Design of a New Integrated Structure of the Active Suspension System and Emergency Lane Change Test

ZHAO Jing-bo, LIU Hai-mei, ZHANG Lan-chun, BEI Shao-yi

School of Automotive and Traffic Engineering, Jiangsu University of Technology, Changzhou, China

E-mail: zhaojb1128@jsut.edu.cn

Abstract. An integrated structure of the active suspension system was proposed in order to solve the problem of the individual control of the height of the body or the adjustable damping of the active suspension system of the electric vehicle, which improve the vibration reduction performance of the vehicle. The air bag was used to replace the traditional spiral spring, and the traditional shock absorber was replaced by the damping adjustable shock absorber, and the control module received the body acceleration sensor and the horizontal height sensor signal. The system controlled adjustable damping coefficient of shock absorber through the height of the car body the output of the air pump relay and the height control valve and the output of the electromagnetic valve of the adjustable damping shock absorber, and the emergency lane change test was carried out under different modes of speed of 60km/h. The experimental results indicated that the damping value was greater, average roll angle, yaw angle and average vehicle lateral acceleration were small when vehicle body was in the state of emergency lane change, which verified the feasibility of the integrated control strategy and structure design of the active suspension system. The research has important theoretical research value and engineering application prospect for designing and controlling strategy of vehicle chassis integrated control system.

1. Introduction

Suspension system of vehicle has an important influence on vehicle ride comfort and handling stability. The traditional passive suspension cannot be adjusted due to its damping and stiffness, and it limits the dynamic performance of the vehicle. The active suspension can take into account the ride comfort and handling stability of the vehicle, however, it is not widely used because of its high energy consumption and high cost. Semi-active suspension overcomes the defects of passive suspension, its performance close to active suspension, which has the advantages of high cost performance, low energy consumption. Therefore, semi-active suspension has been a hot research topic in the field of vehicle chassis technology.

In order to give full play to the vibration reduction performance of the suspension system, it is required that the damper has a variable damping coefficient to meet the requirements of damping in different driving conditions [2]. The main way to change the damping coefficient of the shock absorber is to change the viscosity of the damper and adjust the orifice area [3]. Variable damper and electrorheological damper are used as shock absorber for adjusting damping coefficient of damper [4,5]. Mechanical damping adjustable damper, Pneumatic control damping adjustable shock absorber, Electromagnetic valve controlled damping adjustable shock absorber and Motor control damper are also used as Damper for regulating orifice area [6].

The research and development of damping adjustable shock absorber is mainly focused on the performance analysis of adjustable damping shock absorber at home and abroad [9]. Some papers[10,11] have present a series of orifice area adjustable shock absorber and the damping force can be controlled by adjusting the throttle area of the throttle orifice. It is important theoretical research value application and prospects that how the tension damper and the compression stroke presents different damping characteristics [9]. According to the driving conditions, the damping of the damper's stretching and compression stroke is multi-mode switching to meet the more complex conditions of the ride and handling and stability in the same mode.

This paper presents an integrated active suspension system and analyses the structure and working principle of the integrated active suspension system. And dynamic model and control strategy of air spring and shock absorber for emergency lane change test, in order to grasp the technical principle and the basic characteristics of the electronic control suspension system, It also provides a useful reference for the independent research and development of active suspension system.

2. Structure of integrated active suspension system

Active suspension system uses air spring and shock absorber as integral structure of the vibration damping components, the transformation of the damping force is realized by a single valve PDC in the suspension system. The valve is integrated in the shock absorber and is connected with the air spring through a hose, as shown in Figure 1, The pressure of air spring (which is proportional to the load) is used as an adjustable parameter to control the variable orifice on the valve PDC, which affects the flow resistance and influence spring back and the damping force.

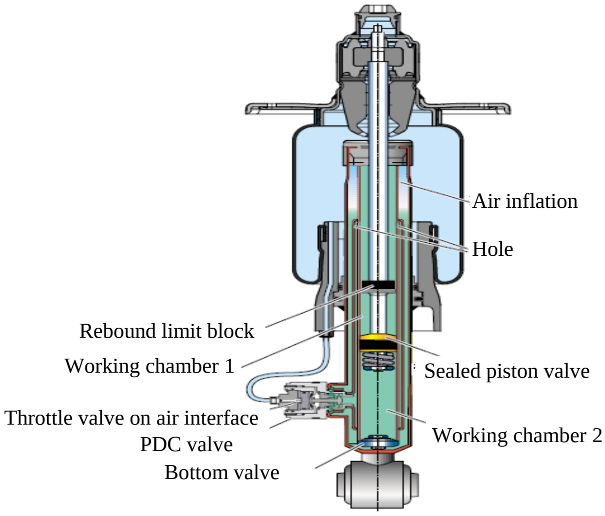


Figure 1. Integrated structure of active suspension system

In order to balance the pressure in the air spring unwilling to change the dynamic pressure (compression and rebound), the air interface of the valve PDC is equipped with a throttle valve. The working process is as follows:

As shown in Figure 2 (a), the elongation process of the air spring when the pressure is smaller. The piston is pulled upward, a part of the oil flow through the piston valve, another part of the oil flow from the working chamber 1 hole to the valve PDC. when the control pressure (air spring pressure) and liquid flow through the valve PDC resistance becomes smaller, so the damping force (damping force) is reduced.

As shown in Figure 2 (b), the elongation of the air spring when the pressure is bigger. The control pressure (air spring pressure) and liquid flow through the PDC valve resistance increased. Most of the liquid (depending on the control pressure) must flow through the piston valve, so the damping force (damping force) increases.

As shown in Figure 2 (c), the compression process when air spring pressure is smaller. The damping force determined by the valve and (to some extent) the liquid which flows through the valve resistance when the piston is pressed downwards, a part of the oil where piston rod extrude flow into the oil chamber through the bottom valve. Another part of the oil flow to the valve PDC through the hole of the working chamber1.

As shown in Figure 2 (d), the compression process when air spring pressure is bigger. As the control pressure (air spring pressure) and liquid flow through the PDC valve resistance increased. Most of the liquid (depending on the control pressure) must flow through the valve, so the damping force (damping force) is increased.

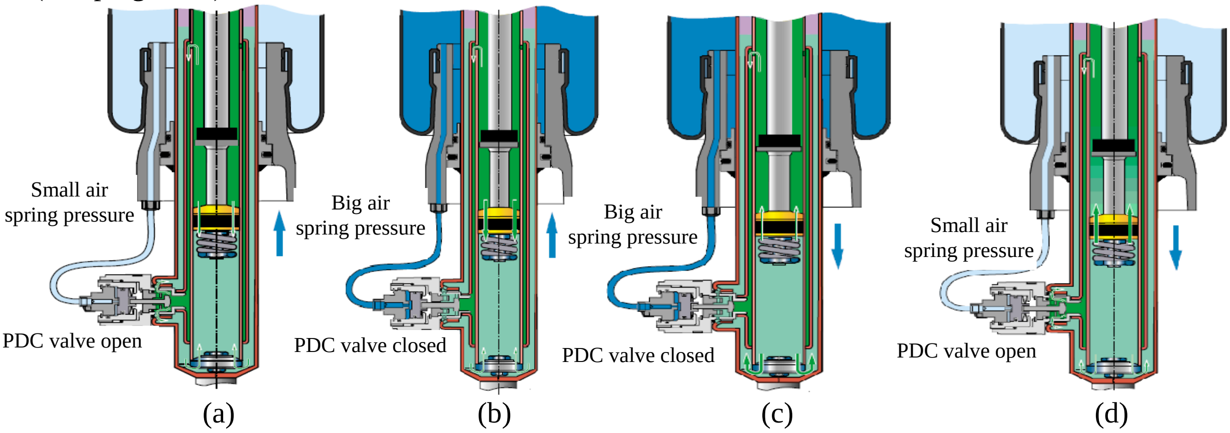


Figure 2. The compression process under bigger stress

3. Dynamic control method of integrated active suspension system

Air spring is an elastic component of suspension, which has the characteristics of variable rigidity, low vibration frequency and anti-bump. And now it has been more and more widely used. According to the equation of state of the gas, the pressure and volume of the compressed air in the air spring are satisfied when the air spring is working.

The minus sign indicates change trend of pressure and the trend in volume. The pressure increases when the volume is reduced. The absolute value is calculated when the stiffness value is calculated. According to the flow conservation, we get the following:

$$\begin{cases} Q_b = Q_t + Q_c \\ Q_t = Q_1 + Q_{crack} \end{cases} \tag{1}$$

According to the relevant knowledge of the cylindrical annular gap flux, the flow rate expression in the annular gap can be obtained.

$$Q_{crack} = \frac{\pi D h^3}{12\mu l_{crack}} \Delta p_1 + \frac{v_0}{2}\pi D h \tag{2}$$

The spring valve plate is deformed when the damping fluid flows through a one-way valve of the damping control valve, there is a gap between the spring valve and the pipeline, and oil in the gap flow to a one-way valve. We obtain the expression of the flow in a turbulent state based on boundary layer theory.

$$Q_{y1} = 2\pi r[-127.8\nu + (2.5\ln\frac{\delta}{2} + 3 - 2.5\ln\nu + 2.5\ln\sqrt{\frac{\Delta p_s \delta}{2l\rho}}] \tag{3}$$

Q_{y1} is the flow of the damping control valve y_1, r is the outer radius of spring valve plate, that is the distance from the outside to the center of the valve plate after the deformation of the valve plate.δ is the transformation value of valve block. Δp_s is the pressure difference between the two ends of the solenoid valve. ν is the kinematic viscosity of fluid, ρ is the density of damping fluid and l is the slit length.

IOP Conf. Series: Materials Science and Engineering **239** (2017) 012004 doi:10.1088/1757-899X/239/1/012004

Domination principle of active suspension system is shown in Figure 3, the control module receives the body acceleration sensor and the horizontal height sensor signal, and the control module analyzes the current road condition according to the body acceleration sensor signal, and the height of the current vehicle is analyzed based on the horizontal height sensor signal. At the same time, the control module obtains the effective information that provided by other control modules through CAN Bus. The control module controls the height of the body by the output of the air pump relay and the height control valve; And by adjusting the output of the electromagnetic damper, the damping coefficient of the damper can be controlled.

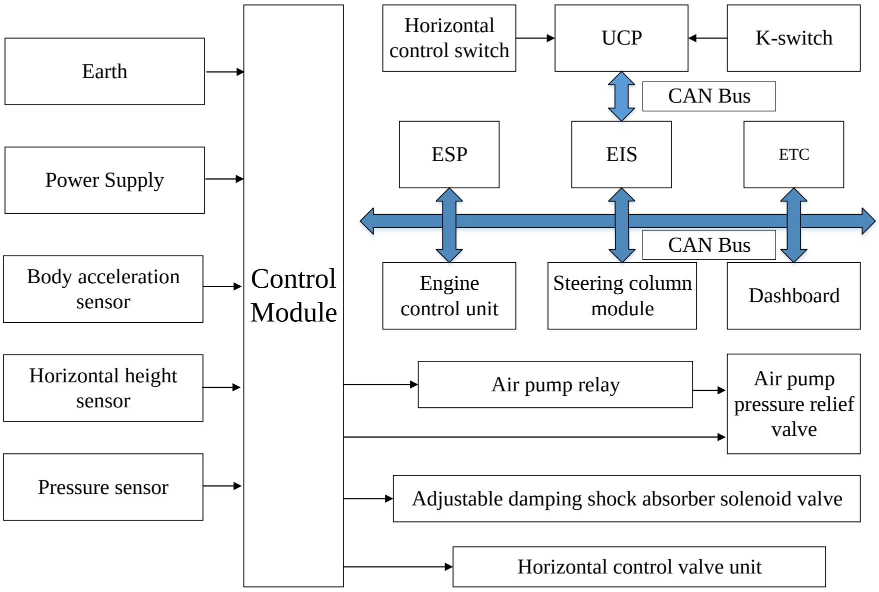
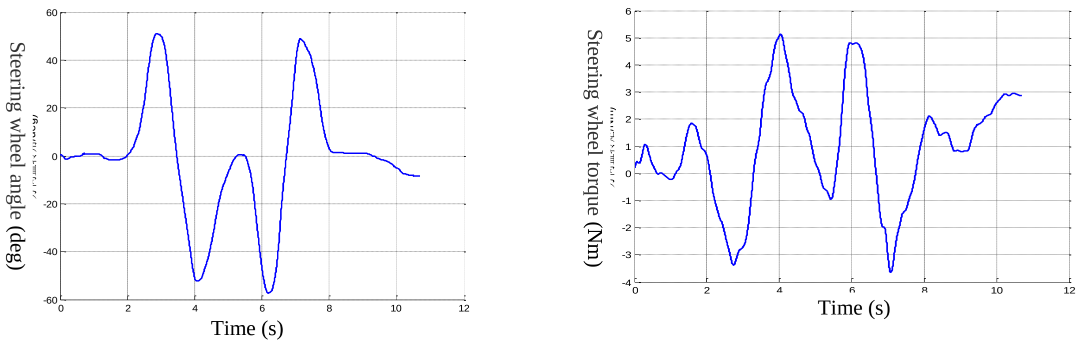


Figure 3. Control strategy of active suspension system

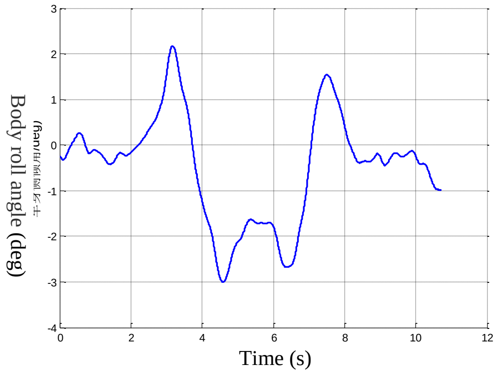
4. Emergency lane change test

The test is a closed loop test for comprehensive determinate the handling stability of “people-vehicle-road”, the test is also based on driver's subjective evaluation criteria. The driving dynamic parameters are determined by driving dynamic parameters through the emergency line path, such as steering wheel angle, yaw angle, roll angle, lateral acceleration, etc. Test must be in accordance with the national standard GB /T 6323.3-94 .

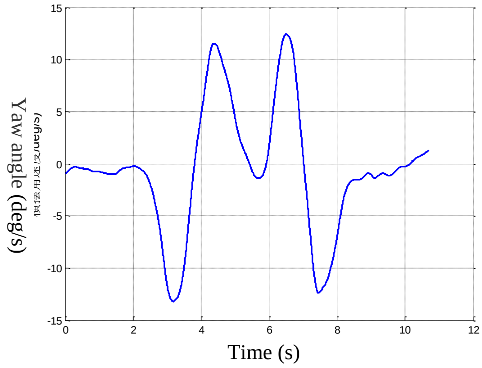
The experimental data were collected, such as steering wheel angle, steering wheel torque, roll angle, yaw angle and lateral acceleration data. The experimental data are shown in Figure 4 and Figure 5, and the results of the test data are shown in Table 1 and Table 2.



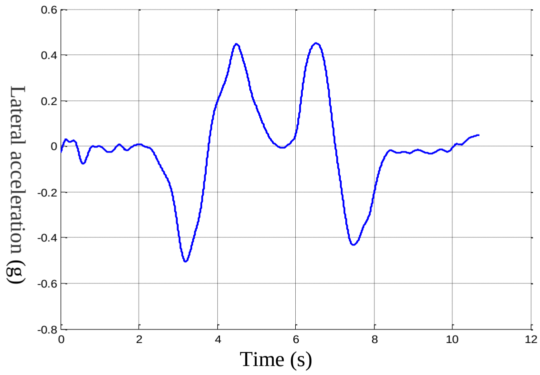
(a) Steering wheel angle (b) Steering wheel torque



(c) Roll angle

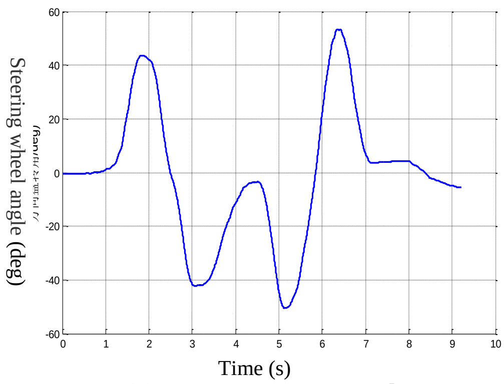


(d) Yaw angle

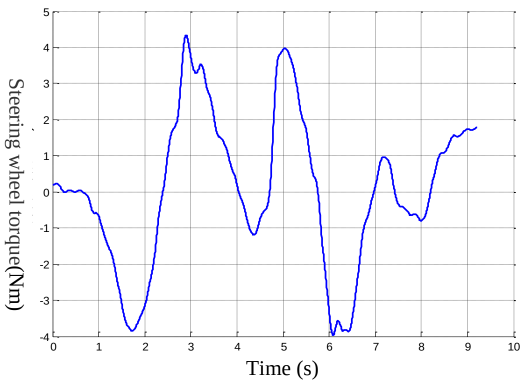


(e) Lateral acceleration

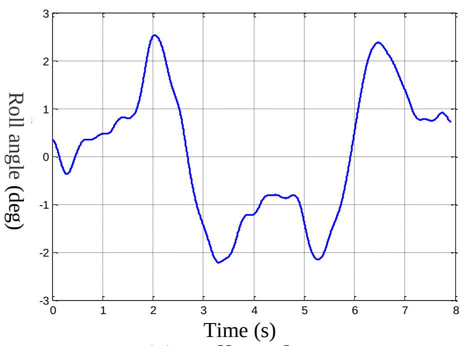
Figure 4. Emergency lane change test results (Hard compression &hard rebound mode, 60km / h)



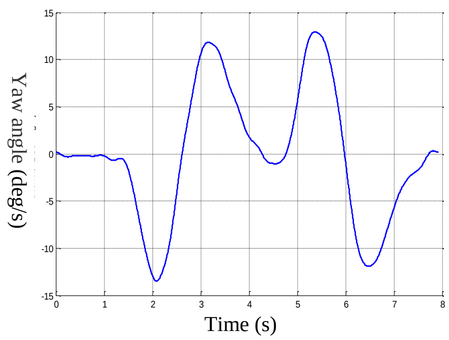
(a) Steering wheel angle



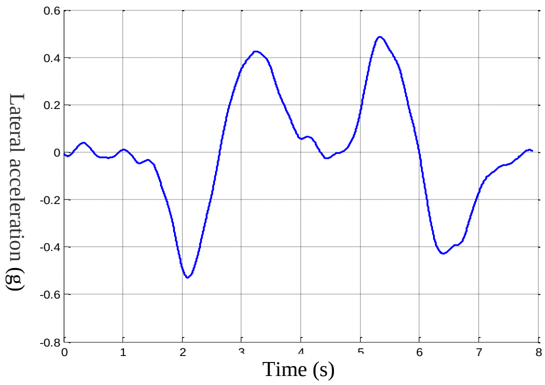
(b) Steering wheel torque



(c) Roll angle



(d) Yaw angle



(e) Lateral acceleration

Figure 5. Emergency lane change test results (Hard compression & soft rebound mode, 60km / h)

From Table 1 and Table 2, in general, the average roll angle, the average vehicle yaw angle, the average body acceleration and other indicators with the increase of vehicle speed are increasing under the condition of emergency lane change. This is similar to the situation of the vehicle with the normal passive suspension, which is in accordance with the basic law of the influence of the vehicle speed on the vehicle handling stability.

Table 1. Emergency lane change test indicators (Hard compression &hard rebound mode)

Speed (km/h)	Average steering wheel angle (deg)	Average steering wheel torque (Nm)	Average roll angle (deg)	Average yaw angle (deg/s)	Average lateral acceleration (g)
30	65.5234	3.1140	1.4065	9.7150	0.1895
40	61.1028	3.4355	1.6696	11.2991	0.2741
50	55.6729	3.7262	1.9533	12.1402	0.3705
60	50.0203	4.1959	2.3209	12.1272	0.4444

Table 2. Emergency lane change test indicators (Hard compression & soft rebound mode)

Speed (km/h)	Average steering wheel angle (deg)	Average steering wheel torque (Nm)	Average roll angle (deg)	Average yaw angle (deg/s)	Average lateral acceleration (g)
30	55.7757	2.9701	1.1154	8.5397	0.1619
40	53.8411	3.3084	1.5514	10.1075	0.2561
50	43.0654	3.3869	1.6692	9.5327	0.3024
60	52.7103	4.2290	2.3159	12.5467	0.4658

From Figure 6, Figure 7 and Figure 8, the damping mode of the shock absorber has an effect on the average body angle, the average lateral acceleration and the average yaw angle of the vehicle body in emergency lane change test.

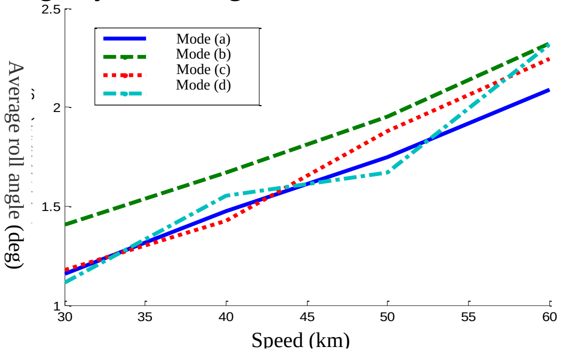


Figure 6. Relationship between speed and the average roll angle

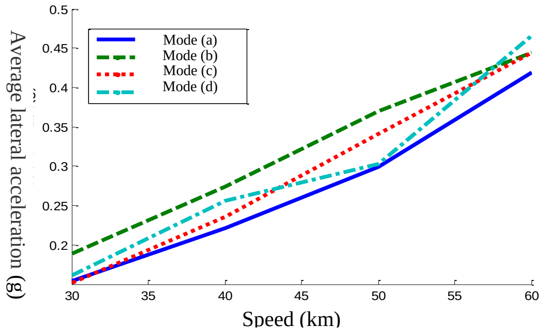


Figure 7. Relationship between speed and the average lateral acceleration

Therefore, the above-mentioned three evaluation indexes are smaller than those of the other three damping modes under the mode of “hard compression &hard rebound”, which is due to the increase of the damping force can effectively inhibit the movement of the piston in the upper and lower chamber. This effectively reducing the tilt of the body, and reduce the average vehicle roll angle and lateral acceleration.

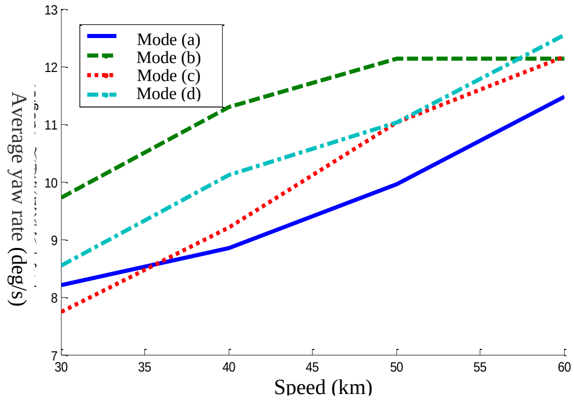


Figure 8. The relationship between speed and the average raw angle

5. Conclusions

The integrated control system of active suspension body height and adjustable damping is replaced by air bag, and damping adjustable shock absorber replace the traditional shock absorber. The height of the body is controlled by the switch between the normal vehicle height mode, the body lift mode and the body down mode, and the adjustable damping control can be used to switch between mode of soft compression & soft rebound, mode of hard compression &hard rebound, mode of soft compression & hard rebound, mode of hard compression & soft rebound. Active suspension system of vehicle body height and adjustable damping integrated control strategy and integrated structure design is reasonable and feasible through the different modes for vehicle speed off hunting test at the speed of 60 km/h road test.

6. References

[1] TUNG S L and JUANG Y T 2011 Expert Systems with Applications vol 38 p 14044
[2] Gysen B L J and Janssen J L G 2011 IEEE Transactions on Vehicular Technology vol 60 p 1384
[3] Kinagi G V and Pitchuka S P 2012 Commercial Vehicle Engineering Congress vol 2 p 111
[4] Zehsaz M and Sadeghi M H 2011 Journal of Terramechanics vol 48 p 439
[5] Wang Ruochen and Zhang Xiaoliang 2012 Transactions of the Chinese Society of Agricultural Engineering vol 28 p 75
[6] Jinshan Lin 2012 Energy Procedia vol 7 p 534
[7] Rongrong Wang and Hui Jing 2015 Journal of the Franklin Institute vol 352 p 468
[8] Li Zhongjie and Lei Zuo 2013 IEEE Transactions on Vehicular Technology vol 62 p 1065
[9] Huihui Pan and Weichao Sun 2015 Mechatronics vol 30 p 363
[10] Weichao Sun and Huihui Pan 2014 Mechatronics vol 24 p 318
[11] Wei Wang and Yuling Song 2015 Applied Soft Computing vol 28 p 167
[12] Jeng-Wen Lin and Pu Fun Shen 2015 Mechanical Systems and Signal Processing vol 62-63 p 63
[13] I. Maciejewski and S. Glowinski 2014 Mechatronics vol 24 p 1242

Acknowledgments

Funding from the National Natural Science Foundation of China (Grant No: 61503163), the "333 project" of Jiangsu Province (Grant No: BRA2016440) and the six talent peaks project in Jiangsu Province (Grant No: ZBZZ-024) are gratefully acknowledged.