Online Semi-Active Control System of a Magnetorheological Fluid Damper using LQR Algorithm

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Abstract-- **In this paper, passive and semi- active suspensions system of a magnetorheological fluid damper for an automobile application under different excitations (step, sinusoidal, and random) as road profiles is studied. This work is presented in two parts, the dynamic responses of the MR fluid damper under the expiation are presented in the first part and developing a simple and efficient controller to control the damper behavior is presented in the second one. Bingham plastic model is adopted for the mathematical modeling and analyze the hysteretic behavior of the MR fluid damper. LQR algorithm is used for the control processes. The results showed that the input current to the magnetic circuit plays an important role regarding the dynamic response and damping force for the excitation, however, current effect is different for the excitations. Magnetic saturation is noticed in the dynamic response. Damping force can be controlled by controlling the input current to reduce the overshoot, steady-state error, and steady state time response. In addition, the linear quadratic regulator (LQR) has successfully stabilized the system and removes the vibration without any abnormal behavior.**

Index Term-- **Online control, semi-active control, Magnetorheological fluid damper, LQR algorithm.**

1- Introduction

One of the important requirements for any dynamic system is an effective control process due to vibration, noise, and instability problems [1]. The fluctuation of system vibration close to system natural frequencies may cause mechanical failure due to resonance domination and that may increase the requirements of maintenance and total operation cost. In the light of these problems, people have found a way to partially solve these issues by design isolations systems [1–**8**] and developing active and passive control methods **[9].** Very good literature about control can be reviewed referring to.A good general introduction to about method of vibration and isolation systems and its application can be found in [10 and 11].One of the promising ways in the direction of counteracts and dissipates the vibration energies is the idea of using semi-active control. The key parameters used to introduce semi-active control are low power, interphase simplicity between the mechanical and electrical parts, and the good performance. Semi-active control has been developed as a combination of the expensive, high performance active vibration control and cheap-low performance passive vibration control **[12].** The respected reader is referred to **[13-18]** for more information about semi-active control mainly used. People have also worked on application semi-active vibration control for vehicle suspension system **[20].** Using magnetorheological fluid damper (MRF damper) is very good example of semi-active control of dynamical system vibration **[21].**MRF damper can be defined as a semi-active controlled device that achieves a wide range of controllable damping fore with high performance compared to the conventional hydraulic passive damper. Low power requirements, high performance, safe to fail, fast response, and high level of reliability are the main advantages of using MRF damper. The MRF damper is composed of the same mechanical parts of the conventional hydraulic damper filled with a specific MR fluid. MR fluid consists of base fluid and magnetic-nanoparticles. In the presence of magnetic field, the nanoparticles align themselves in the direction of the developed magnetic lines producing chain- like structure. Stiffness and strength of the developed chains depend on the magnetic field strength and electromagnetic properties of the nanoparticles. **[19, 20].**The time of the MR fluid is in the order of milliseconds.

However, the mathematical model of semi-active MRF damper is complex and complexity level is high because of the nonlinear dynamic behavior**[22].**Regarding the mathematical model complexity, **F. Ali**adoptedBouc-Wen model for the mathematical modelling taking input current and frequency amplitude into the considerations. He showed that the dynamic response of the MRF damper is well described. **Vincenzo Paciello [23]**developed a new approach for characterization of MRF damper for different mathematical models.**M. Khusyaieet, al[24]**Investigated different parameters of MRF damper and explained how these parameters variations vary the accuracy of the studied models of the MRF damper. He used “nonlinear least square fitting method” to achieve his study.**DavidCaseet, al [25]** characterize the dynamic response for a small-scale MRF damper for tremor-suppression orthosis applications. Third order transfer function is used to model both input current of