system by using a pulsatile pump to move a fluid that mimics blood. The flow sensor design and operation are based on the magnetic flow sensing principal which is built upon Faraday's Law, and states that the voltage induced across any conductor as it moves orthogonally through a magnetic field is proportional to the velocity of that conductor. When applying this to a flow sensor, the result is any conducting fluid flowing through a magnetic field will induce a voltage which can be picked up by two electrodes placed orthogonal to the magnetic field. The next step is to determine the MHD's optimal design by using COMSOL Multiphysics software.

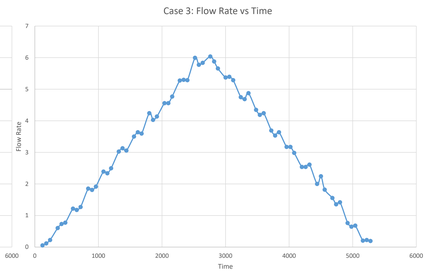




## RESULTS

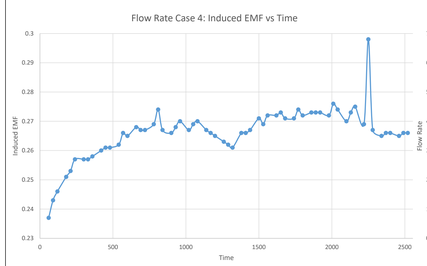
The following results show previous electromagnetic flow meter test done with salt. The total flow range was .2 to 6 L/min. The resulting graphs show a slight variation in the induced EMF as the flow rate increased or decreased. After analyzing the data, it is apparent that our prototype can sense the changes in the induced EMF that originate from changes in the flow rate.

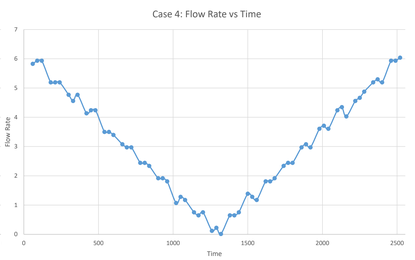
## GRAPHS




These graphs show induced EMF(left) vs time compared to the change in flow rate vs time(right).




## CONCLUSIONS

- ❑ The electromagnetic flow meter shows a trend in the EMF data
- ❑ The data also shows error and a need for a new model
- ❑ A new model has been created
- ❑ The new Model is currently being tested with the new revisions

## REFERENCES


[1]Ellison, W., Balana, A., Delbos, G., Lamkaouchi, K., Eymard, L., Guillou, C., & Prigent, C. (1998). New permittivity measurements of seawater. Radio science, 33(3), 639-648.

[2]Choi, D., & Knight, C. J. (1993). Application of scalar implicit approximate factorization for underwater magnetohydrodynamic propulsion concept analyses. AIAA journal, 31(2), 286-293.

[3]Lin, T. F., Gilbert, J. B., & Roy, G. D. (1991). Analyses of magnetohydrodynamic propulsion with seawater for underwater vehicles. Journal of Propulsion and Power, 7(6), 1081-1083.

[4]Moghaddam, S. (2013). MHD micropumping of power-law fluids: A numerical solution. KoreaAustralia Rheology Journal, 25(1), 29-37.

[5]Haynes, W. M. (2013). Magnetic susceptibility of the elements and inorganic compounds. Handbook of Chemistry and Physics, 2012-2013.

[6]Tomov, T., & Tsoneva, I. (2000). Are the stainless steel electrodes inert?. Bioelectrochemistry, 51(2), 207-209.

[7]Ventricular assist device (VAD). (2019, January 16). Retrieved March 4, 2019, from https://www.mayoclinic.org/tests-procedures/ventricular-assist-device/about/pac-20384529