Self Powered Electrorheological Suspension System for Quarter Car

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Abstract *- This paper emphasis on ER suspension with energy generator which does not require external power sources. This is accomplished by converting kinetic energy of vibration of shock absorber into electrical energy. In order to does this work, a semi-active suspension with an appropriate size of the ER damper have to manufacture. A mechanical mechanism which changes the linear motion of the ER damper to the rotary motion is then constructed. This rotary motion is amplified by gears and makes a generator produce electrical energy. The efficiency of energy generation is experimentally evaluated and the field-dependent damping force of the ER damper operated by the generated power is also investigated. Subsequently, the ER suspension system is applied to a quarter car model, and we can experimentally evaluate the vibration isolation is in frequency domain.*

Keywords *-* Electrorheological fluid, mechanical shear strength, electrical signal, particle polarization, semi active control algorithm.

I. INTRODUCTION

The function of any suspension system is protection of body and occupants from the vibration. The composition ~~and the~~ properties of ER fluid can be changed by applying electric fluid [1]. Alternative preparation of ER fluid is done to improve the fluid shear strength capability. Suspension consisting of dielectric particles dispersed in insulating oil constitutes of ER fluid [2]. Generally, they are nothing but micron-sized particles in a non-conducting fluid. It can become solidify and can be liquefied depending upon application of electric field [3]. If ER fluid has a several kPa and requires a local electric field of 10kV/mm. However, for recently developed ER fluid have shown a yield stress over 100kPa and claimed to have a different mechanism [4]. This paper also provides the mathematical tools for both modelling and simulation of fluid flow in specific ERF devices within a continuum mechanical framework. The ER fluid gives highly response to an efficient control of the transmission of forces. The new generation of ERF's which has been developed in recent years features high ER effects by direct activation of through electrical signals with an adaptation of the forces in the range of milliseconds that goes along with low abrasive wear, good re-dispersibility and high shear stress and sedimentation ability [5]. By using semi-active suspension system, vibration can be suppressed significantly. Due to uncontrollable damping force, performance is limited and cost is also affects. On the other hand active suspension gives high control performance but, it requires high power consumption and much more sensors. The electro rheological phenomenon is based on particle polarization. There are five modes through which particle polarization can be takes place through which electrical phenomenon is considered [7].

II. LITERATURE SURVEY

S.S. Patil, S.S. Gawade and S.R. Patil (2011) have described the "Electrorheological Fluid Damper for Vibration Reduction in Rotary System". This paper emphasis on the vibration phenomenon. This paper concluded that, to enhance the performance of the system reduction of vibration is essential. The objective is to improve the performance of rotating bodies like, turbine and pumps. For dynamic attenuation, ER damper require active media with varying fluidity. Arabic gum based ER fluid was more preferable because better zero field viscosity, maximum breakdown strength and more time for sedimentation. Arabic gum based ER fluid is suitable to reduce vibration of rotary system.

X.P. Zhao and Y.B. Hin (2006) have described the "Advances in ER fluids based on inorganic dielectric materials". This topic covers the simple transformation from electric to mechanical force makes ER fluid potential use in active control of conventional and intelligent devices. Due to insufficient performance of ER materials, researches on high active ER materials for practical technical applications have been continuously carried out. In developing more efficient ER mechanisms and review on the recent progress in inorganic to composite materials. The preparation of high performance materials is one of the most active research topics in electro Rheology in order to make the ER technology achieve industrial applications.

Yu Tian, Miliziang Jille Jiang, Noshir Pesika, Hongbo Zeng, Jacob Israelachvili (2006) have described the 'Reversible shear thickening at low shear rates of ER fluid under electric field'. This topic covers the preparation of electro rheological fluid and mechanical shear strength properties of ER fluid under electric field. This topic also covers mechanism of shear thickening happened in ER fluids, a proposed frictional mechanism for ER effect and discussions with previous results.

Nik Abdullah, Nik Mohmad, Mohd Jailani Mohd Nor (2005) have described the "Compromising vehicle handling and passenger ride comfort using ER-damper". In this paper he discovered the performance of suspension system by compromise between ride comfort and road transmitted to the car. On the other hand, the soft damping level will yields good comfort but reduce the wheel contact to the road surface, which in turns reduce the vehicle handling. The best tradeoff between comfort and stability is obtained with the damping value at the intersection between normalized amplification ratio curve and the normalized transmissibility curve.

Kum Gil Sung, Young Min Han, Kye Hyun Lim and Seung Bok Choi (2007) have described the 'Discrete – time fuzzy sliding mode control for a vehicle suspension system'. This topic covers a real time control characteristics of an ER suspension via fuzzy sliding mode control algorithm which is formulated in a discrete time manner by considering the sampling rate of an electronic control unit for a vehicle system This paper covers the vehicle suspension control techniques like passive suspension, active suspension, semi active suspension. Also they have designed the Electronic control module for this suspension system.

III. SMART FLUIDS

"Smart Fluids" can adaptively change or respond to an external stimulus producing a useful effect. Mechanical stresses, temperature, an electric or magnetic field, photon radiation or chemicals are typical examples of stimuli.[1] A useful effect usually means a dramatic change of one physical property, the structure or the composition, which can be monitored and used in certain applications. Different applications are vehicle vibration control, brakes, clutches, special purpose devices for medical rehabilitation, and erasable Braille displays for blind, as well as for seismic damping and virtual surgery [2].

A. MAGNETORHEOLOGICAL FLUID

A magneto rheological fluid is a type of smart fluid in a carrier fluid, usually a type of oil. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a viscous-elastic solid. Importantly, the yield stress of the fluid when in its active state can be controlled very accurately by varying the magnetic field intensity. The upshot of this is that the fluid's ability to transmit force can be controlled with an electromagnet, which gives rise to its many possible control applications [7].

B. ELECTRORHEOLOGICAL FLUID

Electro rheology denotes the control of rheological characteristics through applied electric field. ER fluids constitute a class of colloids whose viscosity can increase under increasing electric field. Under very strong fields some ER fluids can turn into anisotropic solids, characterized by a yield stress [1]. The recent discovery of the giant electro rheological (GER) effect in suspensions of nano-particles has challenged the conventional wisdom on ER fluids, as the GER fluids can break the theoretical upper bound on the (high-field state) yield stress [2]. Starting from experimental observations of the GER characteristics, we show that the model of aligned molecular dipole layers in the contact region of coated nano-particles can yield predictions in excellent agreement with measured data. The statistical mechanics of the aligned dipole layers is studied through Monte Carlo simulations. We propose electro wetting between the particles and the suspending liquid, with hydrogen bonding as a contributing element, in inducing the aligned state [3].

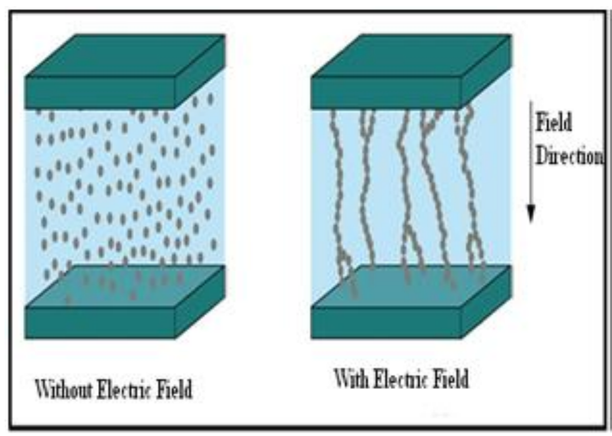

Fig:1 Effect of ER fluid

IV. PREPARATION OF ER FLUID

In this topic the study of alternative preparation of electro rheological fluid can be done to improve upon fluid shear strength capability and to reduce settling of the particulate component in ER suspensions. Four alternative fluid categories are as follows,

1) Homogenous solutions
2) Colloidal dispersions or gels
3) Amorphous substituted alumina-silicates and
4) A zeolite-based suspension that is ultimately used as the fluid specimen for testing the automotive damping device in this study. The consideration of each will be discussed below.

1. Homogenous solutions

For solving the problem of settling, the ER solution presents the conceptual approach. Recent discoveries have shown that solutions of poly gamma benzyl-L-glutamate (PBLG) and poly n-hexyl iso-cyanates (PHIC) exhibit an ER-active behaviour. The PBLGs, although ER active in many solvents, are known to be soluble only in polar solvents, resulting in relatively high levels of conductivity and thus requiring rather high levels of electrical power for sustaining the electric field condition. For this and other reasons, PHIC systems are examined in this study, seeking 25 to 30 percent concentrations of this solute in non polar solvents such as xylene and toluene. The selected solvents are also attractive because of their substantially lower cost than the PBLGs. Unfortunately, since the PHIC materials are not commercially available, it is necessary to develop procedures for preparing them in the laboratory. Initial plans were for preparing samples of PHIC from the monomer form, but it is discovered that only small quantities are available, from a vendor, and that the highly costly material could be obtained only when ordered with a nine-month lead time. Accordingly, steps are taken to synthesize the monomer in our laboratories from more readily available base materials. Published procedures for this synthesis are substantially modified to yield the product quantities and the quality of molecular weight control that the ER application required.

Approximately 1000 grams of PHIC is prepared, yielding 4 litres of an ER solution. The solutions thus prepared are found to be substantially ER-active but exhibited properties which are poorer than those of more common fluids prepared by other methods. Since it is not possible, within this project, to further improve the materials by synthetically modifying the components, the search for a suitable ER solution is discontinued. [10].

2. Colloidal dispersions or gels-

By a second approach, steps are taken to prepare ER fluids which, under quiescent or static conditions, would constitute a gel which inherently resists settling of a particulate phase of the materials. The desired gel formulation, of course, would exhibit an ER response to an electric field but would otherwise have a very low viscosity when deformed over a range of shear rate values. Various colloidal, as opposed to soluble, gelling agents are used primarily because the colloidal systems produce gels that are highly shear-thinning. By this approach, the gel effect would hold the fluid in a semisolid state, at rest, presenting an essentially zero static shear strength in the absence of an electric field. Upon even very slight initial loading, the gel would yield and thereafter exhibit a very low viscosity response to increasing shear rate.

Although many colloidal agents are studied, the most promising was Mont morillonite clay modified so that it could be readily dispersed into an organic liquid [2].

The ER-active behaviour is achieved by using standard zeolite particles dispersed into paraffin oil with 1 to 2 percentorgano-clay added. The fluids had the appearance of jelly but are seen to be highly thinning, even at shear rates down to 0.001 per second. This approach is not known to have been reported previously. Although it is believed to offer a promising approach to achieving stable ER-active suspensions, it is found that the gelled fluid could not be easily loaded into the ER damping device considered here. That is, since the gel-based fluid retains a static shape, it is not possible to fill a complex device with the fluid without entraining a great number of small air pockets. Entrained air is problematic in ER devices because the high field strengths required for the ER effect produce ionic breakdown and arcing across the bubbles. The arcing, in turn, tends to saturate the supply amplifier and thereby disturb the continuous nature of the ER energization voltage. Also, arcing can lead to breakdown of many insulating materials and to the introduction of metallic "spatter" which, itself, can form bridges for further short circuit paths through the fluid. Additionally, optimization of properties of these fluids and techniques for dispersing the clays into the liquids are not straightforward and will require substantial research for their refinement. [3].

3. Amorphous Substituted Aluminous-Silicates

The term, zeolite, applies to a crystalline form of alumino-silicates that are observed to be an effective ER-active particulate. Amorphous forms of Al/Si as the dispersed phase in ER fluids have also been shown to produce ER active suspensions. The amorphous materials are intrinsically more attractive because the chemistry can be much more radically varied without concern for constraints on the crystalline structure and because the materials are much less hydrophilic than the crystalline. Seeking the combined qualities of ready synthesis and dry particles, efforts are taken to develop amorphous ER materials during this study. While this task is carried out only to a preliminary level of achievement, the effort is successful in varying the Al/Si ratio over large ranges and in combining the silicon atoms with a wide variety of elements other than Al. These include boron, germanium, and silver. Although much work remains to be done, small fluid samples are produced showing ER shear strengths three to four times greater than those which have been achieved customarily using the crystalline materials. [10]

V. THE ER FLUID USED IN THE DAMPER

Towards the conclusion of this study, a relatively conventional form of (nominally dry) ER fluid can be prepared using commercial zeolite particulate dispersed into a medium of transformer oil. The fluid is quite low in conductivity and yielded shear strength of approximately 0.15 psi in response to an electric field of 3000 volts per millimetre. The very crucial shear strength question is only modestly addressed in this fluid sample. Indeed it is generally accepted that fluid strengths in excess of 1 psi will be needed before ER fluids are broadly attractive for automotive applications, such as in active damping devices.

The particulate phase of the test fluid did tend to settle when left on the shelf, requiring substantial agitation to disperse the thick layer that would form within a few days or so. When loaded into the test device, the system is kept in a mild state of agitation so as to simply avoid the settling problem for the duration of testing. The ancillary research thrusts outlined in the previous subsections indicate that while various approaches exist for resolving specific shortcomings in ER fluids, a substantial degree of further refinement is still needed. [10].

Although a variety of rather complex changes in the mechanical and electrical properties of electro rheological fluids have been observed in response to an imposed electrical field, the primary characteristic upon which most ER devices seek to operate is the static shear resistance which arises exponentially with increasing field strength. This phenomenon accounts for the common observation that ER fluids can exhibit the properties of a solid, when "energized," and a liquid when de-energized. The electrical field condition is imposed upon a sample of fluid by containing the sample between two opposing electrodes which are energized to some voltage. In order to realize a mechanical stress response from the fluid, a mechanical shear condition is established typically by inducing flow of the fluid between the electrodes or by translating one electrode relative to the other 6].

As field strength increases, an essentially static stress response to shear is observed. Exceeding the static strength level causes the fluid to shear more or less according to the behaviour of Newtonian liquids, assuming that a Newtonian fluid medium has been employed as the liquid phase of the material. Since the imposed field strength has virtually no influence on the shear stress levels developed at increasing levels of shear rate, it is desirable practice to design devices to operate in the regime of low shear rates. By this approach, variation in the electrical signal level more directly controls the mechanical (stress-based) response, thus increasing the control efficiency of the system package. The shear rate regime can be modified, of course, by changing the nominal gains or gear ratios which directly determine either the flow of the fluid through an electrode gap or the translational movement of the electrodes causing uniform shear across the gap. [8].

VI. WORKING OF ER DAMPER

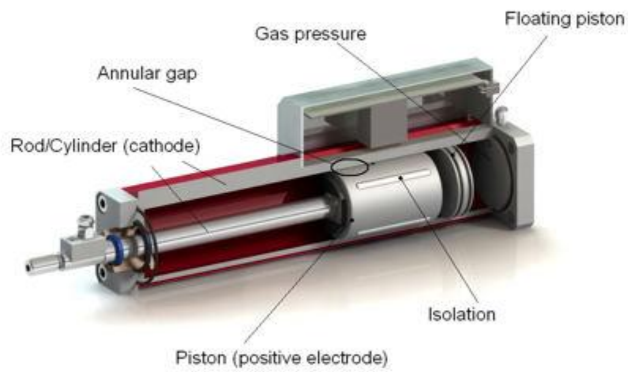

Fig: 2 Working model of ER damper

The model for ER damper is as shown in fig 2. The ER system consists of a piston with an annular gap between the housing and piston. Two chambers are filled with a silicon-based electro rheological fluid. With no electrical field applied, the fluid flows through an annular valve, as in a standard damper. But when an electrical field is applied, the viscosity of the fluid increases, choking the valve and increasing the damper resistance. Raising the electrical field to its maximum solidifies the ERF, stopping any movement. The “smart” PID system adds an amplifier and controller to the damper. In its basic, open-loop form, the controller is adjusted manually to modify the damping properties. For autonomous closed-loop systems, sensors can be added to measure variables such as acceleration, displacement and weight. The technology is said to be energy efficient, with a power consumption of 2–20W. It is silent and has no moving parts to maintain. There is a wide span between soft and hard damping characteristics, and the PID controller needs only a few milliseconds to increase the damping force, allowing processes to be controlled at high frequencies [6].

In this section the design of the semi active control strategy used to implement an ER damper will be considered. As the distinction between active and semi active control lies in the field of force generation. Adjustable damper systems can only dissipate energy whereas active systems can also generate energy. However, this restriction does not necessarily imply that the performance of semi active systems is inferior to active suspension systems. Semi active suspension control is based on similar control algorithms as applied to active suspension systems. However, the most important difference between active and semi active systems is that a semi actively damped suspension is only capable of dissipating energy.

Since the adjustable damper cannot supply power to the system, the best it can do is to generate no damping force at all when the active solution requires a force that cannot be generated by a damper. In practice this means that the ER-damper is switched to the lowest setting possible. In a broad, simplified sense, improvement in ride comfort can be obtained simply by softening the suspension. On the one side, the suspension spring can be softened; on the other hand the suspension damper can be altered in such a way that the sprung mass accelerations are reduced. But these steps must be taking within the constraints of package space and adequate motion control. Semi active control provides a good means to do this.

The starting-point of semi active suspension control is active damping based on an ideal actuator, situated between sprung and unsprung mass with actuator force to be specified. The theory of linear quadratic Gaussian (LQG) control has been applied by many authors to determine a state feedback controller for active suspension systems. The LQG theory is based on the minimization of a quadratic performance index. The performance of a quarter-car suspension system can roughly be assessed quantitatively in terms of ride comfort (sprung mass accelerations), road holding (variations of the vertical tire load) and suspension working space. These three criteria can be used to setup a quadratic performance-criterion. The relative importance of the different performance parameters can be expressed by weighting factors. After having chosen the weighting factors, the optimal control algorithm will select a state feedback gain matrix such that the quadratic cost function is minimized. This feedback can either be a full state feedback or a partial state feedback. The full state feedback considers all the states of the system (such as displacements and velocities of sprung and unsprung masses) and uses this information to compose an active suspension force applied between axle and vehicle body. On the other hand the limited state feedback looks only at particular states (such as the sprung mass velocity). The limited state feedback is favorable because fewer states have to be measured when the controller is implemented in a real vehicle.

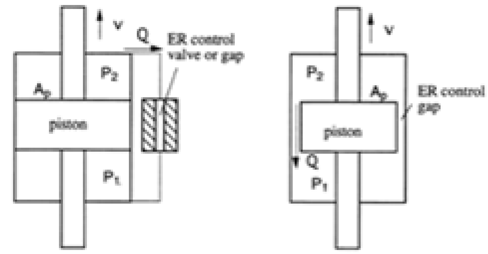

Fig: 3 Flow mode and mixed mode damper

VIII. DESIGN OF ER DAMPER

A shock absorber, made by this is mounted inside a coil spring. To make minimum changes to the existing suspension system, the ER damper is also situated inside the mechanical spring, and its outer diameter is therefore limited by the inner diameter of the spring.

Followings are the basic parameters have to be considered while designing the damper:

1. Inner diameter of spring (d)
2. Outer diameter of spring (D)
3. Overall stroke (L)
4. Spring stiffness (k)
5. Damping ratio (§)

A conventional shock has bilinear characteristics. It offers more damping during extension than during compression. Also, the shock has a pressure relief feature which limits the damping force to a maximum value when the relative velocity creates a certain relief pressure. Relief velocities and limit damping forces at the wheel spindle are taken directly from the vehicle test data sheet from TACOM.

1. NUMBER OF ELETRODE PLATES

The influence of the inertia force is small in a shear-mode damper, such that the damping force in the strut can be approximated with a Newtonian damping force (F~N)and an ER damping force responding to the effects of the plastic viscosity and the yield shear stress (T,), respectively, in the Bingham model.

Normal damping force is given by (Fdn)

Fdn =4πn(r40 – r41)/ ehDp2tan2λ

Damping torque on the rotator Td is related to the damping force (Fd) as follows

Td = eDtanhFd

2. MATERIAL FOR SELECTION

The material used for the rotator must satisfy both mechanical and electrical constraints.

The maximum shear stress is given by,

fs = 16Td D/ π(D4 – d4)

3. ROTATOR DESIGN

According to moment balance,

Td = r.ko.td.tk.n.kn
Where, nk is inner radius of the hot electrode plate. The maximum imposed torque results in a shear stress on the key.

4. STATOR DESIGN

Each stator key is fixed by eight screws for easy manufacturing. Each screw will bear shear stresses according to the relationship:

Td = 8rs.ns. π. D2s /4

Where, rs is the outer radius of the ground electrode plate.

VIII. CONCEPT OF ELECTRICITY GENERATION

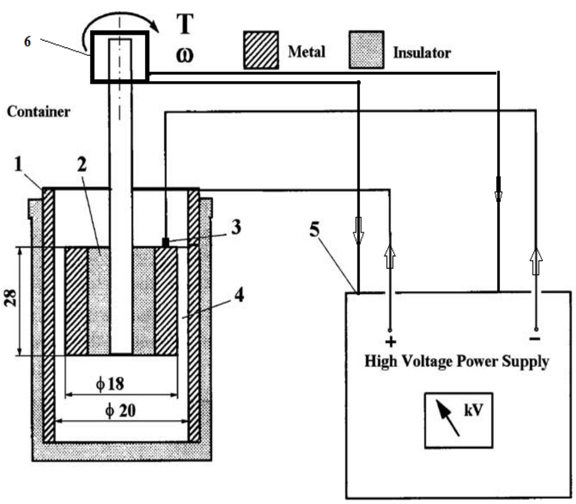

Fig. 4. Generation of electric power through the concept of proposed design

In this type of system, at the upper portion of the stator we are mounting a device which converts the vibratory motion in to the electrical energy. Here, we are using the principle of converting the kinetic energy of vibration into the electrical energy. The connection of stator is connected to the battery supply. As per the requirements battery can supply the amount of voltage for generating the electric field.

IX. CONCLUSION

The electrically controlled ER suspension system has some useful properties, however development is still required. This device is superior to that of conventional shock-absorber damping. It is practically impossible to design and construct the full-load vehicle, therefore only the design and construction of small ER damper module can be developed. Also, the weight of conventional ER damper is quite heavy therefore suitable material has work proceeds to the reduction in vibration and noise level.

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