WINTER 2019

Magnetorhelological Fluid Controller Design

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FUNDED BY LAB FUND ENGINEERING STUDENTS

Introduction

Magnetorheological (MR) fluid is an intelligent fluid that demonstrates varying levels of viscosity depending on the intensity of an applied magnetic field. The strength of an applied magnetic field influences the yield stress of the fluid, reflecting the important property of the MR fluid changing states from a viscous-free flow liquid to a quasi-solid [1]. This property can be applied to many different markets and fields of research, such as robot-assisted minimally invasive surgery in the medical sector or the design of responsive control flaps in the aviation industry.

Problem Statement

MR fluid demonstrates a unique property of changing between viscosities almost instantaneously, making MR fluid very useful in applications that require a quick, accurate response. However, the main drawback to the current state of MR fluid application and development are the lack of affordable controllers and data sheets. The main objective of this design is to create a proof-of-concept demonstration system that showcases haptic feedback by changing MR fluid viscosity with respect to the varying magnetic field strength of an electromagnet.

Design Solution

The final proof of concept (Fig 1) can perform 2 different configurations:

1) The user is capable of experiencing haptic feedback by turning the crack at the top of the apparatus. The gear in turn rotates the encoder, which is programmed to alter the MR fluid viscosity at different angles of rotation. The user should feel an alternating pattern of smooth rotation and resistance as they turn the crank.
2) The second configuration includes the addition of a DC motor and potentiometer. The potentiometer can be used to adjust current output to the MR fluid. The fluid viscosity increases with respect to current and as it thickens, the speed of rotation of the DC motor slows. The rotary encoder directly measures the changes in motor rpm, as the gear sizes are at a 1:1:1 ratio.

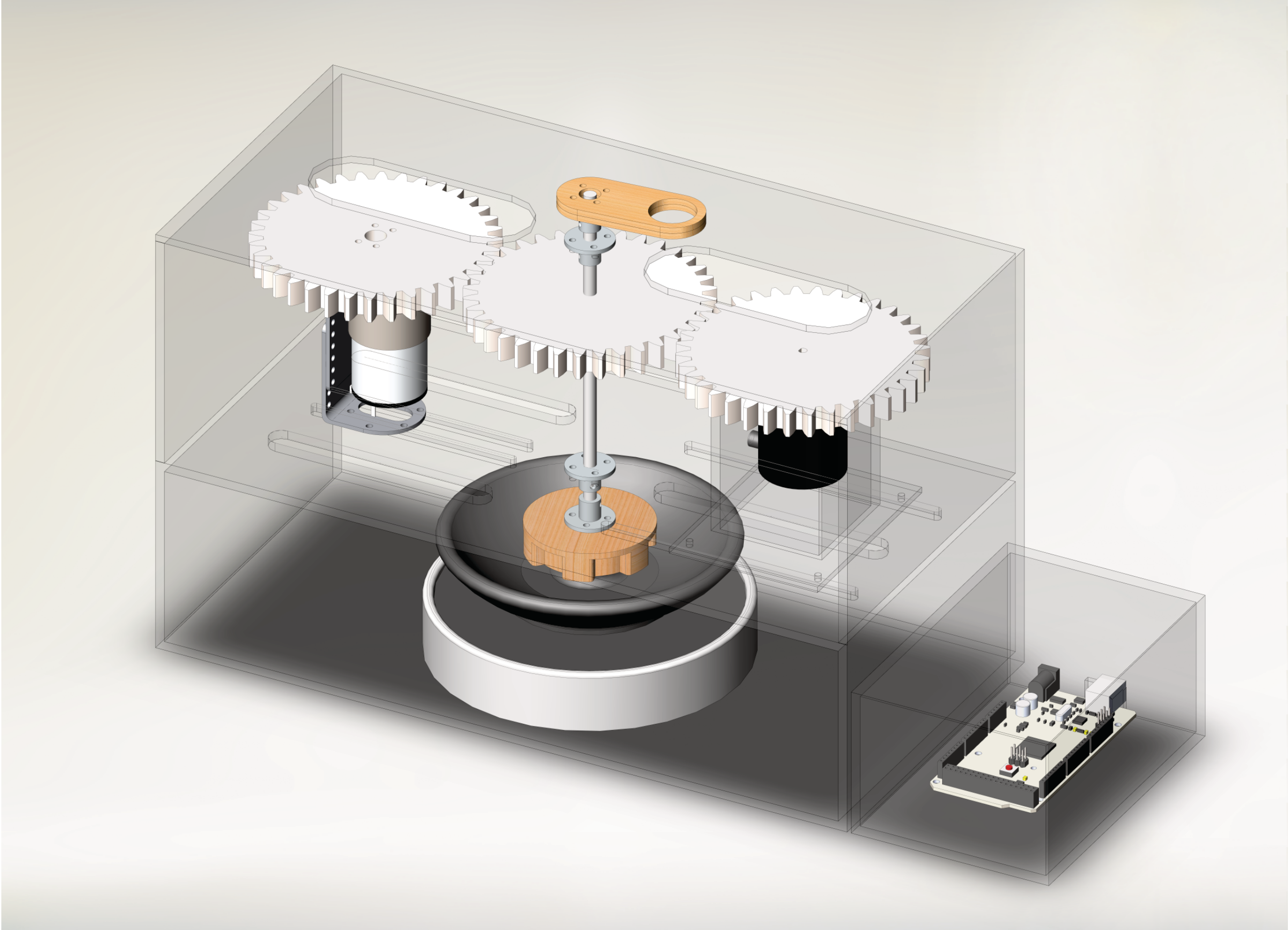

Figure 1 Solidworks rendering of the final demonstration apparatus (Isometric view)

Results

Configuration #1 was used to observe the relationship between the encoder's rotational position and current output over time (Fig 2). Specified conditions for activation and deactivation of the supplied current were set based on the angular position of the encoder from a point of reference. The supplied current increases with the rotation of the encoder, increasing the MR fluid viscosity until a turn angle of 250° is reached. At angles greater than or equal to 250°, the current drops to zero. Due to the identical gear sizes, the two curves for current output and encoder position follow similar cycle paths. Within 150 ms, the shaft can make about 8 full rotations and the user can feel the fluid relax and stiffen up each time they rotate the central shaft.

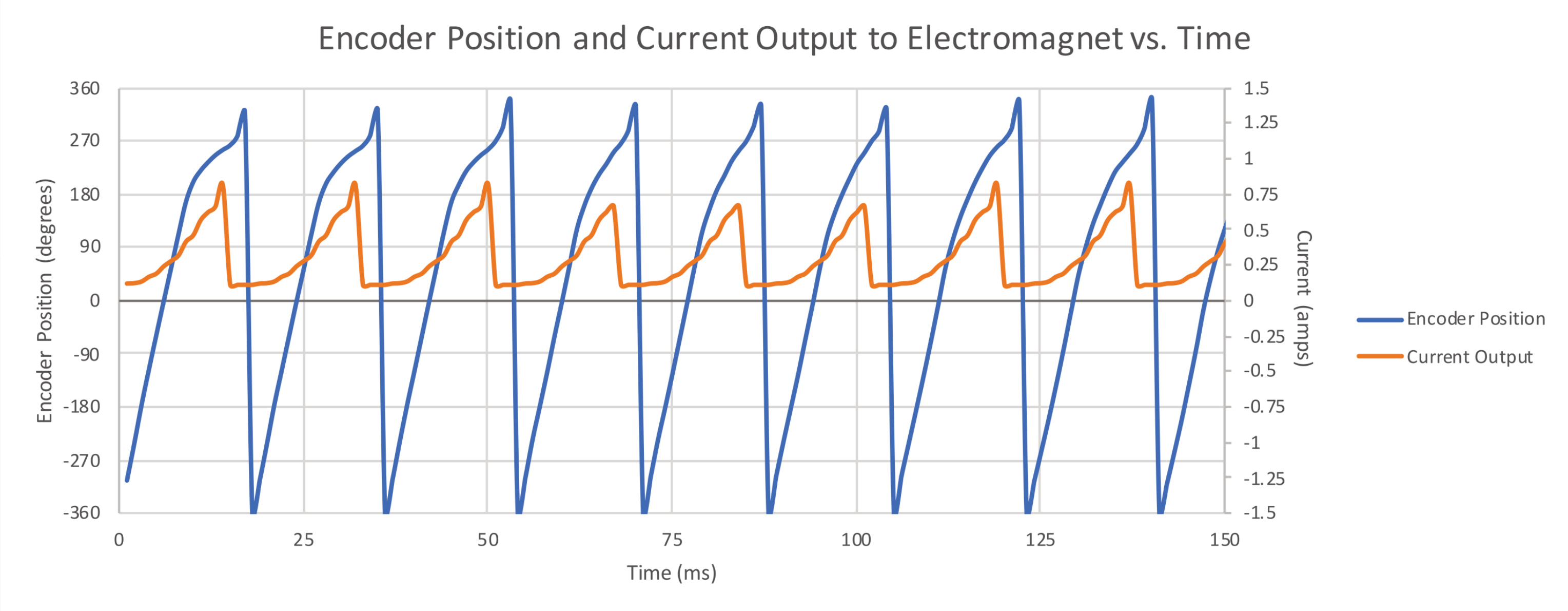

Figure 2 Relationship between encoder position and current supplied to the electromagnet over time.

Conclusion and Recommendations

The demonstration system is designed to highlight the advantages of utilizing MR fluid as a smarter, more adaptable alternative to traditional hydraulics. Because of its ability to change viscosity within milliseconds, MR fluid has the additional benefit of performing haptic feedback for a variety of systems. The goal of this technology is to provide a higher degree of controllability to preserve human safety across all possible fields of application.

References:
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Acknowledgements
Faculty Advisor: Dr. S. Andrew Gadsden, Ph.D., P.Eng
Special Thanks to: Kevin Dong and Andrew Lee

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