소형궤도차량 시스템에서 속도 프로파일 추종을 위한 제어시스템 구축에 관한 연구

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A Study on a Construction of Control System for the Tracking of a Speed Profile in the Personal Rapid Transit System

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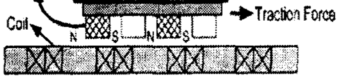
Abstract - This study is concerned with the control system design using Labview Simulation Interface Toolkit and Matlab/Simulink combined system for an application to the personal rapid transit system which has very short headway, requiring accurate speed control to avoid the impact between the vehicles. A simple equation of motion for a vehicle which is activated on the linear motor is introduced. A speed profile that should be tracked by a rear vehicle is produced based on the state information of the two vehicles(the preceding vehicle and the rear vehicle). The speed profile tracking control system is designed by Matlab/Simulink. The simulation results show that the proposed control system is effective to evaluate the speed tracking performance.

1. Introduction

Since the fundamental concept of the PRT system is to make possible for the vehicle to go to its final destination without stopping, and with very short headway, the vehicle control algorithm plays a very important role to avoid the impact between the vehicles. The vehicle control module is basically made of the state information of the preceding and the rear vehicles, vehicle dynamics, and the speed profile that the rear vehicle should be tracked. The speed profile is produced by the central control computer or by the vehicle on-board computer based on the state information of the preceding and the rear vehicles[1][2][3][4]. In this paper we deal with a novel method to construct a control system using Labview Simulation Interface Toolkit and Matlab/Simulink combined system which is composed of modulized blocks. The vehicle equation of motion is expressed by using the simple linear DC motor. In order to guarantee the tracking performance we employ a proportional and differentiation compensator. First we show the equation of motion for the vehicle and the inducement of the quadratic equation to derive the speed profile, and then the construction of the control system is introduced. Finally the simulation results present that the proposed control system is effective to show the tracking performance.

2. Motion of Equation



<Fig 1> Schematic diagram of the vehicle traction

Fig. 1 shows the simple schematic diagram of the vehicle traction. Linear DC motor is employed as the traction system. The equation of motion of the linear DC motor is

$$M\ddot{x}+c_m\dot{x}=F=k_f i \tag{1}$$

where F is the traction force produced by the linear motor, i is the coil current to control the traction force, x is the vehicle displacement in longitudinal direction, k_f is the motor torque coefficient. The voltage equation of the coil is

$$E=Ri+L\frac{di}{dt}+E_b \tag{2}$$

where E is the coil voltage, E_b is the back electromotive force(emf) which is expressed such as

$$E_b=k_b\dot{x} \tag{3}$$

where k_b is the Back EMF coefficient.

Equation (1), (2) and (3) yield the state space model that is

$$\begin{bmatrix}\dot{x}\\ \ddot{x}\\ \dot{i}\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\ 0 & -\frac{c_m}{M} & \frac{k_f}{M}\\ 0 & -\frac{k_b}{L} & -\frac{R}{L}\end{bmatrix}\begin{bmatrix}x\\ \dot{x}\\ i\end{bmatrix}+\begin{bmatrix}0\\ 0\\ \frac{1}{L}\end{bmatrix}E \tag{4}$$

3. Speed Profile

In order to produce a speed profile of a vehicle, the relation of the speed between the two vehicles should be considered. If vehicle A reduces the vehicle speed vehicle B should also reduce the speed with the safety distance d_s. In this case the initial speed of the vehicle B, v_{ci}, should be reduced to the final speed of the vehicle B, v_{cf}, with a deceleration, a, to maintain the safety distance. Thus if the deceleration is constant the speed of the vehicle B is

$$\begin{aligned} v_B &= \int_t^{t_f} -a\,dt \\ &= -at_f + at \\ &= at - v_{cf} \end{aligned} \tag{6}$$

where t is the initial time that the brake of the vehicle B is activated, t_f is the final time to be reached to the final speed. The integration of the velocity yields the moving distance of the vehicle from t to t_f such as:

$$\begin{aligned} d_B &= \int_t^{t_f} v_B\,dt \\ &= \int_t^{t_f}(at-v_{cf})dt \\ &= \frac{1}{2}at^2 - v_{cf}t \end{aligned} \tag{7}$$

The instantaneous position of the vehicle is

$$d_{Bp}=D_b-\left(\frac{1}{2}at^2-v_{cf}t\right) \tag{8}$$

From eq. (8) we can get the following equation which expresses the relation between the vehicle speed and the vehicle position:

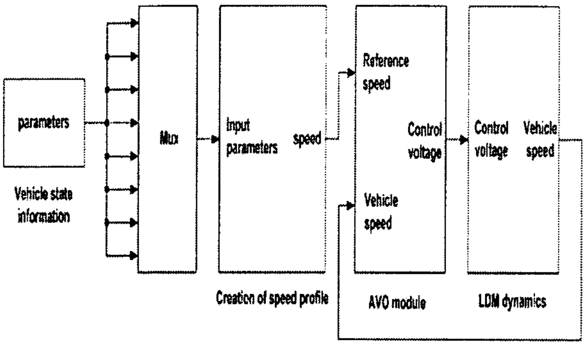
$$D_b-d_{Bp}=\frac{v_B^2-v_{cf}^2}{2a} \tag{9}$$

Eq. (9) yields

$$v_B=\sqrt{2a(D_b-d_{Bp})+v_{cf}^2} \tag{10}$$

4. Synthesis of the Control System

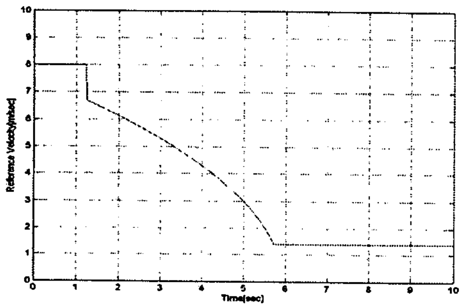
Fig. 2 shows the block diagram of the proposed control system. In this model the value of the input parameters, the state information of the vehicles, are decided for the initial conditions, and then the creation of the speed profile block makes an output of the speed based on the input state information. The produced speed which is the function of the moving distance of the following vehicle is used as the reference speed in the AVO module to make the control command for the LDM. In AVO module it is possible that several different kinds of controllers can be used to control LDM through the feedback of the vehicle speed.



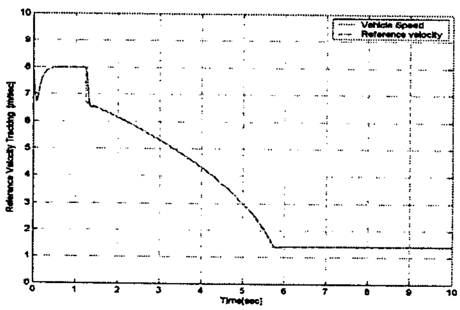
<Fig 2> Block diagram of the control system

5. Simulations

Fig. 3 - Fig. 6 show the simulation results with the different p parameter values. Fig. 3 and Fig. 5 are the speed profile

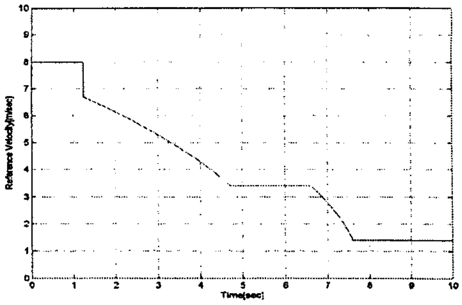


<Fig 3> Reference velocity with one target speed

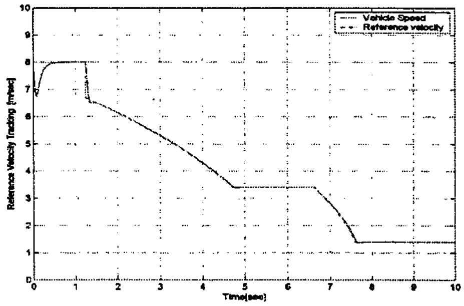


<Fig 4> Tracking performance with one target speed

produced in the creation of the speed profile block. We set the final target velocity to 1.4[m/s] in Fig. 3. Fig 4 presents the tracking performance of the proposed control system. As we see in Fig. 4 the vehicle speed follows the reference speed with great performance, which means the AVO module functions very well. In Fig. 5 we set the two different target speeds: one is 3.4[m/s] and the other is 1.4[m/s]. With the two different target speed we see two slopes in Fig. 5. First slope is more gradual than the



<Fig 5> Reference velocity with two target speed



<Fig 6> Tracking performance with two target speed

second one because of the large velocity difference from the initial speed to the target speed, which means that the first slope starts from 6.7[m/s] and ends in 3.4[m/s], while the second slope starts from 3.4[m/s] and ends in 1.4[m/s]. Fig. 6 shows the velocity tracking performance for the two target speeds with the significantly good tracking performance. In Fig. 4 and Fig. 6 there are the transient overshoot in the initial states. This is because of the control effort to track the reference velocity which has the non zero initial conditions.

6. Conclusions

In this paper we showed the construction of the control system using Labview Simulation Interface Toolkit and Matlab/Simulink combined system for an application to the personal rapid transit system. The speed profile which has been used in the AVO module as the reference speed was calculated in the speed profile creation block. To guarantee the tracking performance we employed the simple PD compensator. In this paper first, we showed the mathematical model of the traction system using the LDM without considering the resistance for the simplification, and then the equation for the speed profile has been derived. Finally The simulation results showed the effectiveness of the proposed automatic vehicle control system.

[References]

[1]. Jun-Ho Lee, Ducko Shin, Yong-Kyu Kim, "A Study on the Headway of the Personal Rapid Transit System", *Journal of the Korean Society for the Railway, Vol. 8, No. 6, pp. 586-591, 2005.*

[2]. Markus Theodor Szillat, "A Low-level PRT Microsimulation", *Ph. D. dissertation, University of Bristol, April 2001.*

[3]. Duncan Mackinnon, "High Capacity Personal Rapid Transit System Developments", *IEEE Transactions on Vehicular Technology, Vol. VT-24, No. 1, pp. 8-14, 1975*

[4]. J.E. Anderson, "Control of Personal Rapid Transit", *Telektronikk 1, 2003*