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Line Monitoring and Fault Diagnosis Based on the Estimated Engine Cylinder Pressure

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Abstract: The combustion engine cylinder pressure is to describe the process and online fault diagnosis important parameters, we propose a new method of estimating the cylinder pressure line fault diagnosis based on. Parameters for the disturbance and uncertainty ships SI engine model, and based on the nonlinear characteristics of the engine, the establishment of a nonlinear equation of state, designed Durenberger sliding mode observer and combustion heat release model online fault diagnosis of the engine, according to engine speed measurements provide an accurate, reliable and low-cost way to get these states. Simulation results show that the uncertainty of the designed observer can be a good treatment system, with high precision. When the cylinder piston is moved to the TDC, the system observability change, and this time should be reduced estimation error, then the proposed method is discussed in this online engine diagnostic applications.

Keywords: SI engine cylinder pressure estimated Luenberger SMO online diagnosis

1. INTRODUCTION

In recent years, the rapid development of car networking, intelligent use of advanced technology for integrated comprehensive road and traffic perception to achieve large-scale, interactive large volumes of data across multiple systems, each car for traffic overall control of each full-time road for traffic control, to provide traffic safety and traffic efficiency and network-based applications [1]. Telematics remotely locate, read cars with information, simple troubleshooting information, etc. To give the cars on the roads and convenient user experience is an important part of intelligent cars. However, when the car is moving on the way sudden emergencies complex fault current vehicle networking technology still cannot handle this issue well, to be carried out by the car repair business professional automotive diagnostic repair resolved.

Cars remote monitoring and fault diagnosis system is to protect the safe operation of vehicles, vehicle remote monitoring and fault diagnosis system is to protect the safe operation of vehicles, an important means to improve the reliability of the vehicle. It uses new technology, new means to achieve real-time online monitoring of vehicle operating conditions, check the vehicle electronic control system operating data collection and analysis ahead of the vehicle operating condition data [2], ensure that the car in front and failure to maintain reasonable maintenance for the car manufacturers, dealers and services, passenger and freight business and the majority of owners are having a good guide.

Objective OBD system is to monitor vehicle emissions systems, with the development of OBD, and now more and more applications in fault diagnosis, when the car broke down, OBD fault will generate code, and primary data from remote diagnostic system OBD, only when the car broke down again capable of remote data communication, which reach the car remote monitoring, real-time follow-up car state, based on the cylinder pressure can be most directly see the current state of the car, the car pre-judge and provide a powerful diagnostic information.

Gasoline working status and fault mostly can change over time (or crank angle) of the curve is reflected by the cylinder pressure. Usually the working status of the gasoline engine is determined to take manually, that person's work experience combined with gasoline to determine the phenomenon, such as smoke, temperature, output power, and noise and so on. Some reflect the gasoline engine operating condition parameters cannot be directly obtained, such as the best indicator of the cylinder pressure gasoline engine work and state of the art, in the condition monitoring and fault diagnosis gasoline engine, and is one of the best indicators characterizing gasoline engine running state. Gasoline engine cylinder pressure indicator diagram describing the basic performance gasoline powered tools, a comprehensive reflection of the thermal conversion process gasoline output of mechanical work. Estimation and analysis of gasoline engine cylinder pressure to improve performance gasoline engine, gasoline engine carried optimal ignition timing control or fuel injection control, emission control and status monitoring and fault diagnosis has a very important role.

Since the 1990s, research and development of automobile engine misfire fault diagnosis method of rapid emergence of many new ways. Cylinder once every successful ignition, the engine that is get the power input, thereby causing the engine speed fluctuations. If you ignore the inertia torque, load torque, friction torque and pumping torque, the angular velocity fluctuation waveform and each combustion power generation will be directly related to the speed change research can provide a method for misfire detection. In theory, any exception will be reflected in the variance lead to speed, acceleration or torque. Therefore, the study of the variance of speed or acceleration can be provided based on the speed of the crankshaft cylinder pressure estimated misfire diagnostic method. Since the crankshaft speed measurement method is simple, so the instantaneous angular velocity of the crankshaft is the most widely used of a misfire judgment basis for the instability of the crankshaft angular velocity [3] be normalized, increasing engine misfire detection performance. For the problem of the crankshaft angular velocity contains a lot of noise, the literature [4] on the crankshaft angular velocity signal modulation and order analysis to improve the accuracy of misfire judgment. Compared to the crankshaft instantaneous angular velocity, instantaneous crankshaft angular acceleration of the crank shaft angular velocity more directly reflect the actual work of running state of the engine [5], due to the angular acceleration is included in the temporal information of fire, by a suitable feature extraction methods to obtain the desired fire signal, [6] on the basis of the autocorrelation and triple correlation algorithm, proposed algorithm is used to fire multiple correlations of instantaneous frequency-domain information extraction, can achieve real-time monitoring misfire. Since the crankshaft torque can be measured directly, usually indirect estimation methods available, [7] were established single-cylinder and multi-cylinder engine model, using parameter estimation method, the realization of cylinder torque and friction torque combined torque estimated by in multi-cylinder engine cylinder misfire determination and positioning. These methods are low cost, simple structure.

By comparing all of the method, based on the estimated engine cylinder pressure Misfire diagnosis is more sensitive, more convenient method. Eliminating the need for any additional equipment, so that in the misfire diagnostic has broad prospects. [8] studied the fire of gas, cylinder pressure variation trajectory indicated mean effective torque, the heat release rate and combustion phase measure impact of standards, it was found the maximum cylinder pressure and crank angle corresponding changes starting combustion parameters of the fire detection no effect, and the only point of the cylinder pressure variation different crank angle and fire occurrence has a strong correlation, and further use of artificial neural networks, HCCI engine misfire fault for the detection with high accuracy. Cylinder pressure not only to online diagnosis engine misfire and knocking and other abnormal combustion phenomena, can also be achieved by the engine cylinder pressure transient air-fuel ratio, ignition timing, exhaust gas recirculation (EGR) and other engine control.

Currently, access to the engine cylinder pressure measurement include direct and indirect estimation methods. Wherein the direct measurement depends on the accuracy of the high cylinder pressure sensor. The impact is limited by cost, durability and installation environment and other factors, in the on-board diagnostic rarely directly install the cylinder pressure sensor. Indirect measurement is to obtain information through the engine cylinder pressure to estimate, since the algorithm can be written ECU, do not need to add any device and has attracted wide attention.

For indirect measurements, [9] proposed a dynamic model of the elastic crankshaft by measuring the speed of the crankshaft using cylinder pressure indication torque to give the desired, literature suggests Kalman filter algorithm, based on the power of the engine cylinder pressure in the crank angle domain school model, according to first-order linear time-varying system estimates the cylinder pressure. Extended Kalman filter can eliminate errors due to the edge due to the heat transfer coefficient. Both methods reconstruction algorithm uses feedforward cylinder pressure, so in practice, the measurement of cylinder pressure estimation accuracy of the noise will have a greater impact. [10] use of BP, RBF neural network to build relationships with the cylinder head vibration signal the instant when the speed signal and the in-cylinder pressure signal, the principle can be considered as cestrum analysis, with the identification of the cylinder head and cylinder pressure of the vibration signal between the transfer function. The disadvantage is the need to cover in just mounted vibration sensor, and susceptible to interference from other vibration signals. This method is essentially an offline method not suitable for online troubleshooting. With the variable structure control technology continues to evolve, sliding mode observer design theory is often used to estimate the cylinder pressure, the literature [11] using the engine speed and the estimated speed error correction cylinder pressure measurement error is designed sliding mode observer, However, the estimation accuracy is not high (around 50%). By the methods discussed above, observer build quality of the estimated pressure has a huge impact, which is a low-cost method, only the device in the system device to measure engine speed. Not only can online estimate cylinder pressure, but also provide a theoretical basis for on-line diagnosis.

The study found that research misfire fault diagnosis method based on sliding mode observer design is very extensive, high diagnostic accuracy, and has good robustness [12]. The literature [13] to define the difference between the net crankshaft torque to indicated torque, the torque bias, the design of the cylinder torque variation estimated by the sliding mode observer, the input value estimation problem into a problem tracking control, and torque according to the power stroke deviation estimate, obtained an average deviation of torque, thus achieving different conditions misfire online diagnosis. Document [14] combined with the engine crankshaft dynamics model, using sliding mode control theory in dealing with complex nonlinear problems robustness, tracking ability and strong advantages designed automobile engine dynamic torque sliding mode tracking controller implements for accurate diagnosis of low speed engine operating conditions change, such as failure of the cylinder misfires, unfortunately, it did not realize the fault diagnosis of engine speed operating conditions. For unknown model parameter perturbation, slow convergence time and SMO own existence chattering problem, literature [15-18] Super-twisting based on second order sliding mode observer, can effectively improve the sliding mode observer tracking speed and estimation accuracy, the actual fault diagnosis system has a good guide, but only for a single cylinder engine model has been studied to promote the realization of a multi-cylinder model will be more engineering practice. In this paper, a novel sliding mode observer Luenberger combustion heat release model and engine fault diagnosis online.

2. CYLJNDER PRESSURE AND HEAT RELEASEE STIMATION

Pressure cylinder engine cylinder pressure observer need two dynamic model system status can be measured cylinder pressure transient crankshaft angular velocity and unpredictable, the crankshaft angular velocity information is useful for monitoring the internal state of the engine, the engine control and diagnostic applications most one of the frequent state system, the friction torque, load torque, crankshaft inertia nonlinear dynamics model can be used (1) to represent

$$\dot{\omega} = \frac{1}{J(\theta)}(T_{ind} - T_f - T_1 - T_r)$$

Wherein ω the angular velocity of the crankshaft, θ the crank angle, $J(\theta)$ instantaneous crankshaft inertia, torque indication T_{ind}:

$$T_{ind} = A_p L_{tor} p$$

Here p, A_p and L_{tor} the cylinder pressure and respectively, the piston area and effective pressure on the axis of the arm

$$L_{tor} = R\sin\theta + \frac{R^2\cos\theta\sin\theta}{\sqrt{h^2 - (R\sin\theta)}}$$

$$A_p = \frac{\pi D^2}{4}$$

Wherein the length of the connecting rod h, a crank radius R, the diameter of the piston D, the crank angle q.

T_r Inertial torque generated by the rotating and reciprocating motion, that is $T_r = \frac{1}{2}\frac{dJ(\theta)}{d\theta}\omega^2$. The friction torque and load torque as an extension torque, [15],

Make $z = \omega$, $y_0 = -\frac{1}{J(\theta)}T_r$, $x_0 = \frac{u}{J(\theta)}$, $u = T_{ind} - T$, Second-order sliding mode observer for joint estimation, including observer as follows:

$$\dot{\hat{z}} = y_0 + \chi(s_0)$$

By using the observed torque can be extended torque T.

Suppose the same cylinder load, so that the pressure between the cylinders and the temperature is the same, the cylinder pressure kinetic model can be described by a single combustion thermodynamic equations can be written as:

$$\dot{p} = -\frac{\gamma}{V}\dot{V}p + \frac{\gamma - 1}{V}(1-\alpha)\dot{Q}_{ch}$$

Fuel combustion heat release rate:

$$\dot{Q}_{ch} = m_f Q_{LHV}\dot{x}_b$$

$\dot{x}_b$ Fuel burn rate, usually expressed by the empirical formula Wiebe function, namely $\dot{x}_b = mn\exp(-m((\theta-\theta_0)/\Delta\theta)^n)((\theta-\theta_0)/\Delta\theta)^{n-1}\dot{\theta}/\Delta\theta$

m_f Which here represents the injected fuel quality, Q_{LHV} low calorific value fuel, gasoline fuel of low calorific value $Q_{LHV} = 43.448MJ/kg$, for what I can find from the fuel gauge, the mass fraction of fuel combustion m_b

$$m_b = (1-\exp(-n(\frac{q-q_0}{Dq})^{m+1}))$$

Where is the efficiency parameter n, the form factor m, q_0 for the combustion starting point, Dq for combustion duration.

Engine stage acting in the role of in-cylinder gas pressure, the piston from the top dead center (TDC) bottom dead center (BDC) to move and drive the crankshaft rotation acting through the connecting rod. In this process, the relationship between the displacement of the piston and the crank $V_c = pD^2 s/(4(r-1))$ shaft rotation angle is as follows:

$$y_p = R(1-\cos\theta) + l(1-\cos\alpha_\theta)$$

The total volume of the cylinder V ,The working volume of the cylinder V_s, which is $V = V_s + V_c$, Wherein the combustion volume: $V_c = pD^2 s/(4(r-1))$, s is Piston stroke, r Compression ratio, this

$$\dot{V} = (V_s + V_c)^{-1} = A_p L_{tor}\omega$$

To sum up the engine crankshaft dynamics models and engine cylinder pressure analysis of the model can be obtained as by-cylinder engine model:

$$\begin{cases} \dot{\omega} = \dfrac{A_p L_{tor} p - m_1 R L_{tor} g(\theta)\omega^2 - T_L(\theta)}{J(\theta)} \\ \dot{p} = -\dfrac{\gamma}{V}\dot{V}p + \dfrac{\gamma-1}{V}(1-\alpha)\dot{Q}_{ch} \end{cases}$$

So that we can get the engine nonlinear state system:

$$\begin{cases} \dot{x} = Ax + Bu + f(t) \\ y = Cx \end{cases}$$

After analysis, the rank of the matrix of the judgment matrix is equal to 2, the observability rank criterion can be seen, and the system is observable. To make the observer can overcome the parameters of the model in the presence of turbulence and uncertainty, and improve the tracking speed state estimation, based on this design Luenberger sliding mode observer, sliding mode observer Luenberger consists of two parts: speed up the tracking speed of Luenberger items and processing parameters uncertainties and disturbance sliding mode. First, the engine nonlinear systems design Luenberger sliding mode observer as follows:

$$\begin{cases} \dot{x} = Ax + Bu + f(t) + L(y - C\hat{x}) \\ y = Cx \end{cases}$$

Among of them, $\hat{x}$ the state observation x , $L = (l_1 \;\; l_2)^T$ is the Gain parameter for the Luenberger. In order to be able to accelerate state estimation Luenberger item tracking speed, observation error is defined as $\tilde{x} = x - \hat{x}$, There can be error-type system is: $\dot{\tilde{x}} = (A - LC)\tilde{x}$, Known by the Lyapunov stability theorem, if $(A - LC)$ is a Hurwitz matrix, the real part of the eigenvalues is negative $(A - LC)$, The system error $\dot{\tilde{x}}$ is asymptotically stable. Secondly, in order to be able to handle observer present in the system parameters uncertainties and disturbance, for Luenberger sliding mode observer added to give Luenberger sliding mode observer:

$$\dot{\hat{x}} = A\hat{x} + Bu + \hat{f}(t) + L(y - C\hat{x}) + K\,\mathrm{s}ign(y - C\hat{x})$$

Among $K = (k_1 \;\; k_2)^T$ the sliding mode gain parameters to be designed by the above formula to obtain the cylinder pressure Luenberger sliding mode observer as follows:

$$\begin{cases} \dot{\hat{\omega}} = \dfrac{1}{J(\theta)} A_p L_{tor} \hat{p} - \hat{f}(t) + l_1\tilde{\omega} + K\,\mathrm{s}ign(\tilde{\omega}) \\ \dot{\hat{p}} = -\dfrac{\gamma}{V}\dot{V}p + \dfrac{\gamma - 1}{V}(1-\alpha)\dot{Q}_{ch} + l_2\tilde{\omega} + k_2 sign(\tilde{\omega}) \end{cases}$$

Among them $\tilde{\omega} = \omega - \hat{\omega}$ Measured by comparison we can get the system error:

$$\dot{\tilde{\omega}} = \frac{1}{J(\theta)} A_p L_{tor} \tilde{p} - \tilde{f}(t) - l_1\tilde{\omega} - k_1 sign(\tilde{\omega})$$

$$\dot{\tilde{p}} = -\frac{\gamma}{V}\dot{V}\tilde{p} - l_2\tilde{\omega} - k_2 sign(\tilde{\omega})$$

Among, $\tilde{f}(t) = f(t) - \hat{f}(t)$

Define sliding surface $S = \tilde{\omega}$ when the sliding surface before arrival, by the sliding mode theory known:

$$S\dot{S}=\tilde{\omega}\dot{\tilde{\omega}}=\tilde{\omega}\left(\frac{1}{J(\theta)}A_pL_{tor}\tilde{p}-l_1\tilde{\omega}-\tilde{f}(t)-k_1 sign(\tilde{\omega})\right)<0$$

Then

$$k_1>\left(\frac{1}{J(\theta)}A_pL_{tor}\tilde{p}-l_1\tilde{\omega}-\tilde{f}(t)\right)sign(\tilde{\omega})$$

When the engine speed approaches the estimated value of the actual value is reached when the sliding surface, $S=\tilde{\omega}=0$ and then $\dot{\tilde{\omega}}=0$, $\tilde{f}(t)=0$ by the above formula can be obtained:

$$sign(\tilde{\omega})=\frac{1}{k_1 J(\theta)}A_pL_{tor}\tilde{p}$$

The formula is substituted into formulas systematic errors can be $\dot{\tilde{p}}$, to make $\dot{\tilde{p}}$ a gradual convergence to zero, we need to $\left(-\frac{\gamma}{V}\dot{V}-\frac{k_2}{k_1 J(\theta)}A_pL_{tor}\right)<0$, scilicet $k_2>-\frac{k_1 J(\theta)}{A_pL_{tor}}\frac{\gamma\dot{V}}{V}$, When the piston is moved to the TDC (top dead center) nearby, the array seen by Matrices unobservable cylinder pressure, cylinder pressure should be closed at this time observer of the sliding gain k, only a part of the L Luenberger gain pressure corrections.

Meanwhile, we can estimate the corresponding combustion heat release for the firing cylinder. The heat release rate is given by a single zone combustion model as

$$dQ_{ch}=\frac{\gamma}{\gamma-1}\hat{P}dV+\frac{1}{\gamma-1}Vd\hat{P}+dQ_{ht}$$

Subsequently, the combustion heat release can be computed by integrating the release rate in

$$Q_{ch}=\int_{t_0}^{t}\dot{\hat{Q}}_{ch}dt$$

3. SYSTEM OBSERVER AND OBSERVER PARAMETERS

3.1 System Observer

Take advantage of GT-power set up SI single cylinder engine model to give cylinder pressure “actual “value p and use Malta / Simulink take built observer and co-simulation to obtain the cylinder pressure observation Value $\hat{p}$, The definition of cylinder pressure error $e=(\hat{p}-p)/p*100\%$.

Use Luenberger sliding mode observer, on the compression stroke and power stroke of cylinder pressure were observed, Luenberger gain parameters selected gain parameter according to which the observer Slip Theory.

Crankshaft inertia nonlinear dynamics model, Uncertainty has decided by $\frac{T_r - T_f - T_l}{J(\theta)}$. When the high engine speed, torque inertia would model consists of rotating and reciprocating motion generated uncertainty have a greater impact. As can be seen from the chart, in the high-load conditions, the engine speed estimated value of the actual speed value $\omega = 3600(r/\min)$ Fluctuations around. Its estimated value and the error is within 1%, to meet the estimated value of the engine speed approaches the actual value of the prerequisite to ensure that the actual value is close to that Luenberger sliding mode observer sliding item increases the uncertainty of the model accuracy, thereby reducing the uncertainty in the estimation accuracy on the cylinder pressure.

However, by the formula we know that when the cylinder piston is moved to the TDC or BDC position when the crank angle at this time is 0 or 180 degrees, so there is no offset, in this condition, there is no feedback, then through modeling wrong to estimate the cylinder pressure is wrong, there is no reference value.

That TDC around the area (720 degrees), the pressure and the resulting error is an error rendering speed crank angle. Pressure at TDC, the speed error is always equal to zero even if high error increases. In this case, the observer can observe the system loses it and it cannot be the correct speed error feedback pressure estimation error location. Error in the vicinity of TDC crank angle, speed is not very important, although the pressure error. This explains why big pressure error can occur in the TDC position, although the estimated rate is very close to the measured speed.

3.2 Observer parameters

One way to solve the problem of large pressure errors around TDC is to reduce the modeling errors in the pressure dynamic equation. In the combustion model, the dynamics of cylinder pressure are determined by the combustion heat release rate, cylinder volume change and cylinder pressure. Because the cylinder volume change rate is determined by the engine configuration and speed, the only factor that influences modeling accuracy is the given heat release rate model (the Wiebe function).

In the combustion model, the cylinder pressure is mainly powered by the combustion heat release Q_{ch}, V Cylinder volume is determined by the rate of change, the rate of change of the engine cylinder volume structure and speed decisions. So pressure dynamic equation type of combustion heat release rate model m is the primary factor in determining the accuracy of the model. From the equation (6) and (7) known, heat release rate depends on the fuel injection mass m_f, combustion starting point q_0, combustion duration D_q, form factor n and efficiency parameters m, Wherein the fuel injection is determined by the quality of the engine control module, and the combustion duration is constant, the combustion starting point q_0, n changes in efficiency and form factor of m parameters of the disturbance caused by the system will have a significant impact.

The foregoing analysis, to ensure the same quality of combustion, under conditions of uncertainty it exists, selects $n = 3, m = 2$, at high load conditions and low load conditions of the cylinder pressure estimation, simulation results are shown the following.

From the above chart we can see that in the case of changing the parameters, Luenberger sliding mode observer to estimate the cylinder pressure of any course with high accuracy, especially at low load conditions, the estimation error is reduced to less than 9%, indicating that designed observer can well handle parameter perturbation system.

Of course, because of combustion variation. The shapes of fraction burned or heat release rates are different from cycle to cycle. The shape of each curve is accompanied by a set of n hand m. Even though n and m are adjusted for different pressure levels. Combustion variations can still cause modeling error to produce errors in pressure estimation. We may use the information about the estimated combustion heat release and its rate at the early combustion stage to identify an appropriate a and rn. And apply these values in the observer for the remainder of combustion. However, the early stage of combustion is usually close to the TDC position. Thus, not many data are available to identify the and rri in the current heat release curve. Nevertheless, the adjustable n and m can reduce some estimation errors for the weak or no observations periods.

4. MISFIREA ND COMBUSTION FAULTD ETECTION

The previously described pressure observer can be used as a detection tool for misfire or other abnormal combustion. Ideally, the cylinder pressures estimated by the observer are close to the measured pressures under any combustion conditions. If this was true, it would be easy to recognize cylinder misfire or abnormal combustion by setting some varying thresholds around the pressure profiles. However, actual conditions are somewhat different. Because of the no observability problem occurring around TDC, the estimated pressure is not close to the measured pressure profile if there is a full or partial misfire. It is difficult to use an estimated misfire pressure with large error for misfire detection by setting a threshold around the pressure profile. If we assume that there is a permanent cylinder misfire in a cylinder, and we can detect the first misfire cycle right after it occurs, then we can change the parameters or the injected fuel mass in algorithm. Thus, in the next combustion cycle, the estimation of pressure dynamics will be closer to the measured pressure under misfire. One question arises in applying this method: How can we detect the misfire near the time when it begins? If the cylinder is just in abrupt misfire and retum to a normal combustion condition, changing the model parameters will cause the estimation for the following normal cycle to produce a large estimation error. Now let us suppose that a misfire cycle occurs right after a normal combustion cycle, and that the parameters used in the previous normal cycle are still used in this misfire cycle. For the angles far from the TDC position, because of the strong observability, good pressure estimation is obtained even though the parameters in algorithm are for a normal combustion condition. However, when the piston goes toward or just passes its TDC position, weak or zero observability causes large estimation errors. For the reasons mentioned previously, there is no feedback from the errors between measured and estimated velocities to the pressure estimation at TDC. The prediction of cylinder pressure is determined entirely by the pressure equation in algorithm. Hence, the magnitude of the modeling error in algorithm determines the magnitude of the pressure estimation error. In this abmpt misfire cycle, the parameters of the pressure model in algorithm are designed for normal combustion, not for a misfiring cylinder. Undoubtedly, the large modeling error will cause the observer to produce large pressure estimation errors at angles with weak or no observability. Therefore, the estimated cylinder pressure profile deviates significantly from the measured pressure. No proper thresholds can be set around the profile of this incorrectly estimated pressure to detect misfire. Utilizing the combustion heat release and release rate estimation, a solution to this problem is achieved. Estimated cylinder pressure and measured pressure of a misfired there is no heat discharged from the mixture, the heat release is near zero for every crank angle. After the angle passes the combustion start angle and moves closer to TDC, the estimated heat release rate begins to increase above zero. This apparent increasing heat release rate causes the observer to have a higher cylinder pressure than the measured pressure. Subsequently, higher estimated crankshaft velocity and high velocity error result from this higher estimated pressure. The observer can force the estimated velocity to retum to the sliding surface of zero velocity error, but weak observability prevents the observer from correcting the pressure errors. Since the heat release and release rate continue to increase to their maximum values under the parameters for normal combustion, the estimated pressure continues to deviate from the measured pressure. Consequently, large pressure errors are produced.

5. CONCLUSION

The study introduced the use of a Sliding Observer for estimation of cylinder pressure and combustion heat release for SI engines. In this estimation, the observability problem at piston TDC position may induce large apparent pressure estimation errors. However, adjustable parameters in the observer are used to improve the accuracy. Moreover. The detection of cylinder misfire or abnormal combustion is also achieved by utilizing the estimated heat release or heat release rate. A load torque observer can be added to the engine speed dynamic equation to further reduce modeling errors.

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