Research on the Modeling and Control of Intake System of Turbocharged Gasoline Engine

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Abstract: While the rapid development of the automobile industry has brought great convenience to people's lives, it has also made energy scarcity and environmental pollution one of the great challenges that mankind has to face. In order to achieve the goal of low emissions and low energy consumption, automotive engineers and scholars have proposed many new technologies to improve the performance of automotive engines. Gasoline engine turbocharging technology can effectively increase the power of a car engine with the same displacement, and relatively low fuel consumption, so it has been widely used in automotive products. This paper takes turbocharged gasoline engine as the research object, and studies the modeling and control of turbocharged gasoline engine intake system.

1. Introduction

The development level of the automobile industry is to a large extent a sign of the overall industrial level. This is because the automobile industry involves many fields, including mechanical manufacturing technology, material production and processing technology, electronic control and microelectronics technology. In regions such as North America, dominated by the United States, Europe, dominated by Germany, and Japan, strong industrial accumulation has become the basis for the rapid development of its automobile industry. China's industry started relatively late, and its industrial foundation was very weak. At the same time, it also encountered more obstacles in the development process, which led to the relatively backward development of my country's automobile industry. However, my country's automobile industry has also developed rapidly in recent years. At present, Chinese automakers have been able to produce their own passenger cars, commercial vehicles, military vehicles and other models, and they also have very good performance. More and more core components are gradually localized.

In 2012, my country's annual automobile production and sales both exceeded 19 million, setting a new record, with a growth rate of over 4%, surpassing the United States once again to become the world's number one. The blowout-style automobile development has brought strong impetus to my country's economic development. However, we must also realize that due to the rapid increase in vehicles, the pollution and resource depletion problems caused by exhaust emissions have become a huge challenge for people. At the beginning of 2013, a large area of northern my country encountered haze weather, and automobile exhaust has an inescapable responsibility for the formation of haze weather. In Beijing, motor vehicles are the largest source of urban PM2.5, about 1/4. In February 2013, domestic refined oil prices were adjusted, and the prices of gasoline and diesel increased by 300 yuan and 290 yuan per ton respectively. It can be seen that both the government and users have more stringent requirements on all aspects of the quality of modern cars, not only requiring higher active and passive safety guarantees and better driving experience, but also in terms of exhaust emissions and fuel economy. Improve as much as possible.

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2. The Current Situation of Turbocharging At Home and Abroad

Engine supercharging technology is developed with the development of supercharger technology. Therefore, the progress of engine supercharging technology can be seen from the development process of superchargers. Engine superchargers came out at the beginning of the last century. With the development of technology, the application of engine superchargers has become more and more common. The types have evolved from mechanical supercharging to exhaust gas turbocharging and even dual supercharging. From the diesel engine to the gasoline engine gradually. At the same time, with the continuous innovation of research and development technology and the continuous improvement of production technology, the engine turbocharging technology has been greatly improved, and the torque improvement effect is obvious compared with the unsupercharged engine. High- and medium-power diesel engines have adopted engine supercharging technology, and medium- and small-power diesel engines have used supercharging technology more than 75%. Gasoline engine supercharging has also exceeded 60% in recent years, and it is on the rise.

The turbocharging technology of gasoline engines in foreign countries began in the early 1980s, and due to the accumulation of diesel engine technology, turbocharging technology has been rapidly developed and improved in gasoline engines. By the 1990s, nearly 30% of gasoline engines produced in Europe, the United States and Japan had adopted supercharging technology, and at the same time, the international penetration rate of gasoline engine supercharging technology reached 15%. By the beginning of the 21st century, the penetration rate of gasoline engines using turbocharging technology has reached 50%. In terms of turbocharging technology for gasoline engines, Japan, Germany, and the United States are more advanced in technology. Due to the late start of my country's overall car industry, my country's gasoline engine turbocharging technology currently lags behind foreign countries. my country began to study gasoline engine supercharging in the 1990s and achieved success on CA-10B and DG26100-12 models. Around 2000, several universities such as Tsinghua University and Jilin University also carried out research on gasoline engine turbocharging. In the past ten years, my country's gasoline engine supercharging technology has been continuously developed, and the supercharging performance has been continuously improved. At present, the country is also vigorously developing gasoline engine turbocharging. Many domestic automakers such as Geely, FAW, SAIC, etc. have turbocharged gasoline engine products with complete intellectual property rights. Turbocharged gasoline engines have become the development trend of gasoline engines.

3. Introduction to Engine Modeling Method

The engine is a very complex and highly nonlinear system. There is a strong dynamic coupling between the various mechanical subsystems of the engine. At the same time, the actual operating conditions of the engine system include many kinds of combustion, chemical reactions, and chemical reactions. Physical and geometric constraints, as well as energy conversion, etc., will cause the engine control system development cycle to be relatively long. The rapid development of automotive electronics technology has made both the market and the automotive manufacturers put forward more stringent requirements on the research and development time period. The length of the research and development period plays a decisive role in the launch of products. The use of simulation to shorten the engine development cycle has been widely used in various automobile manufacturers. This requires us to establish an accurate engine model for simulation development. Only in this way can we shorten the development cycle of the entire engine electronic control system. Engine modeling started in the 1960s. After more than 50 years of development, it has been relatively mature. Various modeling concepts and methods have emerged during this period. At the same time, engine modeling has also developed from simple low-precision models to Complex high-precision model. Next, according to the development history of engine modeling, four typical engine models are briefly introduced.

Graphical model: The models in the early stage of engine control research are relatively simple.

Among them, the engine mathematical model established by Dobner in 1980 is a representative graphic model. The main feature of the model is that the establishment of the model mainly depends on the fitting of test data. In this way, the calculation of the model is mainly based on the look-up table and the fitting formula. The advantage of such modeling is that the structure of the established engine model is relatively simple, and the amount of model calculation is not large; in addition, the simulation of the steady-state operating conditions of the engine can achieve relatively high accuracy and accuracy. However, the disadvantage of this model is that the scope of application of the model is relatively narrow, and it is only suitable for specific types of engines.

The chart model was widely used in the early 1980s, mainly because the computer's real-time simulation computing ability was relatively weak, and the chart model required a small amount of calculation, the model was simple, and the steady-state simulation of the engine was relatively high. Therefore, it just met the needs of specific engine research at that time.

Average value model: In 1981, Aquino proposed the average value model. The modeling process of the model is relatively simple. The average dynamics of the engine over a period of time are specifically described in the form of differential equations and algebraic equations. The disadvantage is that the model cannot be used to study the dynamic change process of the engine under each specific stroke. In 1981, Cho and Hendrick proposed a multi-point injection engine model, which was developed for the control system, but the disadvantage is that the accuracy of the engine transient model was not verified. In 1987, the model established by Powell and Cook studied the effect of time lag on the engine. Among them, the three-state engine dynamics model established by Hendricks in 1989 is the most representative average model.

The average value modeling mechanism regards the engine working process as a continuous system, that is, cancels the concept of stroke, and mainly considers the average value of related parameters in a complete working cycle, such as the amount of air entering the cylinder, fuel flow, and output torque In the form of differential equations and algebraic equations, it comprehensively describes the average dynamics of the engine over a period of time, such as air intake, fuel supply, and crankshaft torque and speed, thereby establishing a dynamic model of the engine. Of course, our commonly used average value model also has its shortcomings, that is, it is not suitable for studying engine state changes under various stroke conditions. Many parameters in the model need to be experimentally fitted, which also brings difficulties to modeling.

Non-linear engine torque generation model: Butts proposed a typical non-linear engine torque generation model in 1995. The model incorporates many theorems and technologies such as physics theorems, mathematics theorems, sensor technology, identification technology, etc., and at the same time comprehensively considers the basic principles of engine physical quantities. The various nonlinear factors that may exist in the engine are comprehensively and systematically studied, and the delay in the intake process and fuel evaporation process is studied. However, the disadvantage of this model is that it does not consider the wet wall characteristics of the fuel pipeline.

Hybrid model: Italy's Andrea Balluchi and others first proposed the engine hybrid model in 2000. They believed that both continuous-time dynamics and discrete events should be considered when modeling the engine, so that the engine control system can better establish an accurate cycle. The model also considers robust technology to meet the increasing demands of passengers for vehicle comfort, safety, fuel economy and emission levels.

Among the four main engine models introduced above, the average value model is currently the most widely used, especially in the field of engine control. For the design and analysis of the turbocharged engine gas path control system in this article, the average value model meets the design requirements. Here, we use the average value theory to establish the gas path model of the turbocharged gasoline engine.

4. The Simulink Model of the Gas Path System is Built

The main work of this section is to build a simulation model of the overall gas system of a turbocharged gasoline engine in the Simulink environment, including: turbine exhaust valve gas flow characteristics model, turbine model, mechanical connecting rod model, compressor model, throttle air Flow characteristics model, intake manifold dynamics model, air volume model entering the cylinder, electronic throttle valve and exhaust valve model. The gas path model is the basis for the offline simulation verification of the gas path control system in Simulink.

Simulink is a simulation software, which is a part of the mathematical software Matlab, and has become the most basic basic simulation software in the field of simulation control. With the development of computer technology and engineering requirements, engineers and technicians have found that only using programming languages such as C or Fortran is already a little too weak. If there is a new programming language that uses a matrix as the basic operation unit, it will be extremely exciting for engineers. Great convenience. Thus, Mathworks formula developed the matrix-based mathematics software Matlab. The software has been widely used in engineering calculations and analysis and scientific research and development due to its powerful matrix computing capabilities.

Matlab is a mathematical software with excellent numerical calculation performance developed by Mathworks. Matlab not only has excellent performance in matrix operations, but its instruction language M language is similar to the C language widely used in engineering, and is more compatible with common language formats such as C, C++, Fortran, etc., and has been widely used in engineering. Other software that uses the language supported by Matlab for secondary development all use Matlab as the platform. Software developed based on Matlab is also very common now, and most engineering software is compatible with Matlab. The main work of this section is to build a simulation model of the overall gas system of a turbocharged gasoline engine in the Simulink environment, including: turbine exhaust valve gas flow characteristics model, turbine model, mechanical connecting rod model, compressor model, throttle air Flow characteristics model, intake manifold dynamics model, air volume model entering the cylinder, electronic throttle valve and exhaust valve model. The gas path model is the basis for the offline simulation and verification of the gas path control algorithm in matlab.

Enter the Simulink model of cylinder air volume. This part of the model simulates the air mass flow characteristics entering the engine cylinder. The volumetric efficiency is obtained by map calibration. The volumetric efficiency refers to the ratio of the actual air flow entering the cylinder to the air flow estimated by the ideal state equation, which represents the engine's suction Qi ability. The greater the volumetric efficiency, the greater the torque output of the engine. When the structure of the intake system is constant, its size changes with the engine speed and intake manifold pressure. The usual treatment methods are obtained through experiments. The building in the Simulink environment is shown in Figure 1:

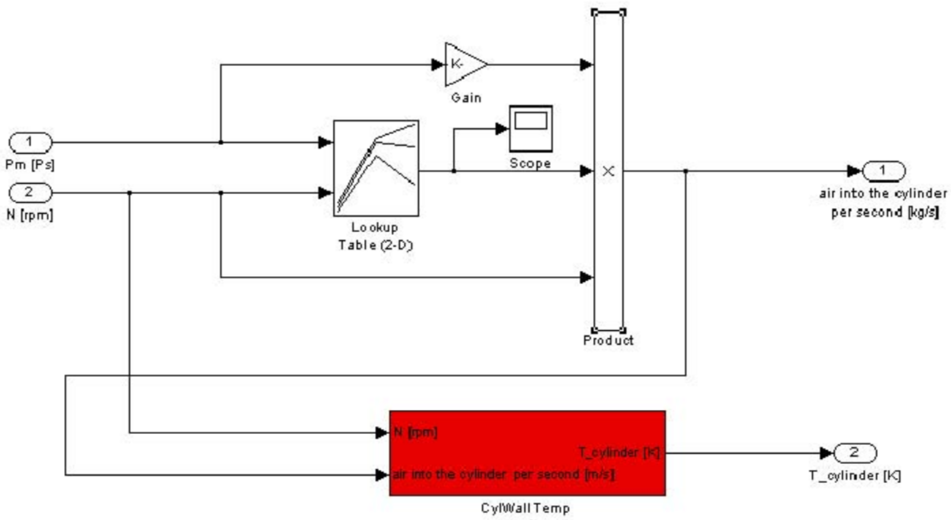

Fig.1 Simulink Model of Air Volume Entering the Cylinder

The turbo exhaust valve and the throttle valve are two electronic components with the same physical structure on a turbocharged engine. The working state of turbocharged engine is very complicated, so the opening degree of turbo exhaust valve and throttle valve is constantly changing and contains nonlinearity. Both the turbo exhaust valve and the throttle valve are flow valve bodies, which control the gas flow by controlling the opening of the baffle. Since both the electronic throttle valve and the turbo exhaust valve use a flow valve body, the model structure and mechanism are the same, but the parameters are somewhat different. Only the representative models are given below. Establish accurate electronic throttle and turbo exhaust valve models to pave the way for subsequent simulation experiments.

5. Conclusion

With the continuous increase of car ownership, the continuous deterioration of the environment and the continuous rise of global oil prices, both the government and the people have higher and higher requirements for vehicle emissions and fuel consumption. For turbocharged engines, fast and precise intake air volume control directly affects the fuel injection volume, because it is the prerequisite for precise control of the air-fuel ratio, and it also affects the adjustment of the ignition advance angle, which is reflected in the fuel economy. Sexually. Therefore, under the framework of torque-based engine control, the precise modeling and control of the engine gas path is very meaningful.

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