An Electronically Controlled Damper System to Reduce the Roll and Pitch in Automobiles.

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Abstract – *Automobiles today still use the traditional form of suspension which used a hydraulic type of damper; but it only has a fixed response to different road conditions. This paper presents an electronically controlled semi-active suspension; it uses a magnetorheological damper which provides a much wider response range than the traditional hydraulic damper. The suspension response is based on the readings of an accelerometer. This accelerometer measures the change in orientation along X-Axis and Y-Axis. The X-Axis values show the roll suffered radially by the vehicle and Y-Axis shows the change in the pitch of the vehicle along its axis. The magnetorheological damper (MR damper) is then actuated using a controller to improve ride comfort and road handling of the vehicle. The goal is to demonstrate how an MR damper based shock absorber is able to adapt to various road conditions.*

Key Words: MR damper, MR fluid, Accelerometer ADXL335, Arduino, CATIA V5 Software

1. INTRODUCTION

The role of suspension in a vehicle is to isolate the vehicle from the vibrations produced due to irregularities of the road and to improve road holding. This improves the comfort level of the passengers and more importantly increases safety by allowing the vehicle to turn, accelerate, climb steep slopes and brake without compromising stability. Suspension and dampers are not associated with automobiles alone. Dampers are also used in special purpose applications such as prosthetic knees to adapt knee damping to the gait of the amputee [1]. Dampers are used in aviation industry, to damp the shock which occurs during landing. They are also used to reduce the flapping of helicopter rotor blades which occur due to sudden gusts of wind. Dampers are also used in weapons; they are used to reduce the recoil of high power guns and missiles.

The history of suspension is as old as that of automobiles. The Ford Model T produced in 1908-1927 is recognized as the first affordable car and it used leaf springs for suspension. The leaf spring is one of the earliest forms of suspension. It worked on the principle of friction between the individual leaves to reduce shocks to a vehicle. They worked in both directions but the friction changed depending on if the weather was wet or dry. Later helical springs were introduced which eliminated this problem. But the characteristic to and fro motion of the spring remained an issue. C.L Horock came up with the solution of hydraulic damping in 1901 but the hydraulic dampers did not go into production until 1912.

A suspension generally consists of two components a spring and a damper. The spring absorbs the energy produced due to vertical movement when a vehicle hits a bump or rolls or pitches during a turn or while accelerating. This causes the spring to undergo a to and fro movement (compression and expansion) which in turn causes the occupants to suffer the same. The role of the damper is to dissipate this energy by valving of oil and reduce the motion.

Suspension can be classified as passive suspension or active suspension. Suspension made using traditional springs and damper with fixed value of stiffness is known as passive suspension. Here the suspension reacts directly to road conditions. Active suspension controls the movement of the wheels relative to the chassis. It reacts to a stimulus provided by an onboard electronic system. Active suspension can further be classified as fully active and semi-active suspension. The fully active suspension in addition to the above requirement also contains an actuator to move the chassis. The semi-active or adaptive suspension changes the stiffness of the damper according to the signal provided by the onboard system. There are several methods of implementing a semi-active suspension; one such method is using a magnetorheological damper or MR damper. A typical damper contains a hydraulic fluid of fixed viscosity and yield strength. An MR damper contains Magnetorheological fluid or MR fluid which is a suspension of micron-size solid particles in non-conductive carrier oil, which undergoes a transition from a fluid to a pseudo-solid in the presence of magnetic stimuli [2]. As a result it has variable viscosity and yield strength.

MR fluid is a smart material. Smart materials are those capable of responding to environmental changes and manifesting their function according to them in a coordinated fashion [3]. MR fluid allows the suspension to react to external stimuli in a manner mimicking natural and biological methods which are self adapting to external conditions. The smart material forms a part of a smart system. Smart systems sense and respond to external stimuli by forming a feedback loop between input and output. These types of systems form the basis for Adaptronics, a term used for smart adaptive technologies. Adaptronics is a multidisciplinary field which incorporates several fields such as material sciences, electronics and computer technology. It allows for more organic solutions to engineering problems such as vibration control, energy harvesting, health monitoring, etc.

2. Materials, Devices and Software used.

Technology has allowed the cost of components to go down. More and more software now allow the development cycle to become shorter. The materials, devices and software used in this study are given as follows.

2.1 MR damper

In the automotive industry a damper is known misleadingly as a shock absorber. The spring performs the action of absorbing the shock and it is the job of the damper to dissipate the energy which results in the typical to and fro motion of the spring. Conventionally vehicles have used dampers filled with hydraulic fluid. But this can only provide a fixed resistance.
For the purpose of this study a simple MR damper was designed and fabricated. The entire construction is made up of mild steel. Mild steel is also known as Carbon Steel as it contains 0.05% - 0.25% carbon. This provides the advantage of being easy to shape as its malleability and ductility increases. The MR damper designed for this piston mainly consists of three parts the electromagnetic piston, a cylindrical outer casing and the MR fluid. A connecting rod attached to the piston acts as a force transferring part. They are described as follows.

2.1.1Electromagnetic Piston

The electromagnetic piston is used for providing a magnetic field and for pumping the MR Fluid through the cylinder. The piston body was coiled with 28 gauge wire of approximately 250 turns around the piston core of length of 100 mm length and 28mm diameter. The magnetic field produced due to these coils flows through the core and outwards in radial direction from the piston poles. The piston poles of 38mm diameter have 6, 2mm holes located hexagonally at distance of 1.6mm from the piston axis. The piston poles allow MR Fluid to flow in valve mode where the flow is constricted due to the magnetic field. The **Fig-1** shows the 3-D rendition of the design done using CATIA V5 software. Given below are the piston dimensions in **Table-1**.

TABLE-1: Piston Dimensions

Part Name	Dimension(mm)
Piston Head length	10
Piston Head Diameter	38
Valve Diameter	2
Piston Core Length	100
Piston Core Diameter	28
Connecting Rod	300

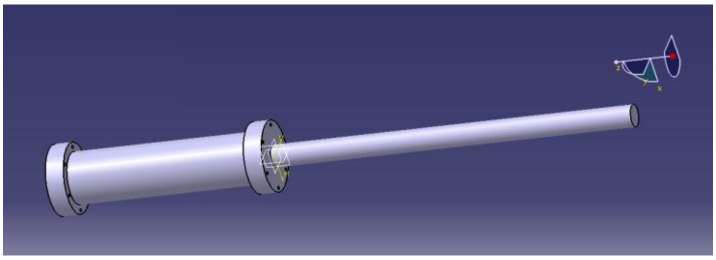

Fig-1: Electromagnetic Piston

2.1.2MR fluid

MR fluid is a suspension of a carrier liquid (mineral oils, silicone oils, and perfluorinated polyethers.) and micron sized iron alloy particles which usually lie within a range of (1-500 μm)[4]. In a non-magnetic environment the MR Fluid is a free flowing liquid. In the presence of a magnetic field the iron alloy particles get aligned parallel to the magnetic field and results in the fluid acting as a pseudo-solid. Here Fe particles of approx 5μm and silicone oil of viscosity 0.2Pa.s were mixed in the proportion of 2/3 by to create the magnetorheological fluid.

2.1.3Outer Casing

A cylindrical casing of 40mm diameter was used to act as the vessel of length 300 mm and thickness 1.5mm. The **fig-2** shows the 3-D rendition of the design done using CATIA V5 software.

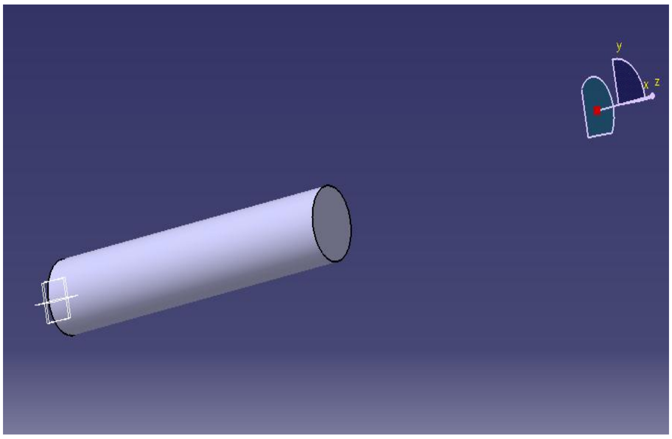

Fig-2: Outer Casing

2.2Accelerometer ADXL335

An accelerometer is a device used for measuring static acceleration. The ADXL335 is a 3-axis acceleration measurement sensor. In this application it is used for measuring tilt due to static acceleration due to gravity [5].

Specifications

- Full scale range of ±3 g acceleration.
- Bandwidth of 0.5 Hz to 1600 Hz for the X and Y axes and 0.5 Hz to 550 Hz for the Z axis.
- Input voltage of 1.8 V to 3.6 V and current of typically 350 µA.
- Ratiometric output, the output sensitivity is proportional to the supply voltage. At input voltage of 3.6 V it gives a sensitivity of 360mV/g.
- It has and analog output.
- Communicates serially at 9600 baud.

2.3Arduino UNO R3 development board

This system was developed and tested on the Arduino UNO R3 development board. The board is based on the ATmega328p which is a 8bit microprocessor.
Specifications

- It has a flash memory of 32 Kb.
- It has SRAM of 2 Kb.
- It has an EEPROM of 1Kb.
- Clock speed of 16 MHz.
- It has a 10 bit Analog to Digital convertor.
- The board has 10 digital I/O pins and 6 analogue pins.
- It works on both USB and adapter power supply of 5V and maximum input current 50mA.

2.4Arduino IDE

The Arduino IDE (Integrated Development Environment) is a program or more specifically a compiler that allows the user to write programs (known as sketches in the Arduino environment) which is modelled after the Processing language [6]. The Arduino IDE compiles and debugs the sketch and also facilitates uploading of the program. The programming environment is shown in **fig-3**.

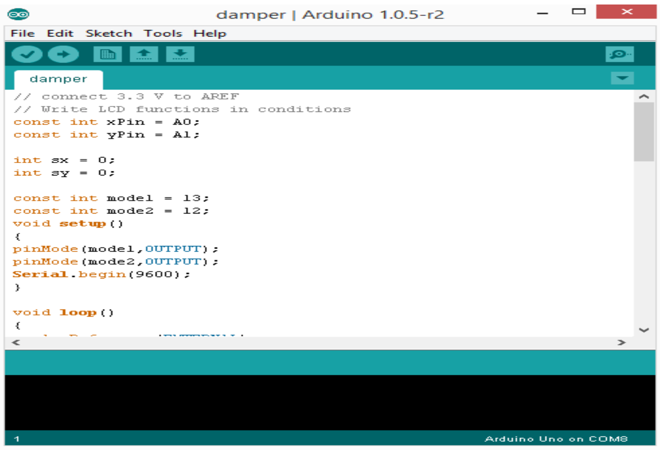

Fig-3: Arduino IDE

3. Methodology

The system block diagram is shown in **fig-4** which represents the circuit designed. The flow chart for the designed system is shown in **fig-5**. The system is first powered on. The accelerometer starts capturing the static acceleration data. The microcontroller on the Arduino board starts receiving data from the accelerometer in the form of an analog signal. The atmega328 has a 6 channel and 10 bit analog to digital converter. This means that it will map the input voltage of 0V – 5V into 0 – 1023 as a 10-bit ADC has 1024 levels. Therefore it has a resolution of 4.9mV per level [7]. The accelerometer ADXL335 has a working voltage of 3.3V. Therefore the AREF pin has to be set to 3.3V.
The X-Axis values indicate the roll values of the vehicle due to turning. The Y-Axis values indicate the pitch of the vehicle while accelerating and while braking. Various conditions are set in the code for various driving situations. The driver is notified of which mode the vehicle currently is in by a LCD screen. Each driving mode applied corresponds to three different currents supplied to the MR Damper. Two of these modes are controlled using the GPIOs of the Arduino which are used to switch between different current levels. When different currents are passed through the electromagnetic piston different yield stresses are developed in the MR Fluid present in the damper.

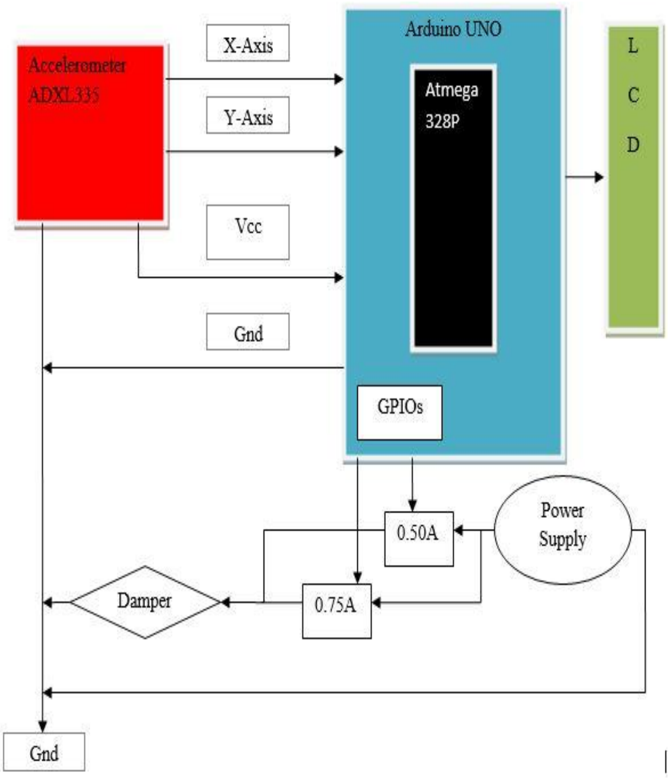

Fig-4: System Block Diagram

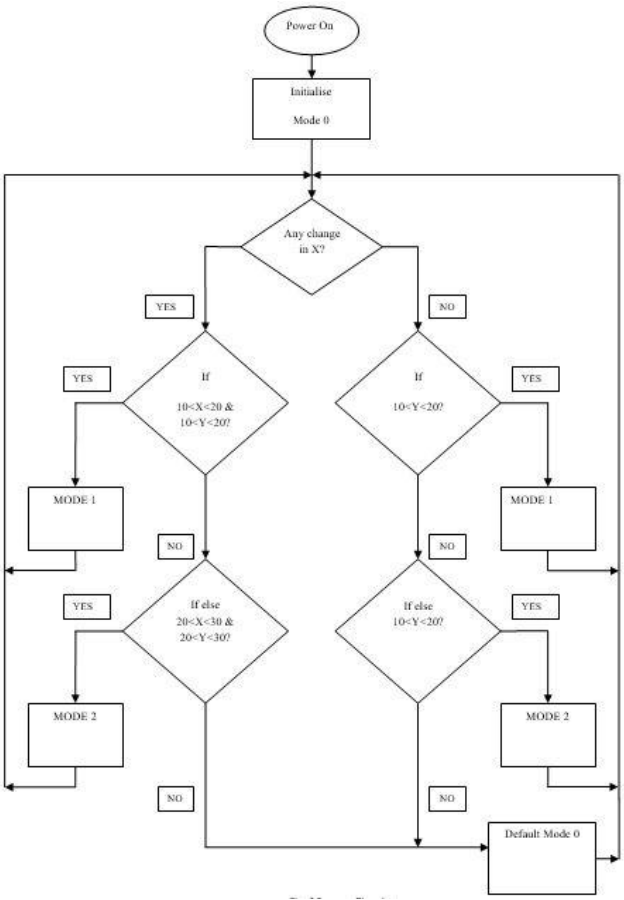

Fig-5: Program Flowchart

The modes shown in the flowchart refer to three different modes of the MR damper. In low values of pitch and roll of the vehicle the MR damper will act as a normal damper. No current and voltage will be passed. This condition is termed as Mode0. During slight variations of pitch and roll the MR damper will function in Mode 1 where 0.5A and 12V current will be passed. While driving on steep roads or sharp turns the MR damper will be in Mode 2 where a 0.75A and 12V current will be pass through the coil. The various damper modes are shown in **table-2**.

TABLE-2: Damper Modes

Mode	Current (A)	Voltage (V)	Magnetic Field (mT)
Mode 0	0	0	0
Mode 1	0.5	12	2.24
Mode 2	0.75	12	3.37

4. Results

This new system exhibits a wider response range to road conditions than a conventional hydraulic damper based suspension. Although there are hydraulic damper systems where the stiffness of the damper can be modified it requires manual calibration. The system developed in this study allows the damper to adapt to road conditions in real time.The circuit designed switches smoothly between the stated modes according to change in roll and pitch values offered by the accelerometer on the Serial Monitor of the Arduino IDE as shown in **fig-6**.

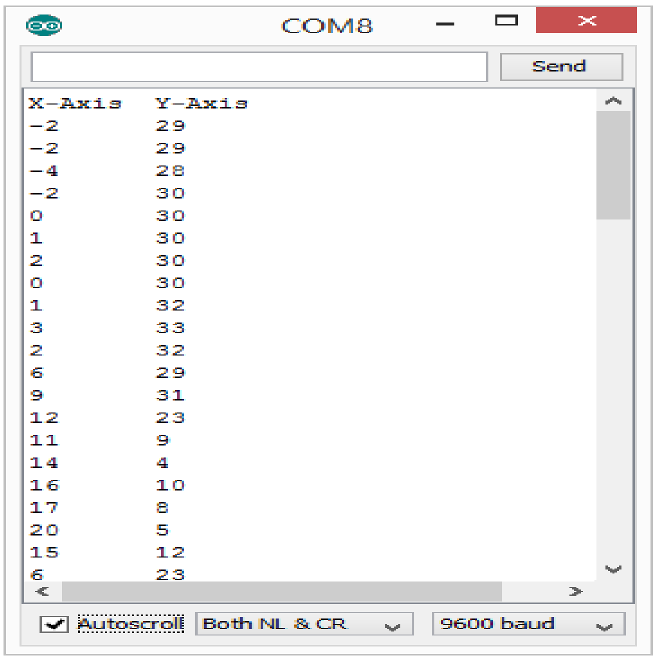

Fig-6: Accelerometer Readings on Serial Port

The piston was fabricated and manufactured and is operating within stipulated range. The final manufactured device is shown in **Fig-7**. The theoretical value of magnetic field generated by the coil was calculated by the formula

$$B = \mu (N/L) I$$

Where μ (Permeability for carbon steel) = $1.26 * 10^{-4}$ H/m

N (Number of turns) = 200

L(Coil length) = 5.6m

I(current) = 0.5A,0.75A

Thus magnetic fields generated for 0.5A and 0.75A currents were 2.24mT and 3.37mT respectively.

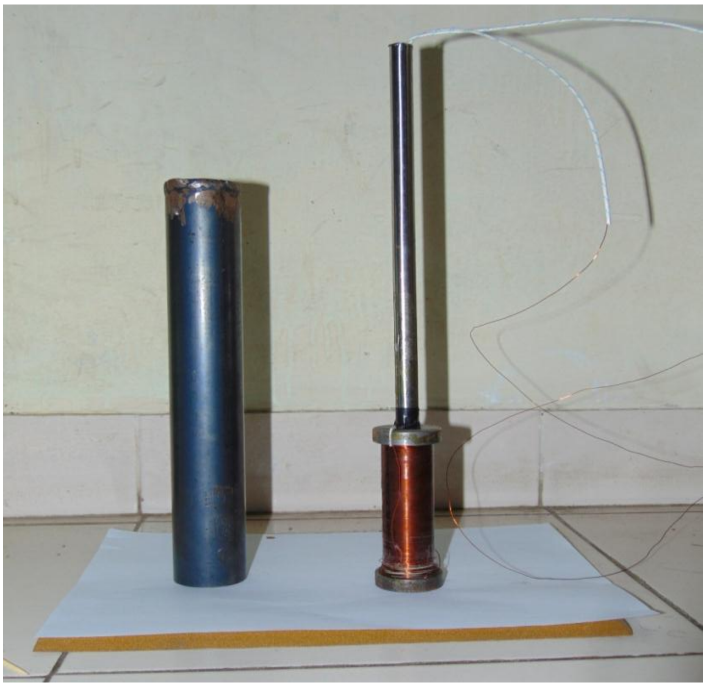

Fig-7: MR damper prior to final assembly

5. Conclusion and Future Work

In this study a new system is proposed with the task of improving road handling of a vehicle suffering from changes in roll and pitch due to road conditions. Using this system the ride comfort of the occupants will also improve. This system provides a reliable solution to increase road safety as the driver will be able to drive with more ease. The Magnetorheological damper when combined with other factors such as tire conditions, vehicle speed, collision warning systems, etc will be able to provide an even more comprehensive safety mechanism. Future work may include energy harvesting where energy dissipated by the damper may be reused to power the suspension system itself. An additional field to explore is experimentation with multiple independent coils on different parts of the piston to examine the effect of different polarities being given to different areas of MR fluid. We wish to examine the effect of pulsating and changing EM fields on MR fluid and to see what applications are possible. Using the Arduino microprocessor, we will be able to alter the EM field programmatically and will be able to control several EM coils in different sequences simultaneously. We are not aware if any work has been carried out in this domain previously.

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References

[1] Hugh Herr, Ari Wilkenfeld, User-adaptive control of a magnetorheological prosthetic knee, Industrial Robot: An International Journal, Volume 30-Number 1-2003

[2] Janusz Gołdasz, Bogdan Sapiński, Insight into Magnetorheological Shock Absorbers, Springer Cham Heidelberg New York Dordrecht London, Springer International Publishing Switzerland 2015

[3] Takagi, T. (1996), Recent research on intelligent materials, Journal of Intelligent Material Systems and Structures

[4] Carlson, D. J., & Weiss, K. D. (1995). Magnetorheological materials based on alloy particles, US Patent No. 5,382,373

[5]https://www.sparkfun.com/datasheets/Components/SMD/adxl335

[6] Massimo Banzi, Getting Started with Arduino, 2nd Edition,O'Reilly, September 2011

[7] Jeremy Blum, Exploring Arduino: Tools and Techniques for Engineering Wizardry, Wiley 2013