Session 3264

Smart Materials

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Smart Materials represent a relative new branch of material science that is comprised of materials that respond with a change in shape or state upon application of externally supplied driving forces. These materials often carry titles as Intelligent Materials, Active Materials, or Adaptive 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 and responsiveness of hydraulic power transmission.

The purpose of this presentation will be to provide a method of classification for these smart materials, and to also provide an update on recent and new applications. In addition, a smart materials (magneto-rheological fluid) will be demonstrated in the context of experiments suitable for classroom instruction. Perquisite knowledge in the form of elementary power transmission concepts would be helpful but not required, and this activity is suitable for any level participant.

Introduction

Magneto-rheological fluid is a smart 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 (Korane, 1991).

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 smart materials.

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 the ball, robot's move in an awkward, lumbering fashion because conventional hydraulic valves cannot keep pace with the commands of the computerized controllers.

With an smart material such as magneto-rheological fluid, this type of response time is possible. 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 smart 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 (Scott, 1984).

When a magnetic field is applied to the smart 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 (Duclos, 1988).

Magneto-rheological 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 (Duclos, 1988).

According to Hans Conrad, professor of materials science and engineering at North Carolina State University, magneto-rheological fluids will lead to a whole new generation of brakes, automatic transmissions, actuator devices, hydraulic valves, pump parts, and motors (Conrad, 1992).

The following smart material testing activity utilizes a magneto-rheological clutch assembly and a power supply that are available commercially. These components are also found in exercise devices such as the “Stair Master”.

Procedure

Safety is always the most important consideration when working with students. It is essential that eye protection be utilized and that all participants read the operating instructions that accompanies the magneto-rheological clutch assembly and power supply. Be sure to obtain a "Material Data Safety Sheet" on the fluid from the supplier. Read and understand the sheet. Observe all recommended safety procedures.

With the power supply off, notice how easily the shafts can be rotated by hand. Increase the power output through the range of 4, 8, 16, 32, 60, and 80 % and record your observations on a data sheet that you develop.

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 observations on the data sheet.

Any common word processing or spreadsheet application software can be used to develop the data sheet. Include areas for both the varying power output and the varying frequency.

The results should indicate that the power being transmitted through the clutch increases proportionally when the power output is increased. At the lower settings, it is easy to rotate the shaft. Then, as power is increased, the amount of required torque also increases. For a more involved activity, attach a torque wrench to the shaft for quantifiable results.

A second result should discuss the relationship between the impulses of power transmission and the cycling frequency. It should be observed that as the frequency of the power supply is increased, the speed of the power transmission impulse is also increased in a proportional relationship. Two terms that are frequently used in this evaluation are instantaneous and deliberate cycling.

Bibliographical Information

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"Procedure Demonstration Power Supply Controller" directions, which accompany the tunable clutch. Clutch available from http://www.rmit.edu.au/departments/ch/rmpc/

Biographical Information

Dr. JOHN ALLEN MARSHALL taught senior high school prior to receiving his Ph.D. from Texas A&M University. He has eighteen 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.