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Interfacing Adaptive Magneto-rheological Materials with Micro Controllers

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Introduction:

Adaptive materials represent a relatively new branch of material science that is comprised of materials that respond with a change in shape or state upon application of externally applied driving forces. These materials often carry titles such as intelligent materials, active materials, or smart materials.

Many of these materials, such as shape memory alloys, develop enough usable force during their shape change to power small linear actuators and motors. Conversely, some of these materials can also be used as sensors where a strain applied on the material is transformed into a signal that allows computation of the strain levels in the system.

Rather than exhibiting a shape change, other smart materials demonstrate unique properties such as change of state. Electro- and magneto-rheological fluids, for example, can change viscosity over many orders of magnitude upon application of an external magnetic or electric field. This change of state has the potential to revolutionize the control aspects of vibration and the responsiveness of hydraulic power transmission. "The application of magneto-rheological fluids for damping is a unique and novel approach to an age-old problem". [1]

Magneto-rheological fluid is a responsive material that changes its flow characteristics when subjected to an electrical field. "Response, which takes only milliseconds, is in the form of a progressive gelling that is proportional to field strength. With no field present, the fluid flows as freely as hydraulic oil". [2]

Magneto-rheological fluids represent a technology that has the potential to widen the performance range of automated electromechanical and electrohydraulic equipment. Research and ongoing developments are refining this active material and experts predict an important future for these fluids.

Magneto-rheological fluids are important for many reasons. Current automation capabilities are not advanced enough to build a robot that could catch a ball. Even though cameras and computers could direct the robot towards a ball, robot's move in an awkward, lumbering fashion because conventional hydraulic valves cannot keep pace with the commands of the computerized controllers.

Adaptive materials, such as magneto-rheological fluid, can "cycle" at a rate of 200 times per second. As a result, this technology will allow devices that can operate instantly and without mechanical valves. Increased productivity and better product quality through more dependable and responsive automated equipment is just a small part of what this maturing technology can deliver.

The method of operation for this adaptive material is very simple. Magneto-rheological fluids are composed of two primary components. They are the carrier fluid and the suspended particles. "The carrier fluid needs to be a good insulator, compatible with the materials they contact. Typical particle materials include polymers, minerals, and ceramics". [3]

When a magnetic field is applied to the adaptive fluid, positive and negative charges on the particles respond by separating, so each particle then has a positive end and a negative end. Particles of the magneto-rheological fluid then "link together in the same manner that the north pole of one magnet is attracted to the south pole of another magnet". [4]

Magneto-rheological (MR) fluids can activate from solids to liquids so fast, they will work well with fast-acting computers. "These characteristics suggest a number of unusual engineering applications such as fluid clutches and vibration isolators". [4] According to J. David Carlson of the Lord Corp, "A good example of unwanted vibratory motion is a washing machine in its spin cycle trying to walk out of the room. MR damping can correct this and other problem vibrations". [5] A professor of materials science and engineering at North Carolina State University also feels that "magneto-rheological fluids will lead to a whole new generation of brakes, automatic transmissions, actuator devices, hydraulic valves, pump parts, and motors". [6]

Student Background:

This activity will be useful to students studying material technology as well as those involved in industrial power transmission, automation, and process control. Students with just a cursory understanding of magnetism will find the concept of state change within a material, based on a magnetic field, fascinating and can serve as a basis for a more advanced investigation into magnetism and materials. Those students who have insight into industrial power transmission systems (electrical, mechanical, hydraulic, and pneumatic) and process control technologies (programmable logic controllers, etc.) will see the enormous advantages this technology has to offer over traditional methods.

Outcomes and Post-Lab Analysis:

A suggested post-lab analysis would be to contrast response times and "mean times between failures" from a traditional power and control system, to one that utilizes magneto-rheological fluids.

Even though hydraulics has the highest power to weight ratio of any industrial power transmission system, the mechanical servo valves and directional controls valves are very weak links. Because they are mechanical components, they cannot keep-up with the speed of computer/controller commands. They are a primary source of equipment down-time, and a major contributor to heat generation and system contamination.

Conclusions one may reach during a post-lab analysis may focus of the superior characteristics of adaptive materials such as magneto-rheological fluid and their potential to increase efficiencies and performances in the next generation of equipment. Highly controllable, fast acting and no moving parts makes this technology an intersting engineering activity.

Source of Supplies and Specific Hardware Information:

Many different suppliers offer products that can be used to accomplish this activity. The website identified below has many links to suppliers as well as video clips, magneto-rheological material specifications, and images of current applications. An email address and telephone number is also provided. mrfluid@lord.com 1-919-469-2500, ext. 2150.

http://www.lord.com/

Procedure:

Safety Considerations:

1. Protective eye wear is mandatory for all those in the lab area.

2. Read the operating instructions that accompany the active magneto-rheological clutch assembly and power supply.

3. Obtain a "Material Data Safety Sheet" on the fluid from the supplier. Read the sheet completely and ask questions to any information you do not understand.

Observing the tunable clutch assembly:

1. With the power supply off, notice how easily the shafts can be rotated by hand.

2. Increase the power output through the range of 4, 8, 16, 32, 60, and 80 % and record your findings on the data sheet.

3. Vary the cycling frequency through the range of 4, 8, 16, and 32 Hz and notice the pulsating sensation while rotating the shafts. Record your findings on the data sheet.

Sample Data Sheet A:

Record the characteristics of the clutch when varying the power output.

4 %	
8 %	
16 %	
32 %	
60 %	
80 %	

Sample Data Sheet B:

Record the characteristics of the clutch when varying the cycling frequency.

4 Hz	
8 Hz	
16 Hz	
32 Hz	

Instructor Notes:

1. The power being transmitted through the clutch increases proportionally when the power output is increased.

2. The impulses of power transmission increase as the cycling frequency is increased.

Bibliographic Information:

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6. Conrad, H.: The Impact of ER Fluids. Compressed Air Magazine, March 1992, pp.14-17.

Biographical Information:

Dr. JOHN ALLEN MARSHALL taught senior high school prior to receiving his Ph.D. from Texas A&M University. He has 23 years of university teaching experience, and is currently the Coordinator of the Industrial Power and Control curriculum and laboratories as well as the Internship Coordinator for the University of Southern Maine's Department of Technology.