The Composite Control Method for the GDI Engine Idle Speed Control

Honghui Mu, Jun Tang

Abstract—Engine idle control is related to the engine's fuel consumption and exhaust-gas pollution level, effective idle speed control (ISC) can improve fuel economy and reduce exhaust emissions. Based on the Gasoline Direct Injection engine (GDI) as the research object, the average value of three-state kinetic model is adopted to construct four-stroke gasoline engine dynamics model. The composite controller is proposed to control the engine model, the throttle valve and the spark advance angle are selected as control variable. Fuzzy self-turning PID control mode as feedback controller is presented to control the speed error. The neural network prediction algorithm combines the advantages of predictive control and advance regulation with the advantages of neural network infinite approximation, which has a great effect on improving the following and anti-interference of the system. The simulation results show that the idle speed ripple value is less than 8rpm when the sudden variable load is add to engine, and engine idle speed fluctuation with controlling the throttle value and the spark advance angle is reduced. This control method has better performance than only by controlling the throttle value.

Keywords—Gasoline engine, fuzzy self-tuning PID, idle speed, self-adaptive neural network.

I. INTRODUCTION

IDLE speed is one of the important working condition of automobile engine, according to statistics, about 30 percent of fuel is consumed in idling when a car travels on a dense road [1]. In order to reduce fuel consumption, the idle target rotation speed should be as low as possible, however, rotating speed with too low speed also be avoided, because it can lead to the engine stalling. The external disturbances are exist under engine idle conditions, such as air conditioning, power steering, environmental temperature and fuel quality, therefore, the engine idle condition has the characteristics of nonlinearity, time lag and uncertainty. Two factors affect the engine idle speed performance: one is the flow of mixed gas into the cylinder, which affects the rate of mixed gas combustion rate, pressure and temperature in the combustion chamber directly, then influence engine power, composition of exhaust pollutants and fuel economy finally. The other factor is the ignition timing of the mixed gas in the cylinder, different ignition timing can influence the process of combustion in the cylinder, so the ignition advance angle and idle valve duty cycle can be selected as two important control variables when electric car is working in idling condition.

Due to the nonlinear characteristics of engine idle condition, classical control theory based on accurate model cannot achieve satisfactory results, researchers have shifted the control of the engine to intelligent control without an accurate model in recent years. Parameter self-turning PID, fuzzy control and neural network control already applied to engine control system. An idling PID control based on fuzzy neural network is proposed in [2] for engine idle control, a control platform combining fuzzy control, neural network and PID control, then set up a radial basis function neural network mode with dynamic BP algorithms of three layers forward networks, the experimental results show that this model has better control performance, good robustness and decrease idling speed fluctuation effectively. In [3], a single neural network control method with idle speed is put forward, PID controller and single neural network controller is designed, then simulate model with simulink software, the results show that there is small idle speed fluctuation and converged to the target speed quickly. Aiming at problems of traditional PID controller with poor robustness and poor anti-interference, fuzzy PID control technology is proposed in [4] based on a mean value engine model, model-based development and in-the-Loop technology is used to test and verify the control algorithm, the simulation results show that speed response time is reduced and without overshoot. MIMO nonlinear discrete time model with fuzzy logic is established in [5], the throttle angle and the ignition advance are selected as inputs, the outputs are the idle speed and manifold pressure, the simulation graphs indicate that fuzzy controller smoothens the control surface. In [6], an engine idle speed controller is designed by using fuzzy control theory, the BP neural network is used to realize the relationship of input and output functions in fuzzy control, the nonlinear approximation ability of neural networks can improve the stability of idle speed. Engine idle speed control stabilizes the speed only by adjusting the intake air volume but lack of the control of the ignition advance angle in most of the above literatures, which cause the problem of engine knocking, catalyst overheat and engine stalling.

The composite control stagey is adopt in this paper, adaptive RBF neural network technology and fuzzy self-turning PID control are applied to engine idle speed control, RBF neural network is used to implement feed-forward control which can improve responsiveness when controlling system load disturbances [7]. Replacing the traditional fuzzy controller with adaptive fuzzy control and using the error between actual speed and target speed to realize feed-back control. A car equipped with four-cylinder as the research object, throttle opening and ignition advance angle are controlled, which can improve engine idle speed stability, then establish equations for dynamical simulation model for engine idle condition.

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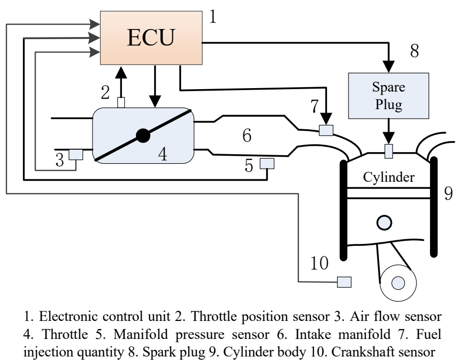

Fig. 1: Nonlinear electronic throttle control system

Simulation results show that a composite control method has good control precision for time-delay system. When the external torques are disturbed, the overshoot is small and the stable time is short, the model has good dynamic and steady state performance.

II. The Description for Engine Idle Model

The engine condition is a complex system with nonlinear and multiple disturbance, a four-cylinder engine 4G15GDI as the research object in the paper, the model structure diagram is established in Fig.1, delay link is added to electronic throttle opening and ignition advance angle [8]. The idling control system contain with electronic choke, intake manifold and cylinder, according to the input signals of each senor, the engine control unit (ECU) compares the target speed with the engine actual speed, the control amount equivalent to the target speed is determined to drive the implementation structure of the control air intake though the difference values which obtained by the comparison.

Engine is an integrated and unified working system, air inlet system, oil feeding system, ignition system, sensor signal acquisition system and controller are involved in this paper. The air enters the air stabilizing chamber through the cracks around the throttle body and the bypass air passage after filtered out by air filter [9], then through the air inlet manifold into each cylinder. The fuel is pumped out by a fuel pump immersed in the fuel tank and flows into the fuel distribution pipe through the fuel filter, the fuel pressure is regulated by the fuel pressure regulator. The starting and closing time of the injector is determined by the controller according to the information that collected by the data acquisition system, which includes the cooling water temperature, the position signal of crankshaft and camshaft, the oxygen content of the exhaust. The fuel injector is driven by a drive circuit, then sprayed into the inlet pipe to form a combustible mixture into the cylinder. The controller also determines the opening degree of the bypass valve according to the speed and cooling water temperature signal, then adjusts the amount of mixed gas in the cylinder.

If the engine operates at idle speed condition, the condition is detected by the throttle position sensor, then the ECU provides the command for the corresponding actuators. When an additional load is added, engine speed is dragged down, the ECU will get the feedback and adjust the speed [10]. Idle speed control is mainly control the volume of idle speed air intake, which is to adjust the opening degree of the idle speed inlet valve to implement the actual speed approach target speed. When the speed is below the set value, open the intake valve flow section large to increase the volume of air, the emission quality is relatively good, but the fuel consumption increasing. The vehicle's fuel consumption decreasing, the mixed gas of the cylinder is diluted by exhaust gas, which causes gasoline engine combustion instability. Therefore, it is important to calibrate the optimal idle speed of engine. The goal of idle speed control is keep the idle running smoothly at lower speed, CO and HC had the lowest emissions can save fuel and reduce emissions effectively.

In order to reduce idling speed, the stability of engine control must be improved to ensure the engine running smooth and the engine do not shut up. The ideal control behavior should be adopted to make the idle speed of gasoline engine stable at the minimum speed which can achieve the aim of save fuel and emission reduction under the premise of ensuring the emission requirement, meanwhile, keeping the speed constant when the load changes. The idle speed target value of the vehicle is 700 $\sim$ 850 r/min generally, actual speed fluctuation amplitude is $\pm$ 50 r/min, which equivalent to the speed fluctuation rate is 5.88% $\sim$ 7.14%.

III. Engine Idle Speed System Model

Mean value model is adopted to construct four-stroke gasoline engine dynamics model, build dynamic model for the intake subsystem, the fuel subsystem and the power output subsystem based on algebraic equation and differential equation. The whole system is divided into several subsystems according to function, and bottom-up modeling method is used to create model. The model is mainly controlled by air intake to control the engine speed. Structure sketch of intake port is shown in Fig. 2, partial molecular model is modified and simplified [11].

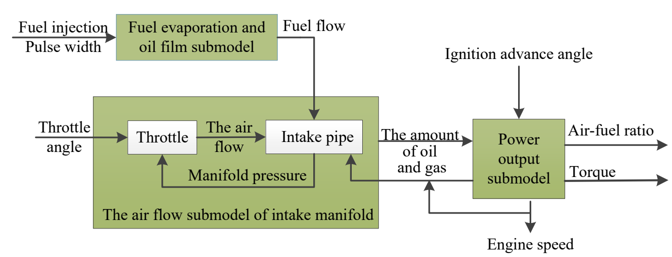

Fig. 2: Structure sketch of intake port

The gas circuit model, fuel evaporation and dynamic oil film model and engine power output model are created as follows:

A. Gas Circuit Model

Gas circuit model is important part of engine model as shown in Fig.3, which can estimate the air flow into the cylinder, then appropriate injection volume is calculated. Cylinder inlet flow model, intake manifold dynamics model and throttle flow model are included in gas circuit model [12].

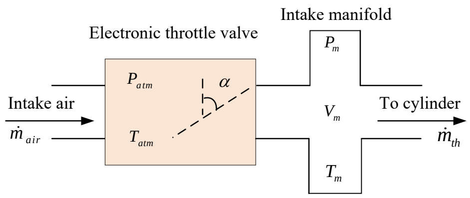

Fig. 3: Structure sketch of intake port

1) Cylinder inlet flow model: The air quality flow into the cylinder is derived from the ideal gas equation which can be described as follows:

$$\dot{m}_{th} = \frac{nV\eta}{120RT_m} \cdot P_m, \tag{1}$$

where, P_m is the intake manifold pressure (kPa), R is gas constant (J/(mol.K)), n is engine speed (r/min), T_m presents inlet manifold temperature (K), V is cylinder volume (m^3), η denotes volumetric efficiency of cylinder, which refers to the ratio between the volume of gas entering the cylinder and the volume of the cylinder during a cycle of the engine, the volumetric efficiency directly affects the calculation value of inlet gas and combustion moment of cylinder. The empirical formula is adopted in this paper:

$$\eta = \frac{f_1(n)P_m + f_2(n)}{P_m}, \tag{2}$$

in the type, $f_1(n)$ and $f_2(n)$ are expression for engine speed: $f_1(n) = a_0 + a_1 n + a_2 n^2$, $f_2(n) = b_0 + b_1 n + b_2 n^2$.

2) The intake manifold dynamics model: Suppose $\dot{m}_{air}$ is the flow of air from atmosphere into the engine cylinder (kg/s), V_m is the manifold volume (m^3), $\dot{m}_{th}$ is the air rate outflow from the intake manifold then into the cylinder (kg/s). The intake manifold pressure p_m is derived from the ideal gas equation [13]

$$P_m = \frac{RT_m}{V_m}\left(\dot{m}_{air} - \dot{m}_{th}\right). \tag{3}$$

3) Throttle flow model: The purpose of building the throttle model is to simulate the air flow characteristics at the throttle, throttle percentage θ as the input (degree), the flow of air from atmosphere into the engine cylinder $\dot{m}_{air}$ as the output, the mathematical model of throttle can be defined as follows:

$$\dot{m}_{air} = M_1 \frac{P_0}{\sqrt{T_0}} f(\theta) g(p) + M_0, \tag{4}$$

where M_0, M_1 are constants, T_0 is atmospheric temperature (K), P_0 is eternal atmospheric pressure (Pa), the empirical formula related to throttle opening which formula can be described as follows:

$$f(\theta) = 1 + 1.4073\cos(\theta\pi/180) + 1.4073\cos^2(\theta\pi/180), \tag{5}$$

$g(p)$ is the function related to the manifold absolute pressure P_i and the external atmospheric pressure P_0, the expression are given as follows:

$$g(p) = \begin{cases} 0, & p < 0.4125 \\ \sqrt{1 - \left(\dfrac{p - 0.4125}{1 - 0.4125}\right)^2}, & p \geq 0.4125 \end{cases}, \tag{6}$$

where, $p = \dfrac{P_i}{P_0}$.

B. Oil circuit model

When the engine works, the gasoline produced by the injector is divided two parts: $\dot{m}_f$ is fuel vaporization entering the cylinder with air (kg/s), $\dot{m}_{fv}$ is attached to the intake manifold wall to form the oil film (kg/s), which gradually evaporates and forms the fuel vapor into the cylinder, this process can be described by first order inertial link. The quality of gasoline to be sprayed is mainly determined by the air-fuel ratio, which ideal value is 14.7. The dynamic equation of the fuel injection process is as follows:

$$\begin{cases} \ddot{m}_{ff} = \dfrac{1}{\tau_f}(\tau_p \dot{m}_{fi} - \dot{m}_{ff}) \\ \dot{m}_f = \dot{m}_{ff} + \dot{m}_{fv} \\ \dot{m}_{fv} = (1 - \tau_p)\dot{m}_{fi}, \end{cases} \tag{7}$$

where, $\dot{m}_{fi}$ is the fuel injection rate enter the cylinder (kg/s), $\ddot{m}_{ff}$ is oil film quality change rate (kg/s^2), $\dot{m}_{ff}$ is oil film evaporation fuel flow into the cylinder, τ_f is oil film evaporation time constant, τ_p is the proportion of gasoline in a jet attached to an intake manifold, the values of τ_f and τ_p are determined by calibration test.

C. Torque generate model

Air and fuel are mixed in the cylinder, then expand generate torque pushing the piston to work after burning. The output torque from automobile engine should overcome the pump gas resistance moment, internal friction of engine and load moment. Assuming I_e is the engine moment of inertia (kg.m^2), $\dot{\omega}$ is the engine angular acceleration (rad/s), T_e denotes the engine output torque (NM), T_L presents the engine load torque (NM). Based on the Newton law, the dynamic equation is obtained as follows:

$$I_e \dot{\omega} = T_e - T_L, \tag{8}$$

the equation translated into the engine speed acceleration as follows:

$$I_e \dot{n} = 2\pi(T_e - T_L)/60, \tag{9}$$

the load torque of the engine as follows:

$$T_L = (n/k_i)^2 + T_d, \tag{10}$$

where k_i is the load factor of the engine, T_d is external load torque. The engine output torque T_e can be described as follows:

$$\begin{aligned} T_e =& c m_{air} + d_1\delta(t - \tau_\delta) + d_2\delta(t - \tau_\delta)n(2\pi/60) \\ &+ d_3 n(2\pi/60) + d_4 n^2(2\pi/60)^2 - 39.22. \end{aligned} \tag{11}$$

where, c, d_1, d_2, d_3, d_4 are fit coefficients which can be fitted by bench test, δ is ignition advance angle ($10^\circ \sim 45^\circ$), τ_δ is the delay time of ignition advance angle (ms), $\tau_\delta = \tau + 15/n$.

The influence of cooling water temperature and physical abrasion are ignored, only the friction torque loss and pump torque loss are considered in this paper. It is assumed that the air combustion ratio is well controlled and always maintained

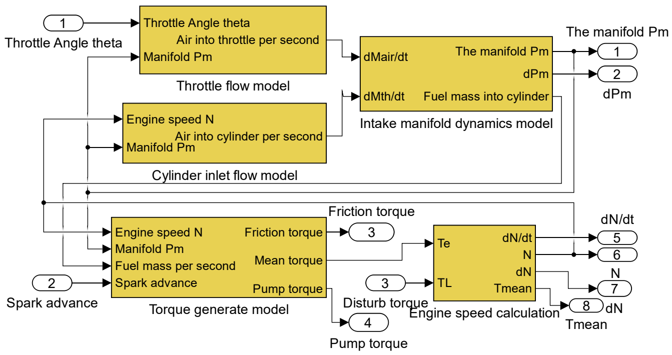

Fig. 4: Engine control model

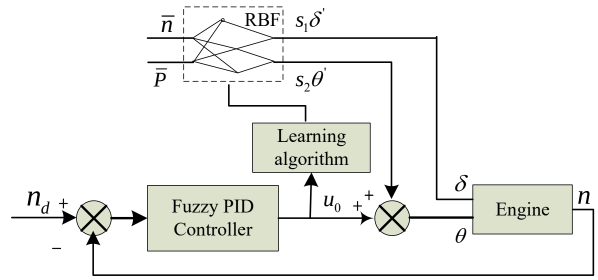

Fig. 5: The composite control stagey structure for engine

in a relatively stable ratio. The drive train model is supplied by simulink showed in Fig.4, the oil circuit module is omitted in this paper, the control parameter is throttle valve opening. The four-cylinder engines model is selected, the parameters are listed in table 1.

TABLE I: the model parameters

parameter	calibration	parameter	calibration
P_0	98000 Pa	T_0	293K
M_0	0.907	M_1	0.00001
I_e	5.2638 kg/m^2	R	8314.3 J(mol.K)
V	0.002m^3	V_m	0.0038 m^3
K_i	263.17	a_0	0.29919064
a_1	0.5542e-4	a_2	0.58025e-8
b_0	0.10136e-7	b_1	0.18778e-10
b_2	0.58025e-13	C	3.2524e-5
d_1	0.6238	d_2	0.675e-3
d_3	0.0216	d_4	0.102e-3

IV. Feed Forward-Feedback Control Strategy Design

The idle running condition of automobile engine is very complicated, it has the characteristics of non-linearity, time-varying and uncertainty, it is difficult to build mathematical model accurately. During idle running, the engine's running speed fluctuates in a wide range due to the unsatisfactory combustion of cylinder, if the ignition advance angle control inaccuracy, the combustion is not good, the pollution is serious and the fuel consumption also increases. So, the focus of idle speed control is stabilized the speed at the target speed to reduce fuel consumption, and then control the air-fuel ratio to reduce emissions. The traditional single linear feedback is difficult to meet the requirements of control precision and response control.

A. Engine Idle Control System

The composite control stagey structure is shown in Fig.5, the composite controller realizes feed-forward feedback control through RBF neural network and adaptive fuzzy PID control. The adaptive fuzzy PID caused feedback control uses the error between the actual speed and the target speed, this method can ensure system stability and inhibit disturbance. The RBF neural network realized feed-forward control to improve the response capability of control system when the load disturbance [14]. The neural network controller adopts the learning algorithm with a tutor and modifies the weight according to u_0, the purpose of learning is to make u_0 tend to be zero. Ignition advance angle δ and throttle percentage θ are produced with neural network through learning. Where, $\delta = \delta' \cdot s_1$, $\theta = \theta' \cdot s_2 + u_0$, s_1 and s_2 are proportional action factor. The inputs of neural network are engine speed $\bar{n}$ and intake manifold pressure $\bar{P}$ after data normalization. This control method during transient conditions do not require complex calibration, the neural network decided to the total output of the control system by learning the output of fuzzy PID controller, it has the strong self-study ability.

B. Feed-Forward control

The RBF network is a three-layer forward network, the mapping from input to output is nonlinear, $x = [x_1, x_2] = [\bar{n}, \bar{P}]$ is the input vector of the network, the mapping from the hidden layer space to the output space is linear, it can great speed up learning and avoid local minima problems. The structure of RBF network as shown in Fig.6.

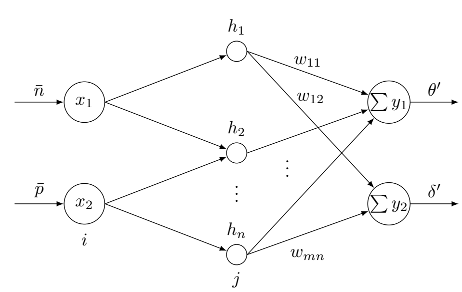

Fig. 6: The structure of RBF network

$H = [h_1, h_2 \cdots h_n]^T$ is the radial basis vector of RBF, h_j is the Gaussian basis function which can be described as follows:

$$h_j = \exp\left(-\frac{\|X - d_j\|^2}{2b_j}\right) = \exp\left(-\frac{C}{2b_j}\right), j = 1, 2 \cdots n. \tag{12}$$

the center vector of the j node $d_j = [d_{j1}, d_{j2} \cdots d_{jn}]$, the basis width vector of the network $B = [b_1, b_2 \cdots b_n]^T$. The outputs of RBF network can be designed as follows:

$$\begin{aligned} \delta' &= y_1 = w_{11}h_1 + w_{12}h_2 + \ldots w_{15}h_n \\ \theta' &= y_2 = w_{21}h_1 + w_{22}h_2 + \ldots w_{25}h_n, \end{aligned} \tag{13}$$

where, W_{mn} are the weight vectors of the networks, which values are defined as follows:

$$W_{ij} = [w_{11}, w_{12} \cdots w_{1n}; w_{21}, w_{22} \cdots w_{2n}]^T, \quad i = 1, 2; j = 1, 2, \ldots n \tag{14}$$

the performance indicator function is calculated as follows:

$$E = \frac{1}{2} {u_0}^2. \tag{15}$$

According to the gradient descent method, the iterative algorithm of output weights, node center and node base width vector parameters are obtained as follows:

$$\begin{aligned} w_j(t) &= w_j(t-1) + \eta u_0(t) h_j \\ &\quad + \beta[w_j(t-1) - w_j(t-2)] \\ b_j(t) &= b_j(t-1) + \eta \Delta b_j \\ &\quad + \beta[b_j(t-1) - b_j(t-2)] \\ d_{ij} &= d_{ij}(t-1) + \eta \Delta d_{ij} \\ &\quad + \beta[d_{ij}(t-1) - d_{ij}(t-2)] \\ \Delta b_j &= u_0(t) w_j h_j C^2 / {b_j}^3 \\ \Delta d_{ij} &= u_0(t) w_j x_j - d_{ij} / {b_j}^2. \end{aligned} \tag{16}$$

in the type, η is the learning rate, β indicates the momentum factor.

C. Fuzzy Self-turning PID Control

The traditional idle speed control of automobile engine is adopted PID control method to adjust throttle opening, the error between the actual speed and the target speed is selected as controlled variable, the control strategy is complex. It has the characteristics of simple principle, use earily, good stability and good robustness, the specific control algorithm is defined as follows:

$$u = K_p \cdot e + K_I \int e dt + K_D \cdot \frac{de}{dt}. \tag{17}$$

Because of the effect of traditional PID control depends on the precise control of mathematical model, it is difficult to build a precise mathematical model for the engine. As a branch of intelligent control, fuzzy control has been widely used in various industrial control, it has the characteristics of shorter transition time, smaller fluctuation and better regulation effect.

Fuzzy self-tuning PID control system with variable universe is designed in this paper, it is improves the disadvantages of low control precision and slow decision-making caused by the fixed input domain of traditional fuzzy controllers, variable domain thinking and scaling factor are proposed by professor Hongxing Li, the basic idea is to make the basic domain of input and output scale with the control requirements according to certain criteria at the appropriate time, the schematic diagram of variable universe fuzzy PID control system is shown in Fig.7. Idle speed deviation e and rate of change of the speed deviation e_c are selected as inputs, the basic domain are $[-e_{\max}, e_{\max}]$ and $[-ec_{\max}, ec_{\max}]$, the fuzzy domain are

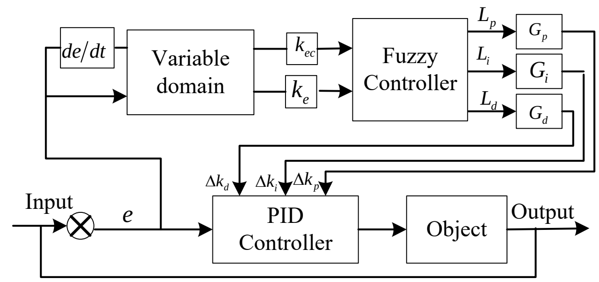

Fig. 7: Schematic diagram of variable universe fuzzy PID control system

$[-E_{\max}, E_{\max}]$ and $[-EC_{\max}, EC_{\max}]$, the scale factor can be defined as follows:

$$\begin{aligned} K_e &= \frac{E_{\max}}{e_{\max}} \\ K_{ec} &= \frac{EC_{\max}}{ec_{\max}}. \end{aligned} \tag{18}$$

Scaling factors are selected as follows:

$$\begin{aligned} \alpha(e) &= 1 - 0.65 \exp(-10e^2) \\ \alpha(ec) &= 1 - 0.6 \exp(-10ec^2). \end{aligned} \tag{19}$$

then the variable domain of the input variables can be described as $[-\alpha(e) \cdot e_{\max}, \alpha(e) \cdot e_{\max}]$ and $[-\alpha(ec) \cdot ec_{\max}, \alpha(ec) \cdot ec_{\max}]$, the corresponding change in the scale factor can be designed as follows:

$$\begin{aligned} K'_e &= \frac{E_{\max}}{\alpha(e) \cdot e_{\max}} = \frac{K_e}{\alpha(e)} \\ K'_{ec} &= \frac{EC_{\max}}{\alpha(ec) \cdot ec_{\max}} = \frac{K_{ec}}{\alpha(ec)}. \end{aligned} \tag{20}$$

Three outputs of fuzzy controller are selected as L_p, L_i, L_d, quantified to $\triangle K_p, \triangle K_i, \triangle K_d$ by quantization factor G_p, G_i, G_d to adjust the three parameters of PID, where $\triangle K_p = L_p \cdot G_p, \triangle K_i = L_i \cdot G_i, \triangle K_d = L_d \cdot G_d$. Three output actual domain are: $[-120, 120], [-18, 18], [-0.3, 0.3]$.

Fuzzy subset L_p, L_i, L_d are divided into 7 states: {NB,NM,NS,ZO,PS,PM,PB}, the triangle membership functions are selected and symmetrical distribution in the fuzzy domain, quantization factors are calculated as follows:

$$\begin{aligned} G_p &= 120/6 = 20 \\ G_i &= 18/3 = 6 \\ G_d &= 0.3/3 = 0.1. \end{aligned} \tag{21}$$

$K_{p0} = 25, K_{i0} = 8$ and $K_{d0} = 2.5$ are the initial value of adaptive PID module, which are got from conventional PID parameters that used $Z - N$ turning method [15].

Following the above fuzzy rules, the fuzzy controller and the simulation diagram of adaptive fuzzy PID control system can be established based on Simulink, fuzzy self-turning PID control algorithm and simulation model is shown in Fig.8, writing S function to change the scale factor in real time and realizing variable domain control.

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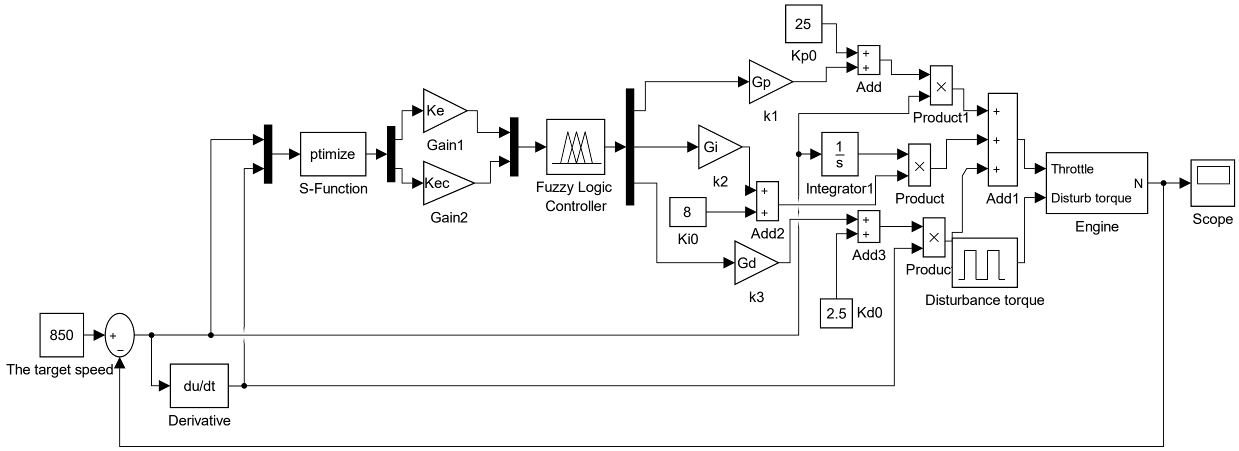

Fig. 8: Fuzzy self-tuning PID control simulation diagram

V. System Simulation Analysis

Engine idle speed control model is shown as Fig.9, the structure of RBF network is 2-5-2, the input variables of RBF network are engine speed n and manifold pressure P , throttle opening θ and ignition advance angle δ are selected as outputs of network, adaptive RBF neural network controller is written with S function, the proportional action factors $s_1 = 10.22, s_2 = 12.34$, the learning rate $\eta = 0.55$, the momentum factor $\beta = 0.05$. Engine idle speed control model

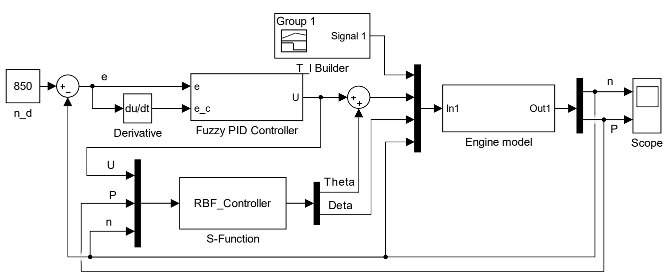

Fig. 9: Engine idle speed control model

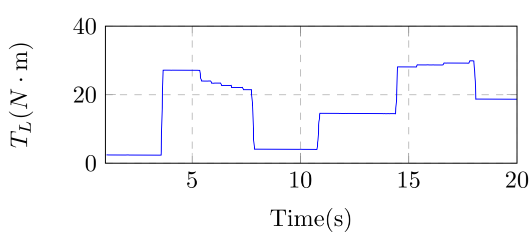

Fig. 10: Sudden external load torque

set at 850 r/min, sudden external load torque T_L are loading as shown in the figure 10, the loads are changed many times. Firstly, the ignition advance angle is disconnected, and fuzzy

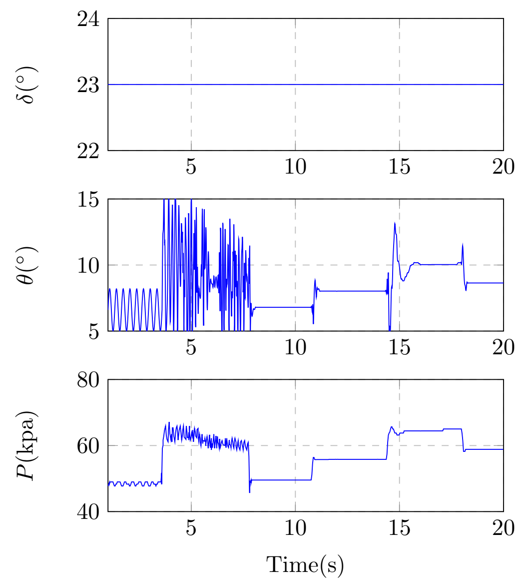

Fig. 11: The response curve of system (Ignition advance angle constantly)

self-tuning PID controller is used to control the system, the constant loading value of the ignition advance angle is 23°, the engine system only controlled by throttle opening θ, the response curve of system as shown in the Fig. 10, the throttle opening θ and manifold pressure P are shown in the Fig.11. Then the composite control method is design to control the engine throttle opening and ignition advance angle at the same time, the output curve of θ and P are shown as the Fig.12.

From the simulation we can see, the curves of throttle opening θ and manifold pressure P are fluctuates significantly at idle start time when the engine only controlled by throttle, the maximum speed fluctuation of the throttle opening is around 10°, there is obvious jitter phenomenon of the manifold pressure. The stability of idle start is improved obviously when the system controlled by throttle and ignition advance angle, the ignition advance angle δ through the adaptive RBF neural networks.

Comparing the engine speed as shown in the Fig.13, the

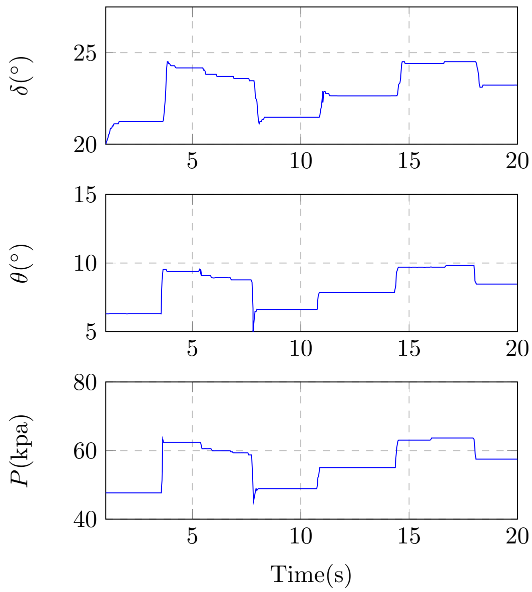

Fig. 12: The response curve of system controlled by throttle and ignition advance angle

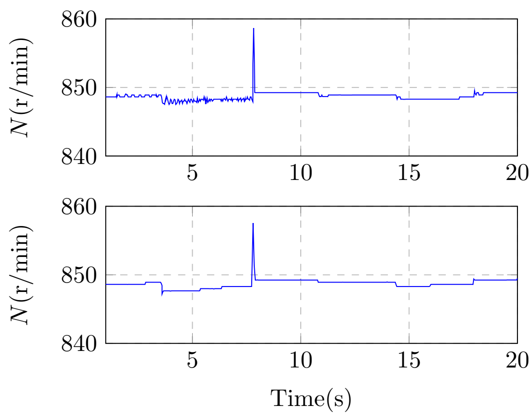

Fig. 13: Engine speed

engine fluctuates obviously at idle start time when only controlled by throttle, but the engine speed tracks the reference speed quite well when the ignition advance angle and the throttle opening are adapted to control the engine. when the torque is added at 2.8s, the maximum speed fluctuation of the tradition control is around 9.5 r/min at 7.9 s, while the transient process cannot cause the engine to stall. Under the effect of the feed-forward-feedback control, the speed stably and no chattering of rotating speed when the system under steady state. The composite control method has better control quality, the system overshoot is small and adjust time is short.

VI. Conclusion

The composite control method for engine idle control is proposed in this paper, control system implements feed-forward feed-back control through neural network and fuzzy PID control, variable domain and self-adjustment are used in fuzzy self-tuning PID control system, which guarantee the stability of the system and suppress the disturbance though feed control. The neural network is used to realize the feed-forward control, this method can improve the response capability and adaptive capability of the control system when the load interferences, the peak error of engine idle speed is only 8 r/min, the simulation results show the effectiveness of the control method. In addition, ignition advance angle and throttle opening are controlled simultaneously, according to contrast simulation results, we can get this control method can reduce adjustment time of control system, improve the smoothness of idle start, reduce the speed jitter at the moment of sudden load change and increase engine idle stability.

Acknowledgment

The work is financially supported by scientific research foundation of Changchun Sci-Tech University(CCKJ201713).

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