IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 19, Issue 3 Ser. I (May. – June. 2024), PP 37-40
www.iosrjournals.org

Algorithm for Speed of Electric Vehicle Based on PID Fuzzy Control

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Abstract:
Considering the running situation of automobile being complex and variable frequently, and cruise control system(CCS) having high nonlinearity and nondeterminacy, it will not obtain a good effect in all the conditions by using the method of traditional PID control. A new kind of CCS is designed based on fuzzy PID. The simulation model of dynamics system is established. By dealing with the subject functions and adjusting rules of parameters, the table of fuzzy matrix of PID parameters had been got. Adjusted the control parameters, we made a simulation contrast of the system based on fuzzy PID control and traditional PID control. The simulation results indicate the fuzzy PID controller has a better effect in keeping the speed steady.
***Key Word**:* Cruise Control System (CCS); Fuzzy PID.

Date of Submission: 29-06-2024 Date of Acceptance: 11-07-2024

I. Introduction

The automobile cruise control system, which called CCS for short is also called cruise driving equipment, speed control system, auto-drive system and so on. The driver could set a cruise speed by using the cruise control switches, when the speed of the automobile equipped with CCS exceeds a level (commonly 40km/h). In the course of cruising control, the automobile will alter the opening range of the throttle or shift automatically along with the change of the road gradient and the resistances during the automobile runs. And the automobile could run steadily with the optimal fuel economy or power rule in the storage of microcomputer.

Cruise control system could lessen the drivers' oppressiveness, reduce unnecessary change of speed, economize fuel farthest, reduce the pollution of exhaust gas and increase the efficiency of using engine. And CCS could also improve the dynamical performance and driving comfort to some extent.

At present, CCS has been the equipment set or chosen by many vehicles especially on advanced cars. The research on CCS begins late at home, and its technology is backward comparatively. So the research is mainly about keeping the speed changeless. Although the research on the electronic cruise control system has already begun at home, it is not mature on the whole. And a suitable control method is very important for the research on CCS [1].

II. Principle of CCS

A cruise control system comprises a controller, an executive unit of throttle, an engine and a gearbox, a speed sensor and so on. The principle structure of cruise control system is shown as Fig.1.

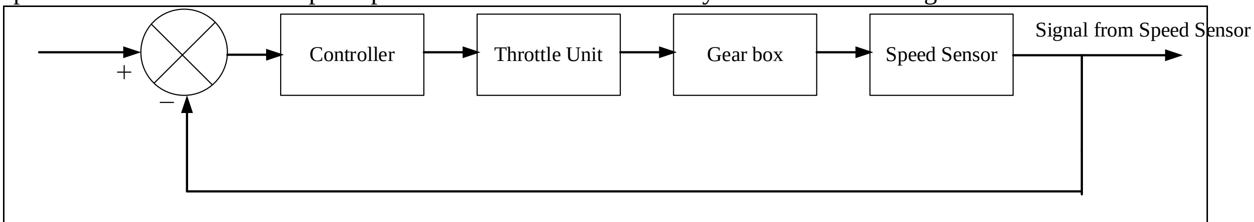

Fig 1:

The controller has two input signals. One is the set speed signal which is set by the driver, and the other is the feed back signal of actual speed. After the electro-controller detects the error between the two inputs, it will produce a throttle control signal and send the signal to the executive unit of throttle. For correcting the error that the electro-controller detects, the opening range of the throttle will be changed by the throttle executive unit based on the signal it receives. Then the speed will be kept changeless.

III. Design of Fuzzy PID Controller

While the vehicle is running, it will be affected by driving force Fc, driving resistance Ff, air resistance Fw, gradient resistance Fh and accelerated resistance Fδ. The model of the vehicle is divided into three parts including the driven wheel, the driving wheel and the body [2]. Suppose the vehicle is running on the ramp, the driving equation of the vehicle is shown as the follow:

$$F_c = F_f + F_w + F_h + \delta ma \quad (1)$$

Where δ is the mass conversion coefficient which reckons in the inertial moment of revolving mass, and δ=1.05. The simulation model of automobile dynamics system is built up in the Simulink of MATLAB (Fig.2). In the figure, max thrust and max brake are the maximal driving force and the maximal braking force respectively. Suppose the simulation vehicle model is a car, and the mass of the vehicle is 1100kg.

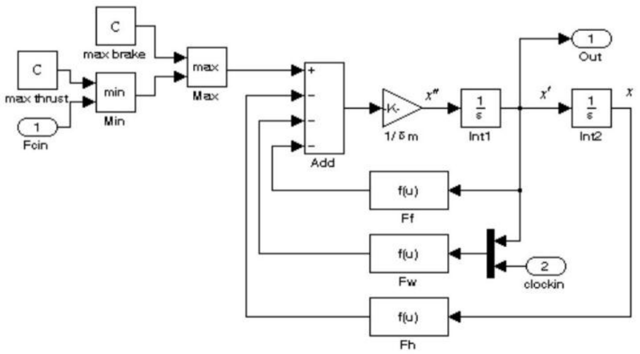

Fig 2. Simulation model of automobile dynamics system

Where

$$F_f = mg.0,014.\left(1 + x'^2/19440\right) \quad (2)$$

$$F_w = 0,01.\left[x' + 20\sin(0,01t)\right]^2 \quad (3)$$

$$F_h = mg.0,01.\sin(0,0001x) \quad (4)$$

During the vehicle is running, it could affected by factors such as disturbance from external load, the indeterminacy of the vehicle's mass and transmission unit's efficiency, and high nonlinearity of the object under control. The process parameters will be changed, so it will not promise to have a content effect in all the conditions by using the method of traditional PID control for CCS. To content the request of timely control, the parameters of PID control are needed to adjust on line during the control process.

Based on PID, fuzzy PID checks the fuzzy matrix to adjust the parameters according to the fuzzy consequence result after calculating the error and the error change rate of current system. Fuzzy PID absorbs the advantages of fuzzy control and traditional PID control. Fuzzy PID has adapting ability, and it not only could recognize and adjust the process parameters automatically and be adapted to the change of process parameters, but also has the excellences of traditional PID controller such as simple configuration, high robustness and high reliability [3]. The principle of fuzzy PID control is shown as Fig.3.

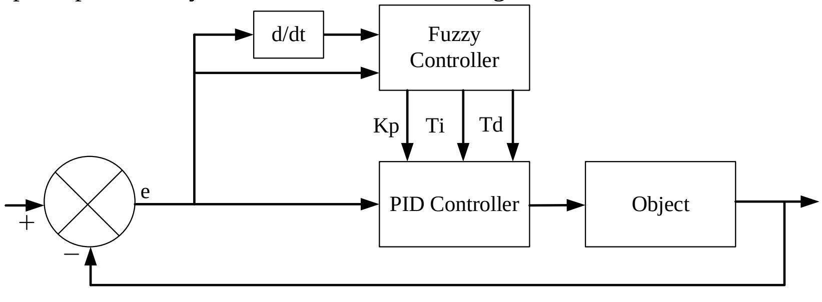

Fig 3. Structure of fuzzy PID control

The change of the absolute value of error |E| and the absolute value of error change rate |EC| are defined as the discourse universe of fuzzy set |E| , |EC|={0,1,2,3,4,5}, and the term set of the linguistic values are defined as |E|, |EC|= {zero(Z), small(S), medium(M), big(B)}. The subject functions are shown as Fig.4. The linguistic values of proportional compensation factor Kp′, integral compensation factor Ti′ and differential compensation factor Td′ are defined as zero(Z), small(S), medium(M), big(B) , and the subject functions are shown as Fig.5.

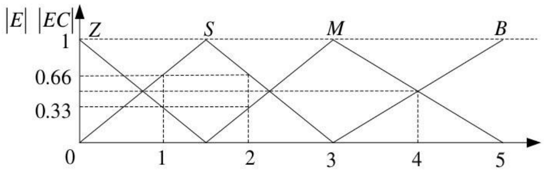

Fig 4. Subject function of |E| and |EC|

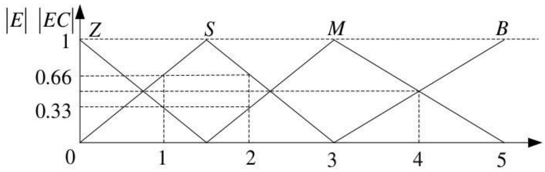

Fig 5. Subject function of Kp′, Ti′ and Td′

Considering the stability, the response speed, the overshoot and the stable state precision of the system, we may get the following constraints [4]:

1) When |E| is bigger, the system should have faster response speed and K_p should be bigger; to prevent the bigger overshoot and the differential supersaturation caused by |E| becoming big suddenly at the beginning, T_i should be bigger and T_d should be smaller.

2) When |E| and |EC| are medium, K_p should be smaller for a smaller system overshoot; T_i should be medium to avoid the effect of dynamic stability; and T_d should be bigger because the adjustive character is sensitive to the change of T_d.

3) When |E| is smaller, for having a good stable state stability, reducing the static error and enhancing the restraining ability of disturbance, the system should have a bigger K_p, a smaller T_i and a smaller T_d.

For the actual automobile cruise control system, the driver will feel uncomfortable when the speed error is zero. So the speed error should not be zero, but be kept in a definite error range. So when we design the fuzzy rules of CCS, the followings are also need to be considered: for allowing an error, the effect of integral element should be weakened and the effect of proportional element should be enhanced when the speed error is smaller correspondingly.

The adjusting rules of K_p, T_i and T_d could be educed according to the rules above and the control requests. The subject functions and the adjusting rules of parameters are input into the FIS editor of MATLAB, and then the table of fuzzy matrix will be got. When the system is running on line, the control system will correct the PID parameters through dealing with the result of fuzzy control, looking up the table and operating [5].

IV. Simulation and Result

The model of CCS will be built up after connecting the automobile dynamics system with the fuzzy PID controller or the PID controller in the Simulink of MATLAB. The initial values of PID control are: K_p =200, T_i =200, T_d =0.15. And the three parameters will be adjusted according to the speed error and the error change rate on line [6].

The following capability of the automobile speed is the ability that the actual speed is changed to the set speed. The simulation is based on the comparison between the fuzzy PID control and the traditional PID control. When the simulation speed is 70km/h and 100km/h with the phase step 30km/h, the results of simulation are shown as Fig.6 and Fig.7. And the y-axis is the ratio of the actual speed to the set speed.

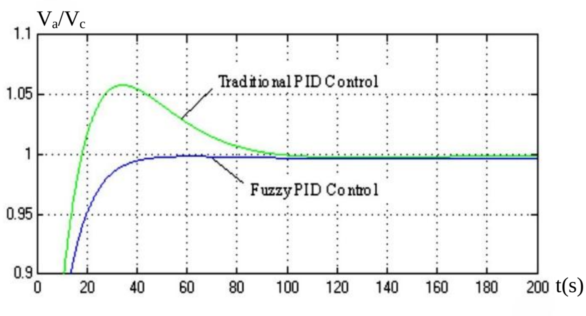

Fig 6. Control curve of 70km/h cruise speed

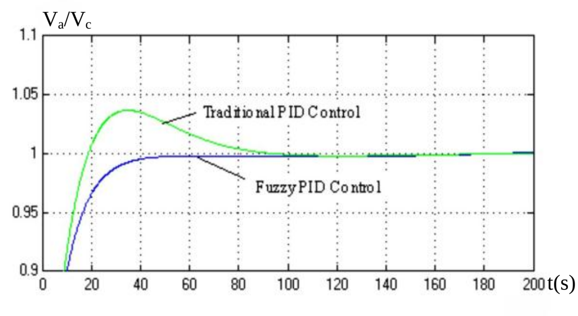

Fig 7. Control curve of 100km/h cruise speed

The keeping capability of the automobile is the ability of the automobile to keep the cruise speed changeless under the disturbers outside. When the simulation speed is 60km/h and 100km/h with the phase step 20km/h, the results of simulation are shown as Fig.8 and Fig.9.

Through the result of the simulation we may know that fuzzy PID controller could make the overshoot smaller and the reaction time shorter comparing with the traditional PID control. Fuzzy PID control could keep the driving speed at the cruise speed well. The fluctuate as sine wave in Fig.8 and Fig.9 is caused by using disturbers with sine wave instead of the actual disturbers when building up the automobile dynamics system. After analysis the results of simulation we may know that fuzzy PID control is better than the traditional PID control with changeless parameters. It could have a good effect at different cruise speeds, and it is a suitable control method for CCS.

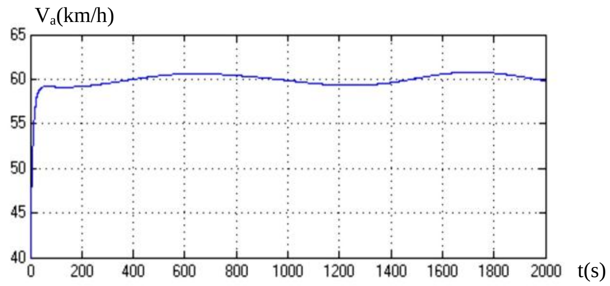

Fig 8. Fuzzy PID simulation result of 60km/h cruise speed

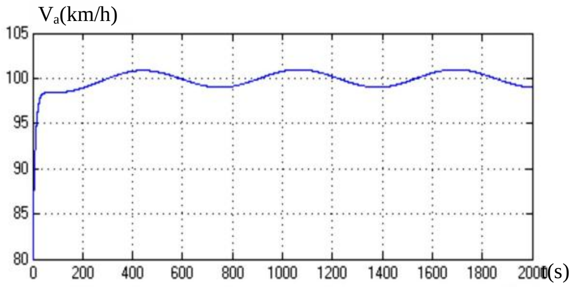

Fig 9. Fuzzy PID simulation result of 100km/h cruise speed

After the simulation, the system is debugged on the automobile control system dais based on the accomplishment of its hardware circuit board and software programming. The result of the test shows that the system could execute some simple orders ideally.

V. Conclusions

Through the result of the simulation we may know that the system have the anticipative control effect with small fluctuate of speed and good stability when using fuzzy PID control. And the test shows that there is a good effect in keeping the speed steady.

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