FORCE TRACKING CONTROL OF MAGNETO-RHEOLOGICAL (MR) DAMPER USING PI CONTROL

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CONFESSION

"I admit that this report is from my own work and idea except for the summary and a few sections which were extracted from other resources as being mention".

Signature :…………………………............

Writer Name :……………………................

Date :……………………………….

FOR MY LOVELY PARENTS, MY BROTHERS AND MY SISTERS, GIVE ME A SPIRIT AND INDUCEMENT TO SUCCESS IN MY STUDIES AND MY FUTURE. TO ALL MY LECTURER AND FRIENDS, SPECIAL THANKS FROM ME CAUSE GIVE SUPPORT AS LONG I WILL BE HERE.

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ABSTRAK

Kertas ini adalah bagi bertujuan memaksa penjejakan kawalan bagi pelembap MR menggunakan kawalan PI. Dengan memajukan polinomial model akan mengeluarkan hasil yang percubaan mengandungi satu subsistem pasangan yakni positif (lengkung atas) dan negatif (lengkung lebih rendah) pecutan. Setiap satu melengkok dimuatkan ke dalam persamaan polinomial memanggil titik keras dalam borang itu daya redaman sebagai fungsi halaju omboh. Pekali-pekali bagi fungsi polinomial adalah dilinearkan dengan menghormati untuk arus masukan digunakan ke atas pelembap gelung-gelung. Keenam mengarahkan polinomial model menunjukkan prestasi lebih baik dalam menghuraikan tak linear histeresis tingkah laku bagi pelembap MR dibandingkan dengan model songsang. Pi kawalan mempunyai satu keupayaan bagi mengesan pasukan redaman terhasrat.

ABSTRACT

This paper is to purposed force tracking control of MR damper using PI control. By developing polynomial model will produce experimental result consists of a pair subsystem namely positive (upper curve) and negative (lower curve) acceleration. Each curve is fitted into polynomial equation calls hard point in the form of damping force as the function of piston velocity. The coefficients of polynomial function are linearized with respect to the input current applied to the damper coils. Sixth order polynomial model shows better performance in describing the non-linear hysteresis behavior of MR damper compared with inverse model. PI control has an ability to track the desired damping force.

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INTRODUCTION

1.1 Background

The purpose of this project is to see the performance of Magneto-rheological (MR) damper using PI control. A few years ago, automotive suspension designs have been a compromise between the two conflicting criteria of road holding and passenger comfort. The suspension system must support the weight of the vehicle, provide directional control during handling maneuvers, and provide effective isolation of passengers and payload from road disturbances.Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serve a dual purpose contributing to the cars handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations.

Damper is the most important in suspension system. Damper function is the control of motion or oscillation, as seen with the use of hydraulic gates and valves in a vehicles shock absorber. Like spring rate, the optimal damping for comfort may be less than for control. Damping controls the travel speed and resistance of the vehicles suspension. An undamped car will oscillate up and down. With proper damping levels, the car will settle back to a normal state in a minimal amount of time. Most damping in modern vehicles can be controlled by increasing or decreasing the resistance to fluid flow in the shock absorber. Now there many types of suspension can make car more comfortable in any road condition. It has three main types of vehicle suspensions like passive, semi-active and active suspensions, which depend on the operation mode to improve vehicle ride. Inside damper it has solenoid and MR fluid to control the hydraulic damper. When current is supply, the particles of MR Fluid forms in direction chains. In this condition, the damper is controlled by MR damper.

1.2 Problem Statement

Magneto-rheological (MR) damper is semi-active devices are controlling by current. MR fluid inside MR damper change from liquid into semi solid when current is applies. MR damper can generate force from viscous or viscoelastic plastic fluid. MR dampers contain controllable fluids that can change their properties when exposed to magnetic fields. By controlling the current to an electromagnetic coil inside the piston of the damper, the MR fluid’s viscosity can be changed, resulting in continuously variable real-time damping system. MR damper is a relatively a recent damping device, in which the magnitude of the resisting force acting upon a mechanical structure can be adjusted in real time. Adjustment takes place by varying the amount of current passing through wires embedded in the damper. Use the suitable method to track the desired damping force.

1.3 Objective

- To study the simulation of Magneto rheological (MR) Damper force tracking control using 6^{th} polynomial model.
- Experimental work of Magneto rheological (MR) Damper force tracking control.
- Validation and evaluation between the desire force and actual force.

1.4 Scope

Experimental of MR damper use Delphi A33 manufactured by Delphi Automotive System. Simulink of Magneto-rheological (MR) Damper use Matlab Simulink. Validation and evaluation between the desire force and actual force for the Magneto-rheological (MR) Damper by experimentally use quarter car test rig.

1.5 Outline

CHAPTER 1

For this chapter is an introduction about this project. Inside chapter 1, it has background, problem statement, objective and scope.

CHAPTER 2

Chapter 2 is a literature review. This chapter include introduction of automotive suspension system, Magneto-rheological (MR) damper, Magneto-rheological (MR) Fluid, Mathematical model, Existing model, PI control, and Force tracking control.

CHAPTER 3

Chapter 3 is about methodology. This chapter content, Flowchart, Explanation, Experiment setup and procedure, Equipment, Instrumentation, Instrument setting, Technical specification, and Result variable.

CHAPTER 4

Result and discussion content in chapter 4. For this chapter include the result from simulation and experimental. The sub-topic for chapter 4 is Simulation of 6^{th} order polynomial, Experiment result and validation, Simulation study of MR damper force tracking control and Discussion.

CHAPTER 5

Last chapter is chapter 5. For this chapter include conclusion and recommendation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Automotive Suspension System

The suspension system isolates the body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It also must keep the tires in contact with the road. When a tire hits an obstruction, there is a reaction force. The size of this reaction force depends on the unsprung mass at each wheel assembly. The sprung mass is that part of the vehicle supported by the springs and unsprung mass not supported by the springs. Vehicle ride and handling can be improved by keeping unsprung mass as low as possible. Basic suspension systems are included like springs, axles, shock absorbers, arms, rods, and ball joints. Modern passenger vehicles usually use light coil springs. Light commercial vehicles have heavier springs than passenger vehicles, and can have coil springs at the front and leaf springs at the rear. Heavy commercial vehicles usually use leaf springs, or air suspension.

Vehicle ride and handling is improved by keeping unsprung mass as low as possible. Now it have damper where it control by current for the damping ratio. It is semi active damper call Magneto rheological (MR) damper control by current. When applied the current, MR fluid inside the cylinder change from liquid into semi solid. A Magneto-Rheological (MR) damper is a damper filled with MR fluid, which is controlled by a magnetic field, usually using an electromagnet. This allows the damping characteristics of the shock absorber to be continuously controlled by varying the power of the electromagnet. This type of shock absorber has several applications, most notably in semi-active vehicle suspensions which may adapt to road conditions.

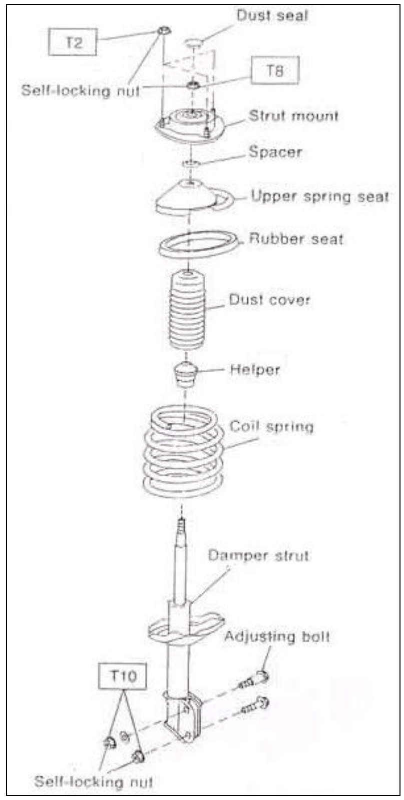

Figure 2.1: Schematic diagram of suspension system

2.2 Magneto-Rheological (MR) Damper

Magneto-rheological (MR) damper is filled with a controllable fluid namely Magneto-rheological (MR) fluid that contains dispersed micron-sized magnetically polarisable particles. When the fluid is subjected to the magnetic field, the particles are arranged in a pattern and the behavior of the fluid is changed from being linear viscous to a semi-solid in milliseconds. By adjusting the current within an allowable range, the resisting force to motion of the MR damper increases or decreases in a non-linear fashion. When various magnitudes and patterns of current are applied to the MR damper, resistance of the damper to motion can be adjusted.

2.3 Magneto-rheological (MR) Fluid

Magneto-Rheological (MR) fluids respond to a magnetic field with a dramatic change in rheological behavior. These fluids can reversibly and instantaneously change from a free-flowing liquid to a semi-solid with controllable yield strength when exposed to a magnetic field.The magnetic particles, which are typically micrometer or nanometer scale spheres or ellipsoids, are suspended within the carrier oil are distributed randomly and in suspension under normal circumstances, as shown in Figure 2.2.

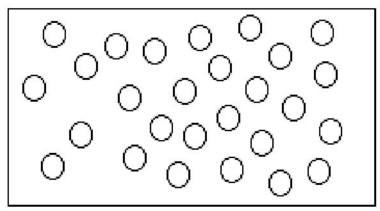

Figure 2.2: No magnetic field

When a magnetic field is applied, however, the microscopic particles align themselves along the lines of magnetic flux, as shown in Figure 2.3. When the fluid is contained between two poles, the resulting chains of particles restrict the movement of the fluid, perpendicular to the direction of flux, effectively increasing its viscosity. Importantly, mechanical properties of the fluid in its on state are anisotropic. Thus in designing a magneto-rheological device, it is crucial to ensure that the lines of flux are perpendicular to the direction of the motion to be restricted.

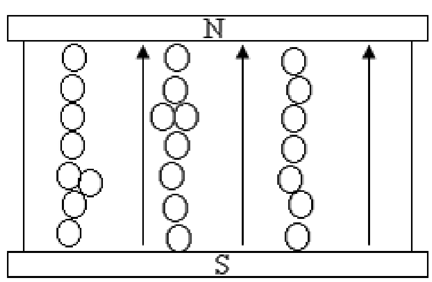

Figure 2.3: With magnetic field

2.3.1 Mathematical model

The stress-strain behavior of the Bingham viscoplastic model can be used to describe the behavior of MR fluids. In this model, the plastic viscosity is defined as the slope of the measured shear stress versus shear strain rate data. That is

$$\tau = \tau_{y(field)} + \mu\dot{\gamma}$$

where $\tau_{y(field)}$ is the yield stress induced by the magnetic field and μ is the viscosity of the fluid.

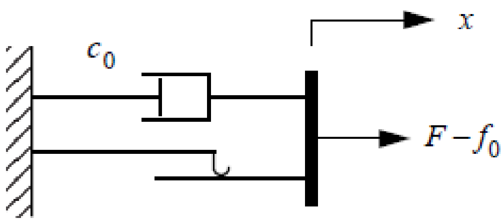

Figure 2.4: Bingham model of a MR damper

(Source: Spencer, Dyke, Sain & Carlson March 10, 1996)

Based on the Bingham model of the MR fluids, a modified model is proposed to describe the behavior of the MR damper. The model consists of a Coulomb friction element placed in parallel with a viscous damper, as shown in Figure 2.4. In this model, the force generated by the device is given by

$$F = f_c sgn(\dot{x}) + c_0\dot{x} + f_0$$

where c is the damping coefficient and f is related to the fluid yield stress and the input voltage. F_0 is used to reflect the offset effect due to the accumulator in the MR damper. The sign function is given as:

$$sgn(S)\begin{cases} +1 & if\ s > 0 \\ -1 & if\ s < 0 \end{cases} \qquad eq.(3)$$

The force f is expressed as

$$f = f_0 + G_v \qquad \text{eq. (4)}$$

where f_0 is the friction force, v is the input voltage to the MR damper and G is the gain of the induced force. After insert eq. (4) into eq. (3), the mathematical model of the MR damper is given by

$$F - f_c sgn(\dot{x}) + c_0\dot{x} + f_0$$

The comparison between the predicted and experimentally obtained responses shows on Figure 2.5. Although the force-displacement behavior appears to be reasonably modeled, examination of the force-velocity response and the temporal variation of the force show that the behavior of the damper is not captured, especially for velocities that are near zero. The measured force has a +ve value when the acceleration is negative for +ve displacements, and a negative value when the acceleration is positive for -ve displacement at zero velocity.

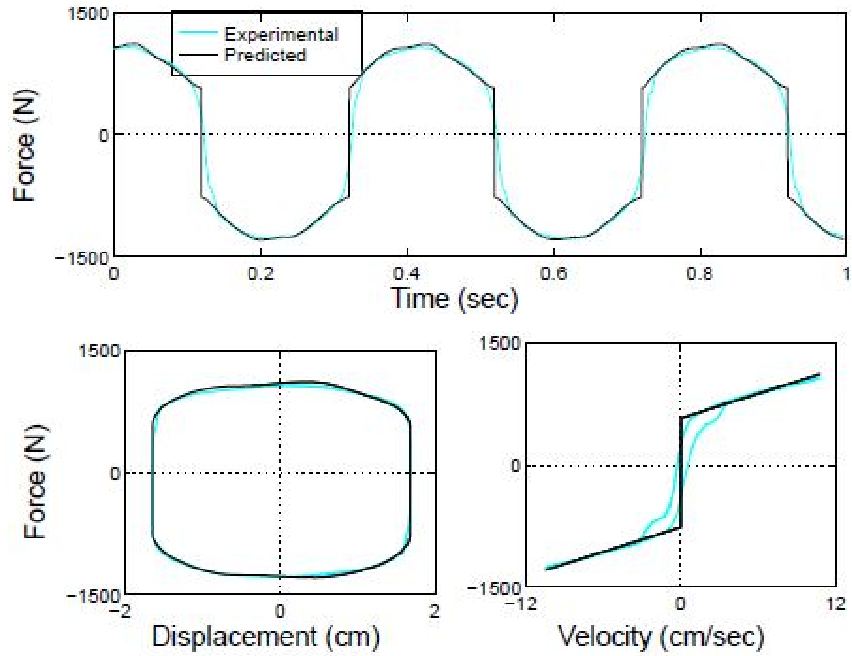

Figure 2.5: Comparison between the Predicted and Experimentally Obtained Responses for the Bingham Model

(Source: Spencer, Dyke, Sain & Carlson March 10, 1996)

Bingham model can portray the force-displacement behavior of the damper well. One model that is numerically tractable and has been used extensively for modeling hysteretic systems is the Bouc-Wen model (Wen 1976). The Bouc-Wen model is extremely versatile and can exhibit a wide variety of hysteretic behavior. A schematic of this model is shown in figure 2.6. The force in this system is given by

$$F = c_0\dot{x} + k_0(x - x_0) + \alpha_z$$

$$\dot{z} = -\dot{\gamma}|\dot{x} - \dot{y}|z|z|^{n-1} - \beta\dot{x}|z|^{n} + A\dot{x}$$

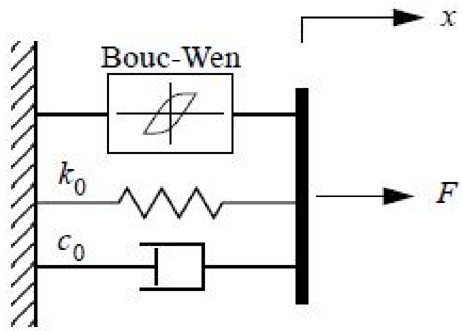

Figure 2.6: Bouc-Wen Model of the MR Damper

(Source: Spencer, Dyke, Sain & Carlson March 10, 1996)

The parameters of the model γ, β and A will be adjusted so that one can control the linearity in the unloading and the smoothness of the transition from the pre-yield to the post-yield region. The force f_0 due to the accumulator can be directly incorporated into this model as an initial deflection x_0 of the linear spring k_0. To obtain the governing equations for this model, consider only the upper section of the model. The forces on either side of the rigid bar are equivalent. Therefore,

$$c_1\dot{y} = \alpha z + k_0(x - y) + c_0(\dot{x} - \dot{y})$$

Where the evolutionary variable is governed by

$$\dot{z} = -\dot{\gamma}|\dot{x} - \dot{y}|z|z|^{n-1} - \beta(\dot{x} - \dot{y})|z|^n + A(\dot{x} - \dot{y})$$

$$\dot{y} = \frac{1}{(c_0 - c_1)}\{\alpha z + c_0\dot{x} + k_0(x - y)\}$$

$$F = \alpha z + c_0(\dot{x} - \dot{y}) + k_0(x - y) + k_1(x - x_0)$$

The total force can also be written as

$$F = c_1\dot{y} + k_1(x - x_0)$$