

Permanent-magnet DC motor actuators application in automotive energy-regenerative active suspensions

Yongchao Zhang, Fan Yu, Kun Huang & Yonghui Gu

State Key Laboratory of Mechanical System and Vibration, Institute of Automotive Engineering,
Shanghai Jiao Tong University, Shanghai 200240

Abstract—Significant improvements in automotive suspension performance are achieved by active suspension. However, current hydraulic active suspension system suspensions have several disadvantages such as slow response, high energy consumption and complexity. A novel energy-regenerative electrical suspension is proposed and shown in Fig.1. The system includes that sprung mass (body), unsprung mass (wheel), spring, motor actuator, circuits of drive and regeneration, microprocessor, sensors of suspension working space, circuits of on-vehicle power and so on. Sensors of suspension working space and motor actuator are mounted in parallel between body and wheel to measure suspension working space. The motor actuator is composed of a permanent-magnet DC motor, a ball screw and a nut. The significant characteristic of the suspension is that vibration energy from the road excitation can be regenerated and transformed into electric energy while good suspension performance can be maintained.

The prototype of motor actuator is designed and produced based on the rear suspension structure of a typical passenger car in Fig.2. The performance tests of the DC motor are carried out. Damping characteristics with different electric resistances are shown in Fig.3, which indicates good linearity in passive status. The bigger resistances are connected in series, the more damping force can be achieved. Fig.4 shows the induced voltage vs. rotate speed curve of motor actuator. Base on Fig.4, the equivalent voltage&toqure constant of motor are calculated.

The regeneration and vibration control performances are verified by the full-vehicle experiments in the IST RoadLab four post rig shown in Fig.5. Experimental results of the electrical system functioning as a passive suspension system show the feasibility of vibration energy regeneration. Fig.6 illustrates the output voltage V_{AB} (the voltage between A and B phase of the motor actuator) in a certain random excitation. According to V_{AB} and the resistance between A and B phase, the output power is obtained and shown in Fig.7.

Besides of the experiments, the simulation of the active drive control and energy-regenerative control in MATLAB is being completed to calculate the active control performance and regeneration efficiency. The good active control law could improve the performance of vibration control and energy-regeneration.

In conclusion, the energy-regenerative electrical suspension is a novel approach of active suspension. The realization of effect energy-regeneration is expected in the future for the aim of saving-energy in automotive field.

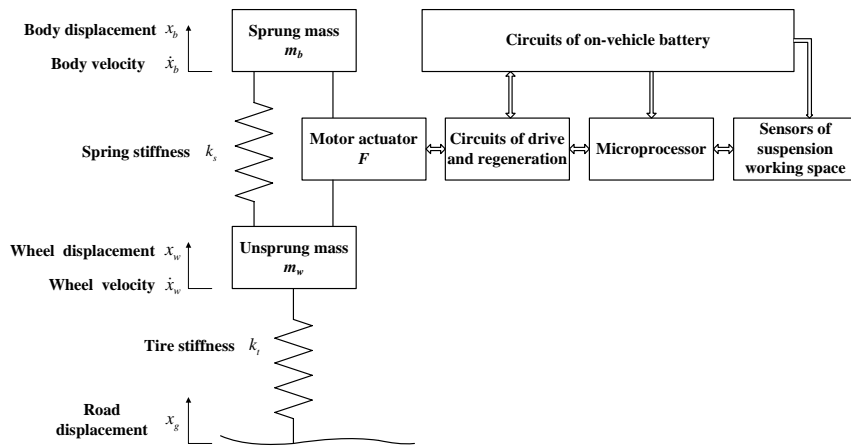


Fig. 1. The model of energy-regenerative active suspension



Fig. 2 Motor actuator prototype

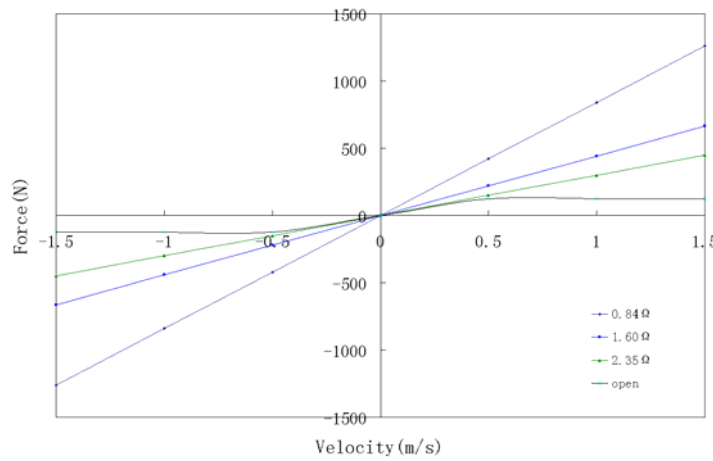


Fig. 3 Damping characteristics with different electric resistances

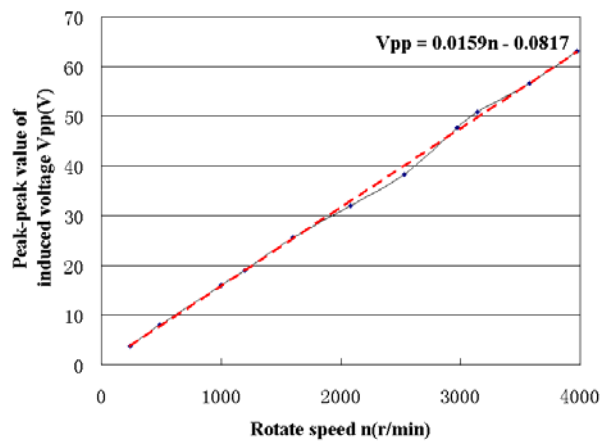


Fig. 4. Induced voltage vs. rotate speed curve of motor actuator



Fig. 5 Full-vehicle experiments in test rig

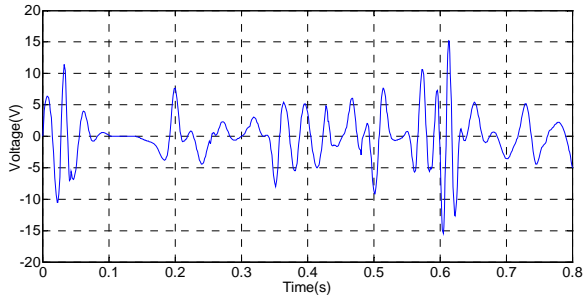


Fig.6 Output voltage of motor actuator in random excitation

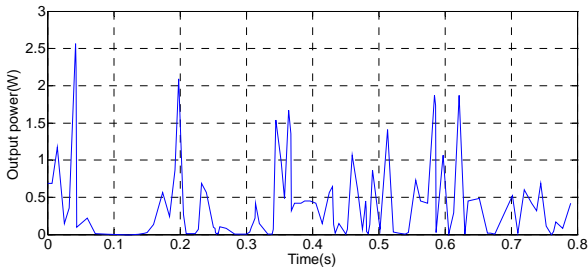


Fig.7 Output power between A and B phase in random excitation