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Examining the Energy Harvesting Methods from a Vehicle Suspension System

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ABSTRACT

In the past few decades, passive suspension system has been broadly utilized in passenger automobile suspension gadget. The requirement of improving the ride and dealing with performance has fueled up enormous researches into controllable suspension which offer variable damping and controllable force to stabilize the vehicle motions. With the increasing population the strength intake has improved which makes the requirement for easy electricity essential, now extra than ever. The delivery sector is one of the most important participants to this consumption and need to therefore be considered when seeking out environmentally pleasant answers. The majority of gasoline power in road bound cars of nowadays is dissipated and is consequently in no way utilized. This work examines electrostatic, piezoelectric and electromagnetic methods of power regeneration and it's far concluded that electromagnetic generators are the maximum viable while carried out to motors. A suspension system using an electromagnetic generator coupled with a magneto-rheological (MR) damper is the maximum top-quality when searching at performance, value, robustness and environmental impact. It can generate as much as 90W and is shown to be the strongest machine due to its few transferring elements. The operating principle of the regenerative electromagnetic MR damper is explained and mathematical models describing the characteristics of the MR damper and the electromagnetic generator are proposed.

Keywords: Energy Harvester, Energy Regeneration, Electromagnetic suspension, MR damper.

1. INTRODUCTION

Suspension method improves passenger's consolation in car and minimizes the harm of vehicle additives caused by road irregularities. A few decades ago, suspension machine for passenger automobiles has been dominated by the conventional passive suspension. As proven in Fig. 1, they may be modeled with the aid of a spring and damper in parallel; each with stiffness and damping coefficients k_1 and c_1, connecting the wheels (unsprung mass with coefficients k_2 and c_2) and the automobile body (sprung mass).

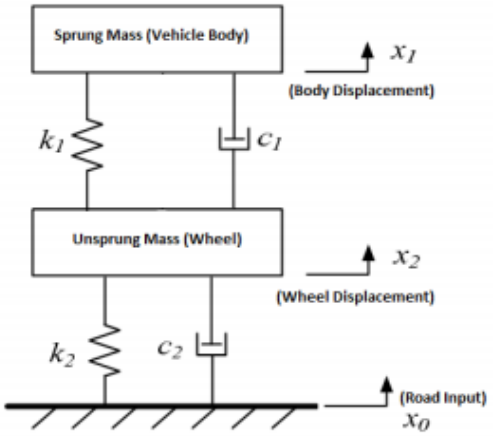

Figure No: 1 Suspension Model of Quarter Car

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While its simplicity and cost effective features has been verified useful, it could best offer confined damping and stiffness to the car throughout maneuvers on abnormal road surfaces. Thanks to the increasing availability of supercomputers and rapid processors, controllable suspensions have been extensively studied within the past few decades to offer variable damping and forces to cater to these desires [6]. These systems can be classified into two primary kinds; semi lively and active suspension structures. In an average passengers' system, maximum of the power generated by way of the power train could be dissipated for the duration of braking, thru inner friction inside automobile components and aerodynamic drag all through everyday cruising. Approximately, handiest 10% of the generated electricity became used correctly to power up the vehicle. In a regular suspension system, power from external excitations specially caused by the road surfaced usually absorbed by using the damper. This energy is converted into warmness energy in the damper fluid and dissipated to the surrounding. A lot of efforts have been made to harvest this power from the suspension and supply it to the primary power educate for added power deliver and advanced performance. Moreover, active suspension machine has been claimed to require excessive strength supply to operate. The regenerated energy can be supplied to energy up the suspension machine itself. The contribution is probably small but with proper electricity control and suitable manipulate strategy; the gathered electricity can be considerable and beneficial.

This method examines electrostatic, piezoelectric and electromagnetic techniques of regeneration of energy and it's been concluded that electromagnetic generators are the most possible whilst applied to vehicles. The running principle of the regenerative electromagnetic MR damper is explained. The purpose of this projected work is to determine what possibilities a regenerative suspension system has for improving the electricity consumption in vehicles.

2. RELATED WORK

The choice of suspension mechanism is essential before determining the control strategies to be implemented. Mechanism of suspension will govern the shipping manner of suspension forces to the vehicle. This section will review various mechanisms normally employed in suspension unit to offer damping and vibration isolation required through the automobile system. The most common suspension mechanisms are constantly variable damper, magneto rheological (MR) damper, electro rheological (ER) damper, and electromagnetic actuator.

Generally, suspension structures for vehicle consist of spring and damper. They are used to isolate the automobile body from avenue disturbance and roll and pitch impact. Common sort of damper used is hydraulic damper because it is cheap and reliable. Hydraulic dampers also are easy to layout, have high force density, and its elements are easy to find. However, due to consistent damping coefficient possessed by using hydraulic damper, it has very low bandwidth this is, it is simplest efficient in compensating low-frequency disturbances i.e. Roll and pitch of the vehicle. This is verified by Gysen et al. [1] whilst anti-roll bar comprising of hydraulic actuator was successfully avoided the roll and pitch movement of the automobile. Hydraulic damper do not successfully remove the excessive-frequency disturbance i.e. Disturbance because of roads irregularities when the vehicle transverse on an instantly path. So, the need of controllable damping force (semi-active and energetic machine) in suspension gadget

is essential when you consider that it can function in wider bandwidth as compared to hydraulic damper. Generally, the primary dangers of the hydraulic system are:

- Considered inefficient due to the specified continuously pressurized system.
- Relatively high device time constant (strain loss and flexible loss).
- Environmental pollutants because of hose leaks and ruptures, wherein hydraulic fluids are toxic.
- Mass and intractable area necessities of the overall device inclusive of supply device albeit that it in particular contributes to the sprung mass.

In this section, the numerous kinds of electromagnetic suspension structures were reviewed. The hydraulic damper, adjustable valve inside the damper cylinder, MR and ER fluid and linear actuator has been studied in element. Based at the researches, using linear actuator in automobile suspension method offers maximum advantages due to its controllable thrust pressure, ownership of high pressure density, and the capability to act as an strength harvester by converting kinetic (vibration) power to electric energy both to be stored for destiny use, or fed again into the actuator. The power harvesting properties of linear actuator might be defined inside the next section. The response time of linear actuator to supply damping force (or thrust pressure) is shorter than hydraulic actuator because of fluid residences accordingly making suspension machine the usage of linear actuator yields better time response. However, due to excessive value, excessive quantity, and complexity, linear actuator isn't always broadly used in traditional motors.

3. EMS AS AN ENERGY HARVESTER

Possibilities on using linear actuator in electromagnetic suspension device as electricity harvester in automobile region have been hardly ever studied. This may be due to the advanced technology in hybrid car that is enough to minimize the fuel consumption problem. However, linear motor has been used widely in other sectors that involve electricity regeneration consisting of harvesting wave electricity from sea. In automotive area, except presenting higher riding satisfactory, linear motor (or linear generator) extensively utilized to generate electric strength from automobile body vibration. The vibration strength is converted into electric electricity by means of magnetic induction. One of the researches changed into conducted by using Okada and Harada [2]. In their research, they have replaced the hydraulic damper with linear generator in region-car version. They have synthesized some formulation representing the frequency reaction of the system earlier than doing the simulation to obtain the regenerated power. They concluded that electricity harvesting handiest viable whilst linear generator is moving with excessive frequency. For low frequency, the strength produced by means of linear generator is zero i.e. the linear generator is not able to regenerate energy.

Montazeri and Soleymani [3] have carried out some other research on power harvesting the usage of EMS. They investigated the idea of the strength regeneration in lively suspension unit in hybrid electric motors. An ultra capacitor (UC) has been delivered as energy garage tool because of its unique strength and the capability to tolerate the frequent charging and discharging without the risk of increasing inner heat and resistance, consequently suitable for storing the harvested energy. The look at additionally investigated the relationship between active

suspension and gasoline consumption in which, via simulation and test, hybrid electric automobiles with regenerative energetic suspension consumes much less fuel compared to hybrid electric powered automobiles with non-regenerative lively suspension however higher in comparison to hybrid electric powered automobile without active suspension machine. Hsu [4] investigated the relationship between linear actuator performance and energy restoration in vehicle electromagnetic suspension system.

4. MR ELECTROMAGNETIC REGENERATIVE DAMPER

Finally, the MR damper gadget cautioned by using Chen et al. [5] is a self-sensing, self-powered, controllable machine in which the power-generation and sensor characteristic systems are integrated into the MR damper itself. Integrating the systems leads to huge space and weight loss, value-effectiveness, reliability and much less preservation compared to maintaining the special arrangements separated, as formerly carried out by using papers investigating MR dampers. The proposed device becomes simulated and a prototype was examined in experiments. The experimental records matched well with simulations and theory for all the tested functions comprising damper manage potential, strength era and sensor functionality. A pass-section of the absolutely assembled damping device is discovered in Figure 2. The vibration this is imposed on the device reasons the piston rod to move linearly. The energy element and the sensor a part of the device are both directly attached to the rod and are therefore shifting with it. The strength element is together with generally permanent magnets and coils. Because the inner layer of the power component is hooked up to the transferring rod a relative pace occurs between the internal layer and the outer layer of the energy part.

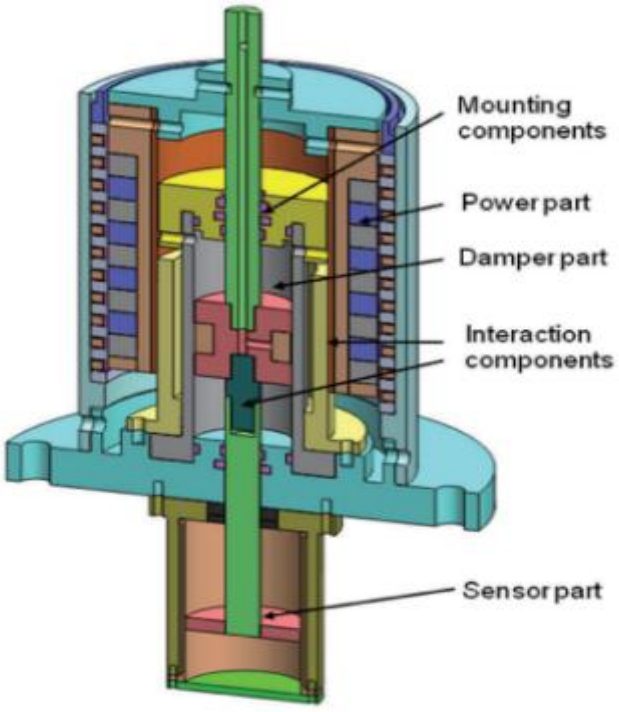

Figure No: 2 Self Sensing MR Damper

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This causes a change in magnetic flux which in turn generates electrical power. The sensor element is in most cases including a coil and a magnetized ring. When it movements with the rod it generates a change in the magnetic circuit. As mounted via Faraday's law of electromagnetic induction the motion will generate an electrical voltage inside the coil that's proportional to the velocity of the sensor. By measuring the voltage the rate of the shifting rod can be obtained. The damping potential of the MR damper is attained by the MR fluid positioned in the damping element. The fluid exhibits a quick transition from a liquid state to a semi-solid state in a matter of milliseconds whilst exposed to an outside magnetic area. This rapid transition and the ability to degree the suspension speed using the sensor is what makes the damping force controllable and effective. The regenerative capability of the strength component is what makes the complete gadget self-powered and consequently enormously effectual. The test confirmed that the quantity of electricity which can be generated and used for damping load in a car suspension with the relative squared velocity of 0.04-0.36 $(m/s)^2$ was 10-90 W. It turned into also shown that as the modern to the damping controller increases, the damping force increases step by step until it sooner or later ranges, due to saturation of the MR-liquid [7]. The quantity of damping force that one MR damper should generate become about 2560 N with an triggered present day of 1 A.

5. WORKING PRINCIPLE OF MR DAMPER

5.1 MR Fluid

The Magneto-rheological fluid (MR fluid) is, as described with the aid of Go ldasz, a suspension of nice, non-colloidal, low-coercive ferromagnetic debris in a provider fluid. This fluid belongs to the class of controllable liquids which has the capacity to trade from a liquid kingdom to a semi-solid state with a yield stress in the matter of milliseconds when uncovered to an outside magnetic discipline. What makes this fluid so applicable for a vehicle suspension machine is that it is controllable, reversible and speedy reacting. It additionally fulfills the vital overall performance standards of having a low initial viscosity, excessive shearing potential whilst reacting to the magnetic subject, low hysteresis, temperature balance and most significantly; low electricity consumption [8].

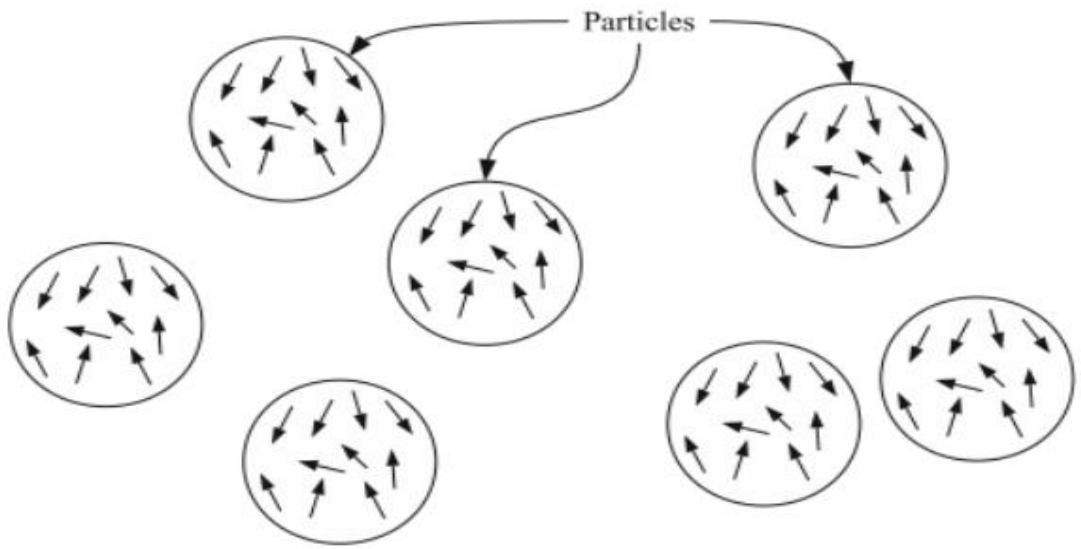

Figure No: 3 MR Fluid Particles in OFF State

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When a magnetic subject is applied to the MR fluid the solid particles dispersed within the fluid, created by means of some of sub-domain names with to begin with randomly aligned dipole moments (see Figure 3), starts to emerge as ordered. This reasons the sub-domains in a particle to align in a single path developing magnetic forces between the particles. This in turn generates chain-like systems in the path parallel with the magnetic discipline (see Figure 4). The particles will entice each other parallel to the magnetic flux and repel each different inside the perpendicular direction.

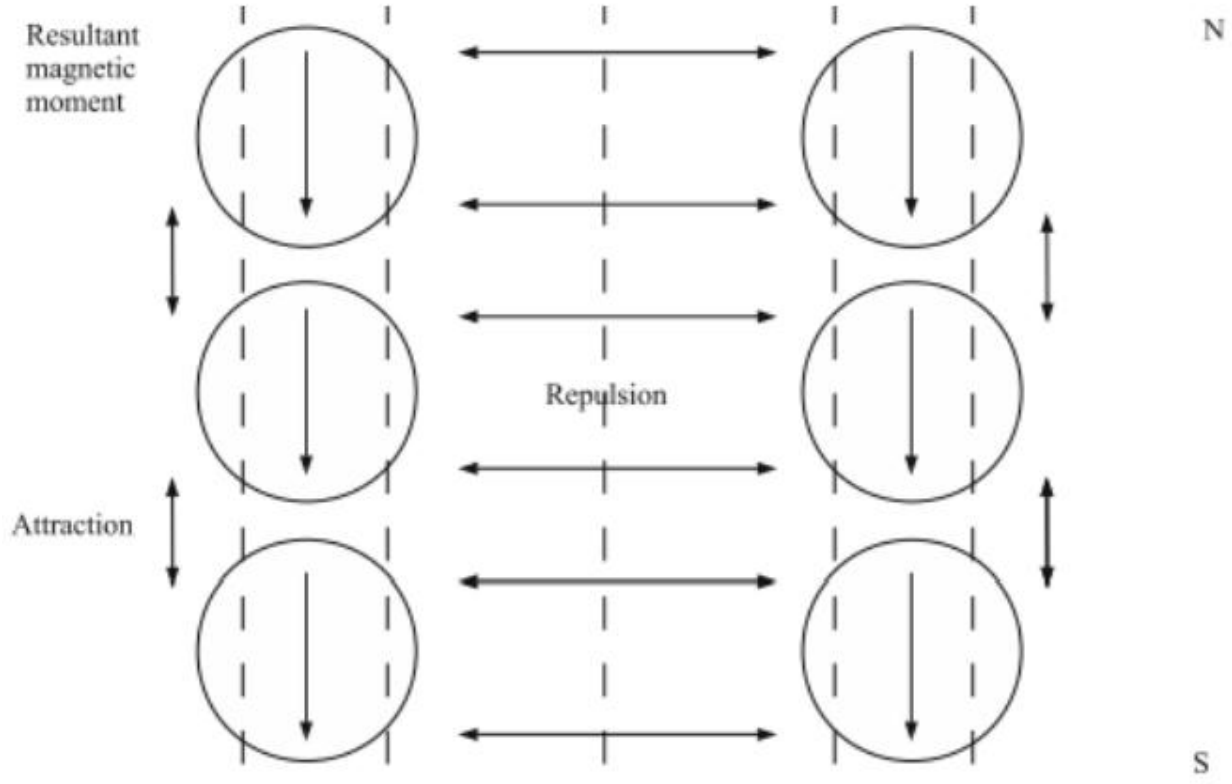

Figure No: 4 MR Fluid Particles in ON State

With the particles based the fluid shows a yield stress that is depending on the magnetic discipline. The reality that the fluid receives an expanded yield stress is what makes the damping effect within the device viable. The charge at which the debris within the fluid form the chain-like systems is generally relying at the charge of which the magnetic subject can growth and organize the debris. The yield pressure of the MR fluid may be increased by adjusting the particle density or via adjusting the magnetic flux density [9]. Adjusting those parameters will result in thicker particle structures which can withstand higher forces and as a consequence provides higher damping capability.

6. THE EQUIVALENT QUARTER CAR MODEL

The model is primarily based on a mass-spring system created to simulate the model of a suspension machine for a vehicle whilst uncovered to a vertical acceleration resulting from avenue irregularities. Figure 5 suggests an example of quarter car vehicle mass-spring device with two degrees of freedom.

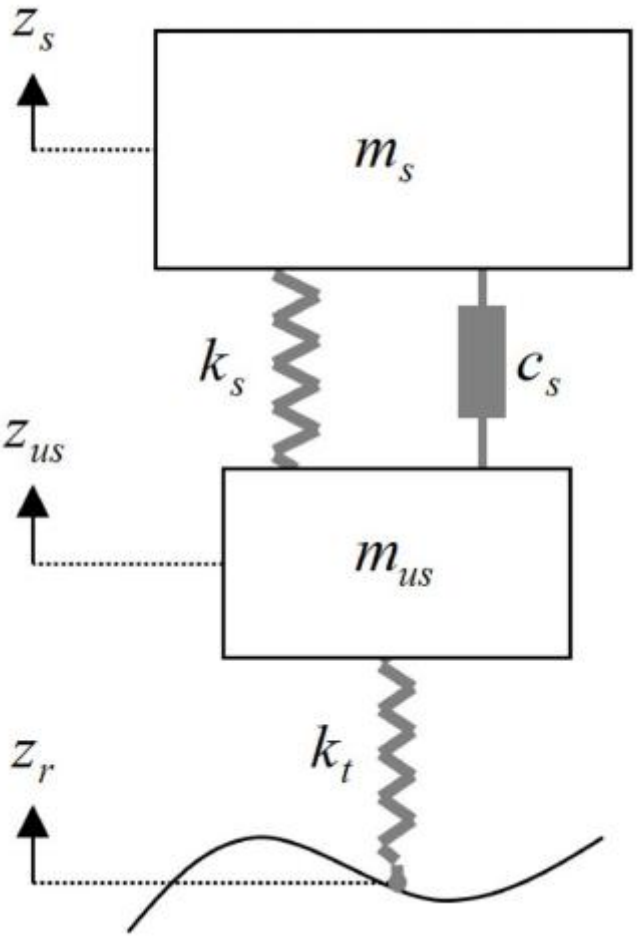

Figure No: 5 Equivalent Quarter Car Model

The quarter car model is obtained by using personally decomposing the aspect elements from the linear, mass-spring gadget, solving them and including them collectively to be able to get a correct description of the blended machine. This generates the governing differential equations describing the force stability for the mass-spring device. These can be derived as

$$\mathbf{M\ddot{Z} + C\dot{Z} + KZ = F_{road}}$$

With M being a matrix contains containing the involved masses, C a matrix containing the damping coefficients, K the stiffness matrix for the device and F_{road} the input force from the road acting at the device.

The vector Z carries the tiers of freedom for the machine. For the unique case while an MR damper is implemented to the mass-spring device the parameter $C\dot{Z}$ is substituted with a view to catch up on the unique damping capability of the MR damper. With MR damper structures carried out to a given mass-spring system, the equation may be rewritten as

$$\mathbf{M\ddot{Z} + F + KZ = F_{road}}$$

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With F being the vector describing the damping forces generated via the installed MR damping systems. When searching at the version defined by Figure 5, with a single MR damper carried out, the vector F is given by using

$$\mathbf{F} = \begin{bmatrix} F_t \\ -F_t \end{bmatrix}$$

Wherein F_t is the damping pressure obtained from the feature. A dating among the enter force, F_{road}, and the displacements, Z can be acquired from fixing the differential equation. This courting is thrilling to have a look at as it shows the amount of displacement that is generated via having a given enter force. More importantly; it implicitly suggests how an awful displacement is generated through having a given damper device; which includes an MR damper.

The MR damper is ready to make use of electricity that in any other case would be wasted which could growth the environmental overall performance of motors when concerning low international impact. Having this type of system implemented in the automobiles we use today can effectively make contributions to creating the automobiles and vehicles more environmental friendly and thereby lessen their carbon footprint. The strength that may be harvested from the regenerative MR damper might be used to make the suspension system self-powered. The harvested electricity may also be used as stored electric electricity within the battery which may be at the disposal for different structures. This manner that the engine could now not be needed to price the battery on its personal and will therefore use this more energy to pressure the car. Having a regenerative MR gadget would consequently be useful for the decreasing of fuel intake in cars and for that reason also in lowering the worldwide impact.

7. CONCLUSION

The surroundings wherein the regenerative MR damper is applied became defined using the sector car model. This version becomes selected to be presented because it affords for a green and compact way of describing the automobile dynamics while excited by vertical displacement. Because the mass-spring device is linear it could without difficulty be solved via obtaining the differential equations generated by way of superimposing the man or woman components of the mass-spring gadget. Furthermore, the version can without problems be analyzed in Matlab, that's beneficial whilst studying simulations. Using this version, however, limits the descriptive variety of the motors dynamics through being linear. This makes the version misguided if nonlinear dynamics comes into play. Because it's far assumed that the tires of the automobile are constantly in touch with the ground, some other quandary could be passed if a detachment of the tire, from the floor, could arise. This instance would result in a behavior of the gadget which can't sufficiently be described by using the proposed version.

The regenerative MR damper turned into tested from an environmental point of view by way of score its diploma of sustainability. This changed into completed by way of searching on the environmental effect from three different views – namely, on a nearby scale, a international scale and by inspecting the useful resource performance of the

damper. It became shown that the regenerative MR damper had amazing environmental performance in all classes, making it surprisingly sustainable. The regenerative MR damper turned into proven to have a standard advantageous effect at the environment and consequently also on our society and the further improvement of sustainable technological answers.

8. REFERENCES

[1] Gysen B, Janssen J, Paulides J, Lomonova EA. Design aspects of an active electromagnetic suspension system for automotive applications, IEEE Ind App Soc Annu Meeting, pp. 1–8, 2008.

[2] Okada Y, Harada H. Regenerative control of active vibration damper and suspension systems, 35th IEEE Decis Control 1996;4:4715–4720.

[3] Montazeri-Gh M, Soleymani M. Investigation of the energy regeneration of active suspension system in hybrid electric vehicles, IEEE Trans Ind Electron2010; 57:918–925.

[4] Hsu P. Power recovery property of electrical active suspension systems, Energy Convers Eng Conf 1996; 3:1899–1904.

[5] Chao Chen and Wei-Hsin Liao, "A self-powered, self-sensing magneto rheological damper", in: Mechatronics and Automation (ICMA), 2010 International Conference on, IEEE. 2010, pp. 1364– 1369.

[6] Amer NH, Ramli R, Mahadi WNL, Abidin MaZ, "A review on control strategies for passenger car intelligent suspension system", Int Conf on Electr, Control and Comp Eng (INECCE), pp. 404–409, 2011.

[7] X Tang et al, "Structure-enhanced yield stress of magneto rheological fluids", In: Journal of Applied Physics 87.5 (2000), pp. 2634–2638.

[8] G Yang et al, "Large-scale MR fluid dampers: modeling and dynamic performance considerations", In: Engineering structures 24.3 (2002), pp. 309–323.

[9] Bart LJ Gysen et al, "Efficiency of a regenerative direct-drive electromagnetic active suspension", In: Vehicular Technology, IEEE Transactions on 60.4 (2011), pp. 1384–1393.