THE DESIGN OF A MAGNETORHEOLOGICAL CONTROLLER

Florin RAVIGAN, Gheorghe MANOLEA, Niculae BOTEANU

University of Craiova

Abstract **4 The present papers presents a design algorithm for a a controller used to control a devices based on magnetorhological fluids. Also are presented some general information about smart fluids and their technical applications.**

Keywords: *smart devices, magnetorheological, controller, pwm, fuzzy, magnetic field.*

1. INTRODUCTION

Magnetorheological (MR) fluid is made of fine iron powders dispersed in silicon oil, which is utilized in many smart structures and devices because of its significant rheological property changes by the applied magnetic field. The magnetorheological response of MR fluids lies in the fact that the polarization induced in the suspended particles by application of an external magnetic field. The interaction between the resulting induced dipoles causes the particles to form columnar structures, parallel to the applied field, as shown in figure 1.

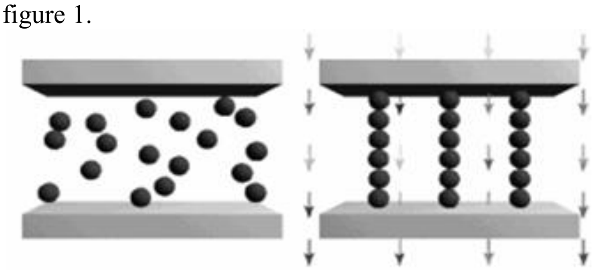

Figure 1. Micro-structures of MR fluids without/with external magnetic field applied

The property of magnetorheological fluid to change its viscosity can be used to design a lot of devices as actuator, dampers, breaks, clutches. All these applications are based on two basic structures: valve mode and direct sheer mode.

2. MR DEVICES CONTROL

All applications of smart fluids are based on the following construction:

• *Stop valve* - the energized zone is fixed, the fluid flow being influenced by the variation of magnetic field applied. This application type ican be used for hydraulic control, servovalves, dampers, actuators.

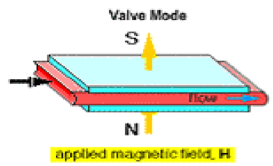

Figure 2: Valve mode

• direct shear mode – the energized zone are in relative movement; It is used for the following applications: dampers, blocking devices, breaks.

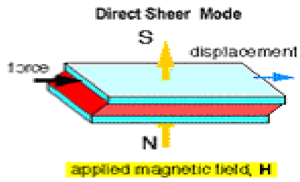

Figure 3: Direct sheer mode

In any case the variation of viscosity is made by the controlled magnetic field. This field is produced using electric coils using a voltage around of 12 volts and a value of current under 10 amperes.

2.1.A MR Actuator

The magnetorheological fluid can be used to build a MR actuator. The popular structure is presented bellow. Four valves are distributed to form a Wheatstone bridge. The opposite twins are connected to same control signal.

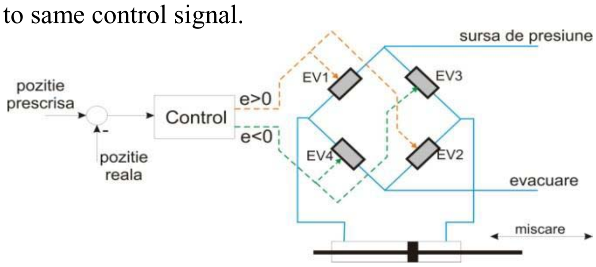

Figure 4: A magnetorhological actuator

Next is presented a classical model of cotroller for pulse width modulation. The following picture indicates the principle of controller's construction and the involved variables diagrams of time.

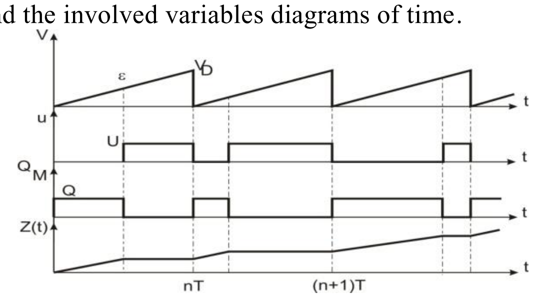

Figure 5: The command generation

The signal generator gives a triangular signal V_D with the period T and amplitude V_{DM}. The system's error is compared with V_D (with supposition that it fluctuates slower than V_D) is obtained a signal u modulated in pulses width. The voltage U permits the valve's control and of flow rate Q.

$$u(t) = \begin{cases} 0 & if\ \varepsilon(t) \geq V_D(t) \\ U & if\ \varepsilon(t) < V_D(t) \end{cases} \quad (1)$$

$$Q(t) = \begin{cases} Q_M & if\ \varepsilon(t) \geq V_D(t) \\ 0 & if\ \varepsilon(t) < V_D(t) \end{cases} \quad (2)$$

In this analyse the response times was neglected.

2.2. The design of MR valve

2.2.1. The Geometric Design

For geometric design of a magnetorheological valve we start from the value of magnetic field, flow rate and pressure drop.

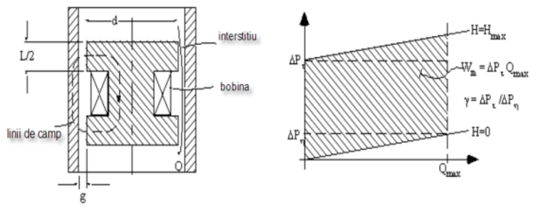

Figure 6: The structure of a MR valve

Furthermore, assume that the magnetic circuit is capable of magnetically saturating the MR fluid and that the approximate shear rate that the fluid is likely to experience at Q_{max} is known. With this knowledge, one can turn to an MR fluid specification sheet and choose appropriate fluid parameters.

Now, the design task is to choose the remaining valve dimensions (L and g) to achieve the requirements given above. If it is assumed that the gap is much smaller than the diameter (g/d << 1), width w can be approximated by w = πd. By choosing parameter c to be betwen 2 and 3, the active fluid volume V | #πdgL can be calculated.

2.1.2. Magnetic Circuit Design

The stages of magnetic circuit design are:

1. Select *operating point (Hf, Bf) in MR fluid* to give desired yield stress (ϑ). Total magnetic flux is given by ϑ= Bf * Af' where Af' is the effective pole area due to fringing;
2. Use principal of *Continuity of Magnetic Flux* to determine flux density Bs throughout flux conduit;
3.Determine *operating point in steel*. (Note, this may not be the same at different places in the flux conduit if cross section varies.);
4. Use *Kirchoffs's Law for Magnetic Circuits* to determine necessary amp-turns (NI);

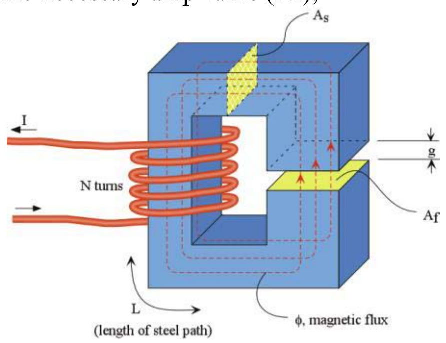

Figure 7: Magnetic circuit

3. THE CONTROLLER DESIGN

The controller for a magnetorheological device have to give the necessary power for fluid's excitation.

The change of viscosity have to be very fast. The magnetorheological fluids produced by Lord Corporation have a response time unde 1ms between states.

That controller is designed around of the Atmega8 microcontroller produced by Atmel. Atmega8 is a powerful 8bit microcontroller at 16MHz with three PWM channels and 6-channel ADC in PDIP package with 10-bit accuracy.

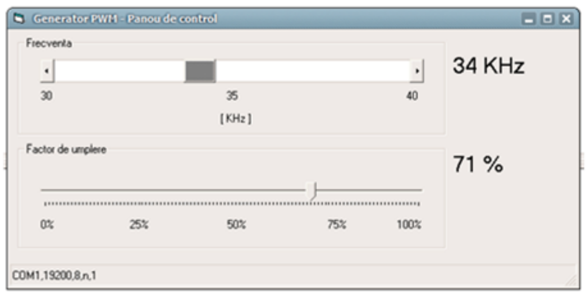

Figure 8:Test application

This microcontroller communicates with a PC via serial and a graphical win32 intefaces. From PC, the user send to microcontroller the command strategy. The strategy are stored inside of microcontroller and after that the connection with the PC is no more necesary.

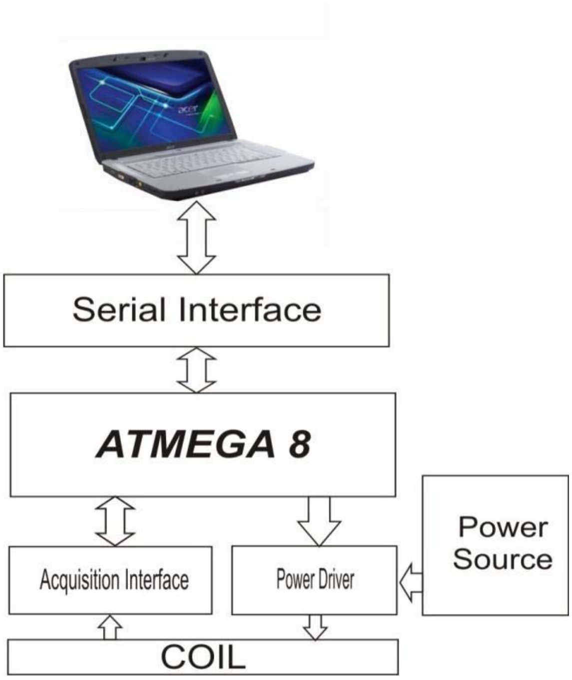

Figure 9:The system architecture

The microcontrollers generates the command for the power driver which have the mission to provide the energy for the coil to produce the magnetic field. The power driver for each MR valve was designed and built with a very fast filed effect transistor(IRF5305). The hole circuit is protected with a diode(BYW29E). The command signal applied to the coil is presented in the following picture(fig.11).

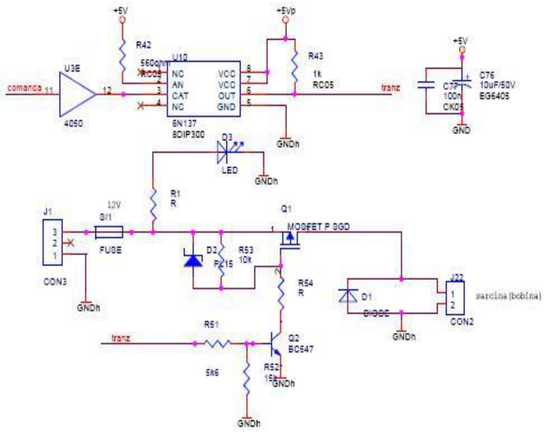

Figure 10: The schematic for power driver

Applying a PWM control until the difference between the reference position and the real position is zero, we have obtain the curves from picture 12.

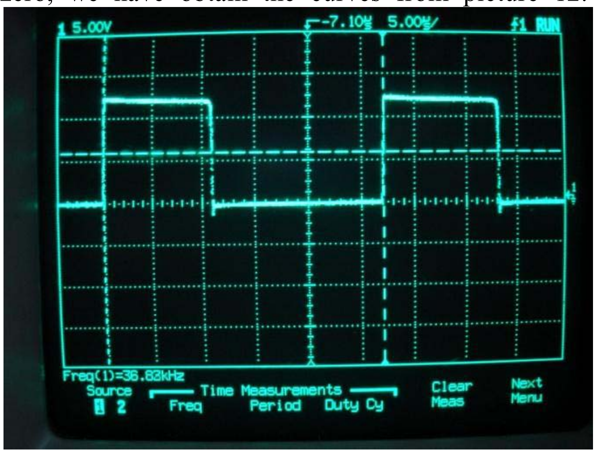

Figure 11: The command signal for the coil

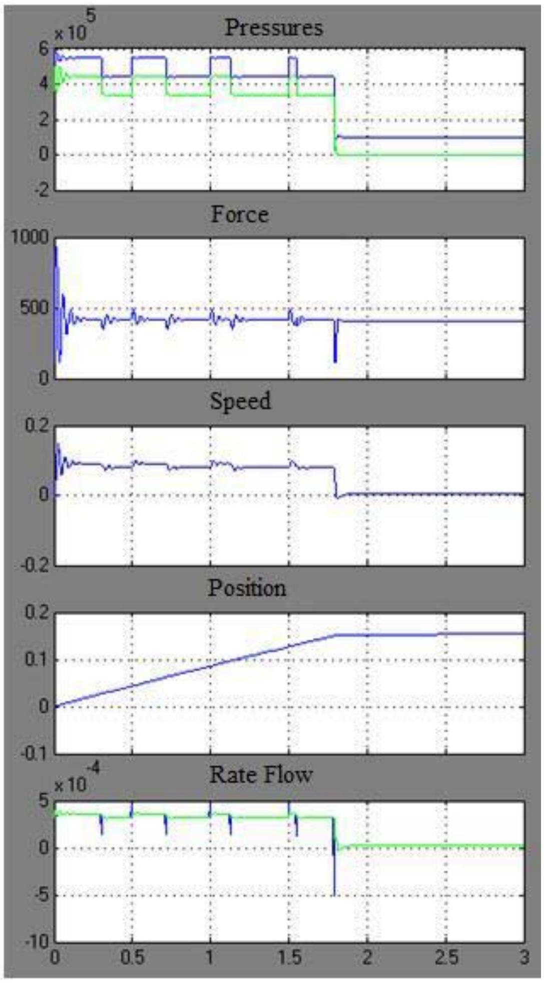

Figure 12: The PWM command of MR valves

4. CONCLUSIONS

The controller was tested in laboratory and the result was very good. It can be used to apply a pulse modulation width control or a fuzzy one. This fluidic controller can be used in electromechanical system, mecatronics, with the all advantages of hydraulic power.

References

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