SURE Program 2021

Rheological Fluid Properties and Applications

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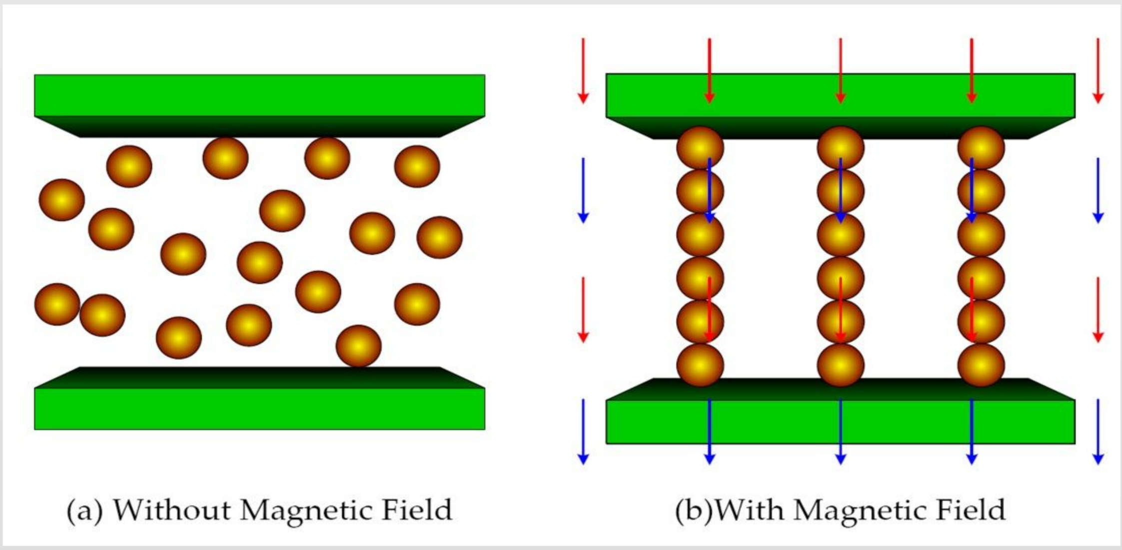
Abstract

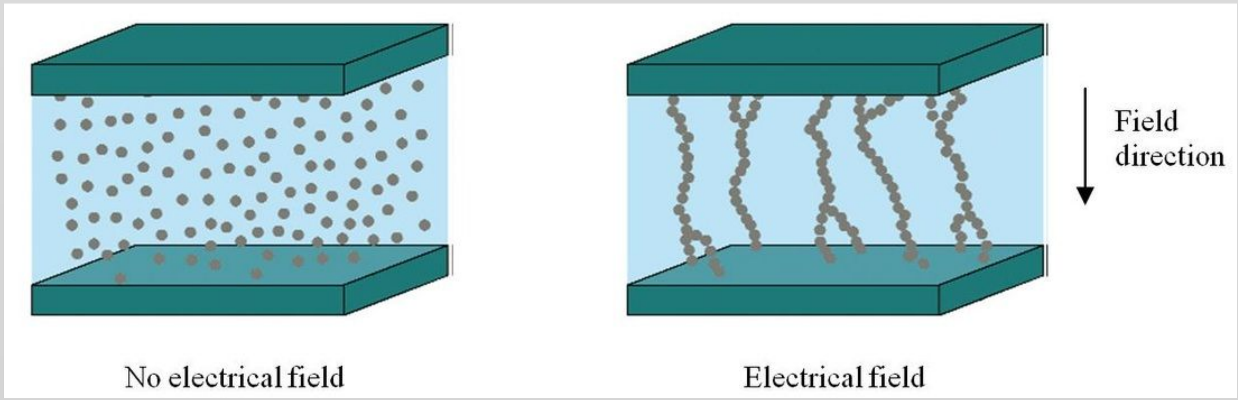
Rheological fluids are smart materials that alter their apparent viscosity when subjected to an external stimulus. Electrorheological fluids (E.R. fluids) consist of electrically active particles submerged in an insulating fluid that increase in viscosity when an electric field is applied. Magnetorheological fluids (M.R. fluids) are composed of magnetic particles that are dispersed in a carrier oil, and also experience an increase in viscosity when a magnetic field is applied.

Theory

When Magnetorheological fluids are exposed to a magnetic field, the fluid changes from a liquid state to a more solid like state. This viscosity increase occurs because the magnetic particles (like iron) suspended in the carrier oil become aligned along the magnetic flux. This creates a more gel like substance.



Electrorheological fluids react similarly when exposed to an electric field. The viscosity increases because the electrically active particles that are suspended in the fluid (such as corn starch) bind together with electric charge and form chains along the electric field. These chains cause an increased viscosity.

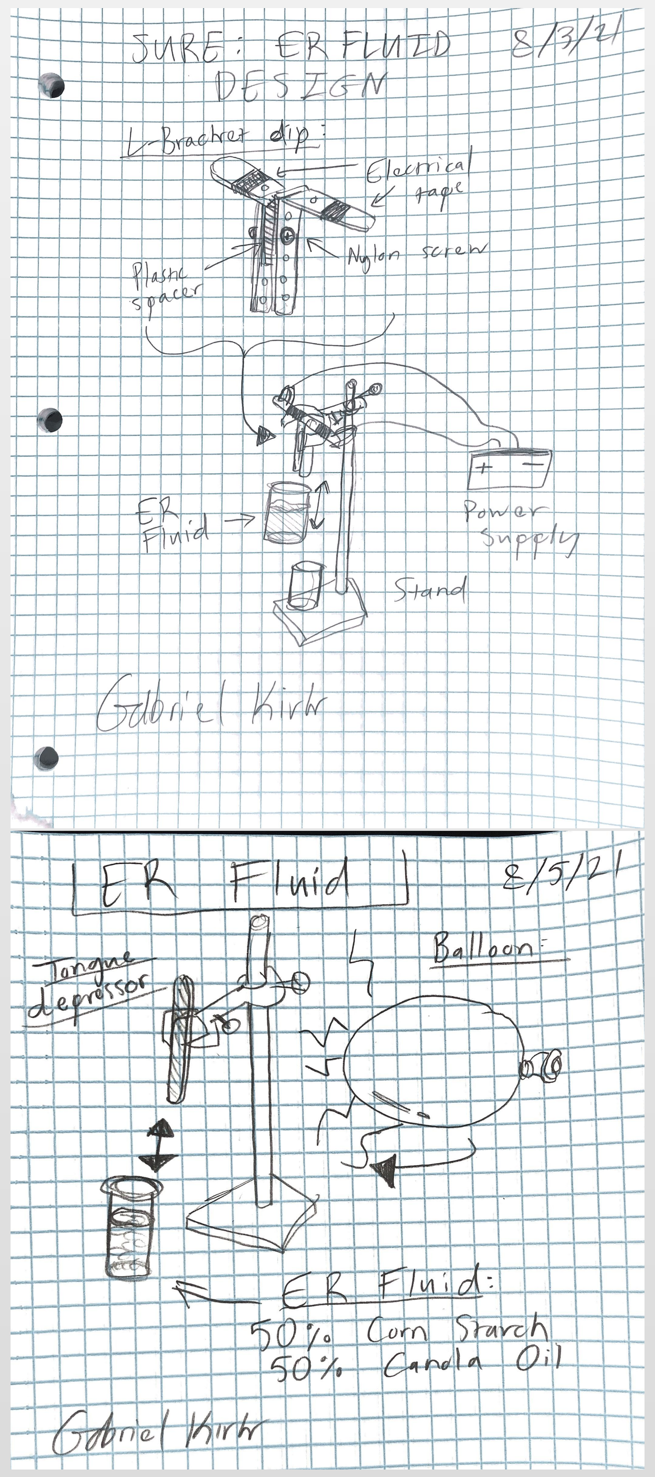


Objective

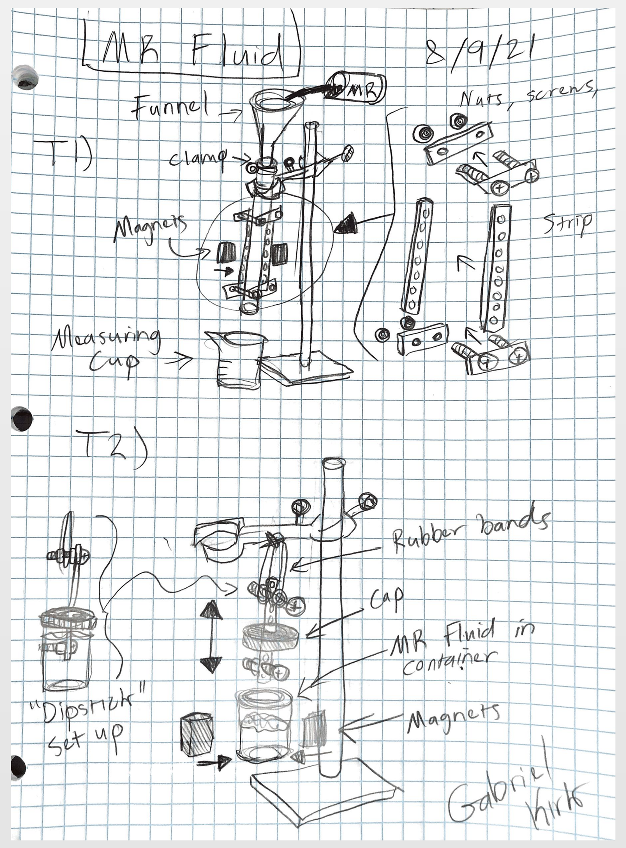
After becoming familiar with the theory behind these two kinds of fluids, our goal was to determine the following:

- How much of an external stimulus is needed to experience the increase in viscosity?
- How quickly does the change in viscosity occur?
- What are some of the possible applications of E.R. and M.R. fluids?

Design



E.R. Fluid Test Designs:



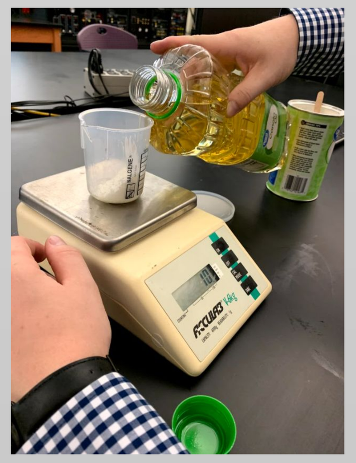
M.R. Fluid Test Designs:

Materials Used

Material List:
Clear Tubing ⅝" ID
Hose Clamp
Support Stand
Nuts, Screws, Mending Plates
Metal Strips
Ceramic Block Magnets
Funnel
Measuring Cup
Rubber Bands
Balloon
Test Container
Tongue Depressor
Electrical Tape
Plastic Spacer
L-Brackets
DC Power Supply
Nylon Bolts & Nuts
Corn Starch
Canola Oil
Magnetorheological Fluid (MRF-132 DG)

Hardware Cost:
$104.57
M.R. Fluid Cost:
$306.00
Total Cost: $410.57

M.R. Fluid (MRF-132 DG)



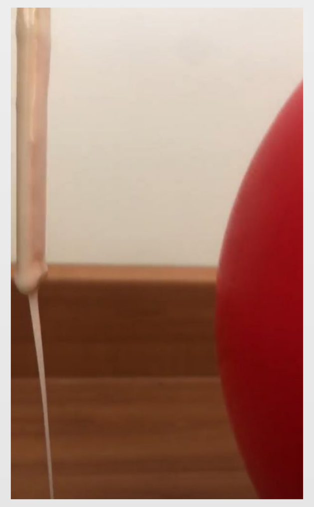
E.R. Fluid (50/50 Cornstarch and Canola Oil)

Testing

E.R. Fluid (concentration of about 50% cornstarch and 50% canola oil):

- Test 1) L-brackets were briefly submerged in the fluid and the visual effect was noted. Test was repeated when the connected power supply was set from 0V to 25V.
- Test 2) A tongue depressor was briefly submerged in the fluid and a statically charged balloon was placed nearby..

E.R. Fluid Test 1

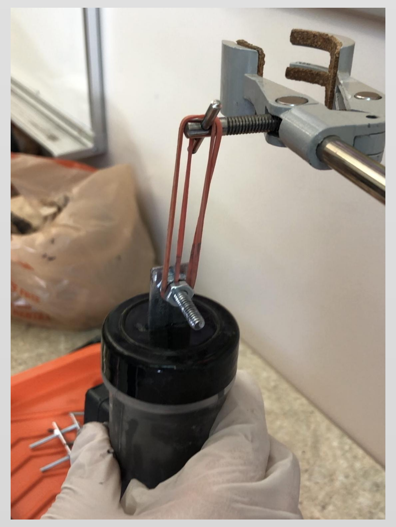


E.R. Fluid Test 2

M.R. Fluid (MRF-132 DG):

- Test 1) Tube held by stand and fluid poured down tube. Magnet applied to metal strip attached to tube as fluid falls.Test repeated but with two magnets on each side.
- Test 2) Stand was set up with rubber bands supporting bracket in test bottle of M.R. fluid. Test bottle pulled down to pull bracket out of fluid. Magnet on either side is applied and the test bottle was pulled down again.

M.R. Fluid Test 1



M.R. Fluid Test 2

Results

E.R. Fluids:

- Test 1) The difference between the fluid with no electric field exposure and the maximum available electric field (25 V/mm) exposure was negligible. The electrical field was too weak for a visible viscosity increase.
- Test 2) Viscosity increased significantly when the fluid was introduced to the electric field of the balloon. The drips would change from liquid to gel like and fall at a slower rate.

M.R. Fluids:

- Test 1) The viscosity greatly increased when introduced to a single magnet (4 lbs pull strength or about 3900 Gauss), but still slowly flowed down the tube. When additional magnets were applied, the liquid solidified and only continued draining once the magnets were removed.
- Test 2) Without a magnetic field, the bracket easily slides in/out of the fluid container and there is no tension on the rubber bands. Once magnetism is applied, the fluid tremendously increases in viscosity and the rubber bands are stretched.

Conclusion

- E.R. fluids only increase in viscosity when an incredibly strong electric field is applied (at least 1kV/mm), making the use of these fluids less practical when compared to M.R. fluids.
- E.R. fluids are easy to obtain and fabricate, since the materials are cheap and common.
- M.R. fluids greatly increase in viscosity and nearly solidify when introduced to magnetism.
- M.R. fluids are very practical and easy to use because they do not require a strong magnetic field in order to increase in viscosity. The amount of effect can easily be controlled depending on amount of magnetism applied and distance.
- M.R. fluids are more difficult to obtain, when compared to E.R. fluids, due to the intensive manufacturing process required.
- Both E.R. and M.R. fluids react quickly and reversibly to their respective fields.
- Both of their effects are limited when particles settle overtime and when exposed to extreme temperatures.

Applications

- Dampers
- Brakes
- Clutches
- Body armor
- Virtual reality systems (shoes, joystick)
- Prosthetic limbs
- Earthquake resistant structures
- Haptic devices (surgery, needle insertion)

M.R. Fluid Damper Concept

Acknowledgements & Research

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