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Engine Optimization Based on GT-POWER Model

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Abstract: The whole structure of gasoline engine and the combustion simulation calculation model have been established with the GT-POWER software, and upon the verification of its accuracy, the model is used for matching calculation of parameters, such as structure parameters and air-fuel ratio of exhaust system of the engine, so as to analyze and calculate the influence of some parameters on engine performance and its rules. Based on this, parameters, including structure parameters and air-fuel of the exhaust system, are optimally calculated, and the experimental verification is available.
Keywords: engine, performance optimization, GT-POWER

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1. INTRODUCTION

This engine is the inline four-cylinder PFI gasoline engine, and remains to be further optimized on performance in satisfaction with demands of the complete vehicle. Structure parameters of the engine shall not be greatly altered under no change of original dimensions and additional product costs. In the process of engine optimization, we firstly know the original machine performance well through the test and test data necessary for calibrating simulation model determined by the test, including cylinder pressure and manifold pressure, etc., and establish the engine simulation model with the one-dimensional simulation software (GT-power) for engine based on results of engine performance test. Then, the optimal matching calculation is conducted for parameters, like structure parameters and air-fuel ratio of exhaust system of the engine, to analyze the influence of each parameter on engine performance, and the optimization scheme is proposed based on test results; finally, the effectiveness of the optimization scheme is simulated and verified. [1].

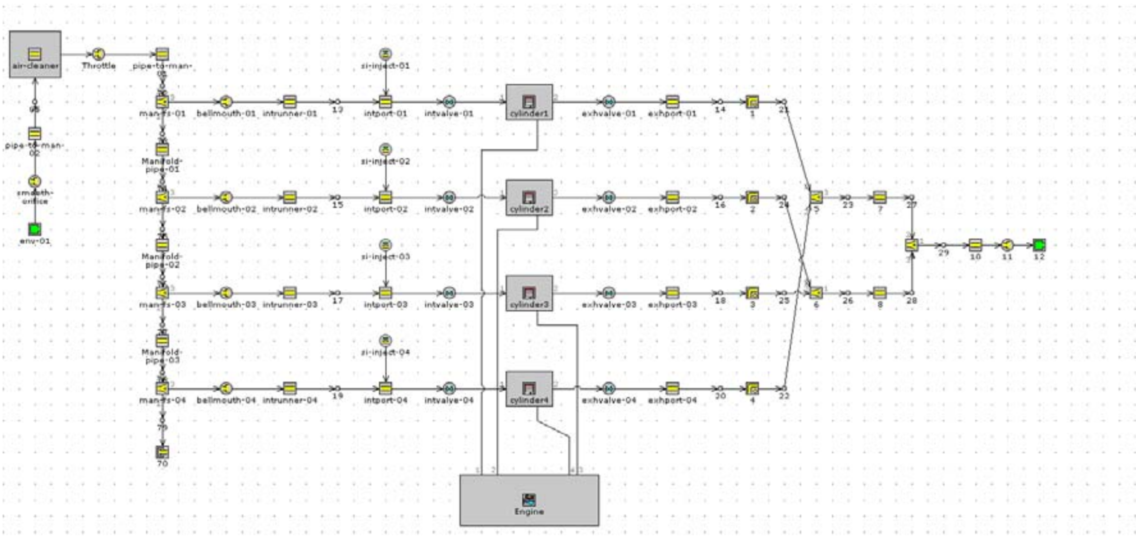
2. ESTABLISHMENT AND VERIFICATION OF SIMULATION MODEL

2.1 Simulation model of engine working process

The GT-power one-dimensional simulation model is calibrated according to relevant technical drawings provided by the engine manufacturer and test data, and such simulation model is mainly composed of air intake system, exhaust system, fuel injection components, cylinder and crankcase etc., as shown below.

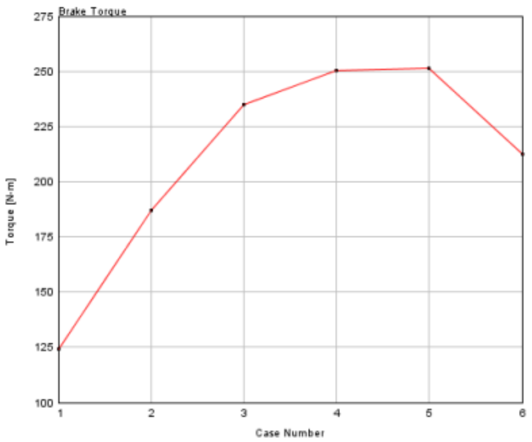
With the relatively complex shape of intake/exhaust manifolds, the size optimization of structure parameter is one of focuses. Firstly, we shall establish the manifold cavity model by means of three-dimensional software UG; then, the stl file generated is imported into GEM3D module for discretization, and finally the hall file generated into the model. The discretization process in exhaust manifold section established in such manner is relatively complicated; therefore, no more descriptions are provided for the length. The relatively simple parts of the rest are constructed directly by referring to the relevant drawings and using the templates provided by the software. Since no air cleaner model is available in the software, it is handled as the pipe, and its flow loss is achieved by defining the flow coefficient in the orifice connector.

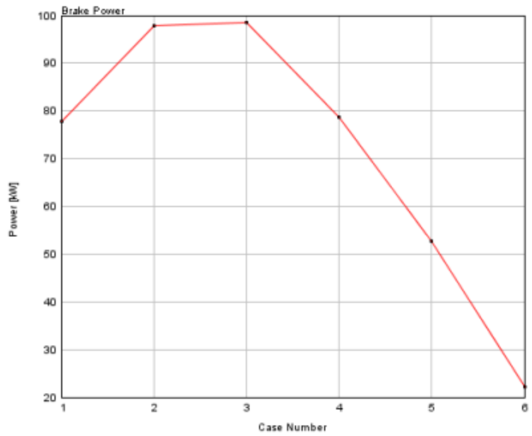
The more accurate quasi-dimension combustion model instead of commonly-used simple Weber combustion model is used for the simulation model. In this model, it is assumed that the flame front surface is the spherical surface centering on sparking plug, and the combustor is divided into two parts, i.e. unburned area and burned area. Combustion parameters are mainly obtained from previous test results and measured data, including the cylinder pressure.



2.2 Engine working simulation calculation and verification

The dynamic performance of several points under full load of the engine is calculated with the simulation model, and the speed characteristic curves shown in the following two graphs are obtained. (Torque – speed curve and power – speed curve)





The case numbers (1-6) in the graph are six rotational speeds of the engine, i.e. 6000r/min, 5000r/min, 4000r/min, 3000r/min, 2000r/min and 1000r/min in descending order. From these two graphs, it can be known that the calculated values of power and torque of the engine coincide with the experimental results, and the errors of all points are below 3%. The errors of calculated values and experimental values on fuel consumption rate of the engine are large in the medium and slow rotational speed areas, but the maximum error is 5.3%/2000r/min, which is in the scope of allowable errors of the engineering calculation (<7%). The main reason for great error of medium and slow rotational speed areas of fuel consumption rate might be selection error of empirical parameter and air-fuel ratio in the combustion model used for the simplified calculation; in addition, the lack of measured data corresponding to combustion quality parameter and combustion duration angle also reduces the calculation accuracy of fuel consumption rate. Overall, the current model reproduces the actual running status of the engine, and has the higher calculation accuracy. It can be used for the optimization and calculation of engine parameters.

3. MODEL CALCULATION RESULTS AND ANALYSIS

3.1 Influence of exhaust system parameters on dynamic performance of gasoline engine

The exhaust pressure wave of the engine has some influence on the dynamic performance and economy of the engine. The reasonable use of pressure wave in the exhaust pipe could make the exhaust more thorough and the air intake more sufficient. At the initial stage of opening the exhaust valve, as the waste gas flows into it, the large positive pressure wave will be generated at the exhaust gate, and is transmitted to the outlet of exhaust pipe and reflected back to the negative pressure wave at the outlet. With the large exhaust energy and high waste gas temperature, the amplitude of exhaust pressure wave is larger, and its propagation speed is faster compared with these of intake pressure wave. At the later stage of the exhaust process, especially in the overlapped valves opening period, the stable negative pressure formed at valve terminal of exhaust pipe could reduce the amount of residual gases in the cylinder and pump gas loss, and is conductive to the access of fresh mixture to the cylinder; conversely, the positive pressure formed at valve terminal might prevent from the access of waste gas and fresh air, and then the volumetric efficiency and dynamic performance of the engine will be decreased. Therefore, the exhaust gas could be cleaned and the charging efficiency increased by appropriately changing the length and cross sectional area of the exhaust pipe and the duration angle of exhaust opening and reasonably utilizing the dynamic effect of the exhaust pipe.

Change the length of the exhaust pipe without changing the other structure parameters of the gasoline engine. With the original length (60mm) of the exhaust pipe, the length of the exhaust pipe is respectively changed by -20, -10, 0, +10 and +20. After the simulation, the following two graphs are obtained.

(3 (invariant); 1 represents -20; 2 represents -10; 4 represents +10; 5 represents +20)

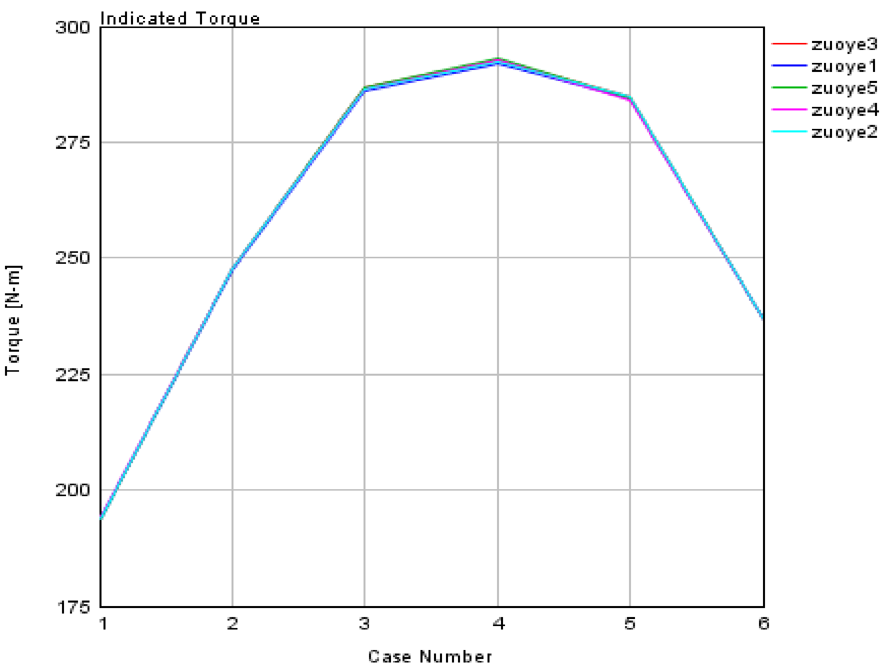


Fig.1 Torque-speed diagram

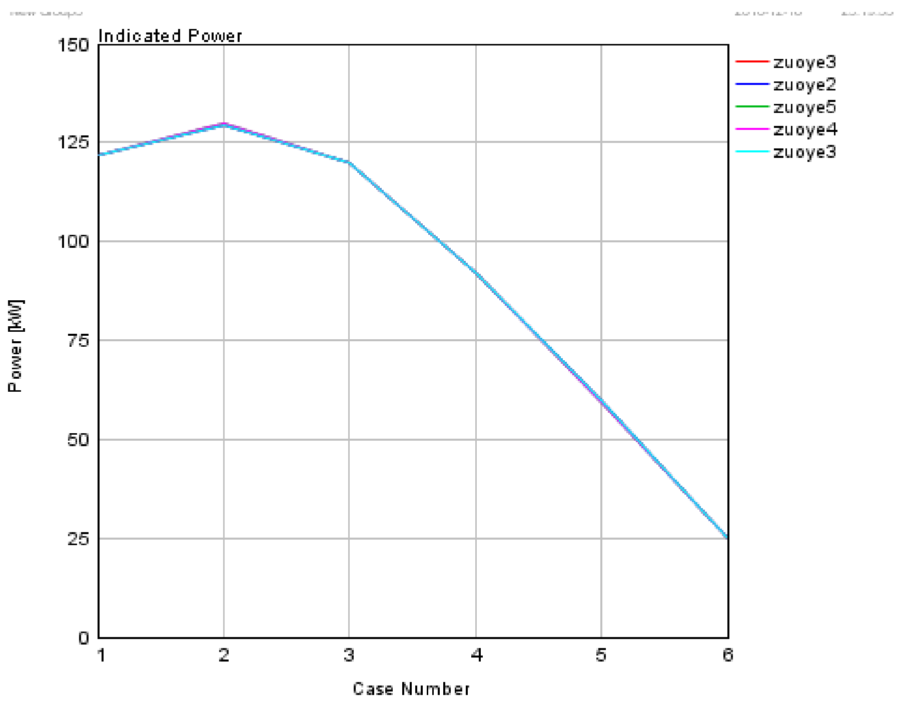


Fig.2 Power-speed diagram

From the diagram, it can be seen that the exhaust resonance effect is obvious with the great exhaust pressure and strong pressure wave in the exhaust pipeline under high engine speed, while it is unobvious with relatively weak pressure wave in the exhaust pipeline under low engine speed. Therefore, the influence of length change of exhaust manifold on the power of high engine speed is relatively great, and that on the power of medium and low engine speed is not obvious.

The change of exhaust manifold length has little influence on the dynamic performance of the complete machine, and the exhaust system of the original machine almost maximizes the dynamic performance of the engine. The exhaust manifold structure of this engine is relatively complex, and the manpower and material resources required for design and processing is large; therefore, the exhaust manifold of this engine is unnecessarily re-designed.

3.2 Influence of air-fuel ratio parameters on the performance of gasoline engine

The air-fuel ratio of the gasoline engine has the maximum power at 12-13, the minimum fuel consumption at 16 and the minimum pollutant concentration at 18. Therefore, to reduce fuel consumption and pollution, the lean mixture with great air-fuel ratio shall be used, and the rich mixture is only accessible when necessary. This practice is called after lean burn, and has been widely used for the existing gasoline engine.

The main factor affecting the emission of a gasoline engine is the air-fuel ratio of the mixture. In theory, 14.7kg air is required for the complete combustion of 1kg fuel. The ratio between air and fuel is called the stoichiometric ratio. When the air-fuel ratio is less than the stoichiometric ratio, the rich mixture is supplied, and then the power of the engine is great; the combustion is incomplete, and the amounts of CO and HC generated are large. When the mixture is slightly greater than the stoichiometric ratio, the combustion efficiency is the maximum; the fuel consumption is low, but the amount of NOx generated is the highest.

The air-fuel ratio of the engine is similarly changed based on the change of exhaust pipe. Then, the simulation curves are obtained.

(1:12.5, 2:13.6, 3:14.7, 4:15.8, 5:16.9)

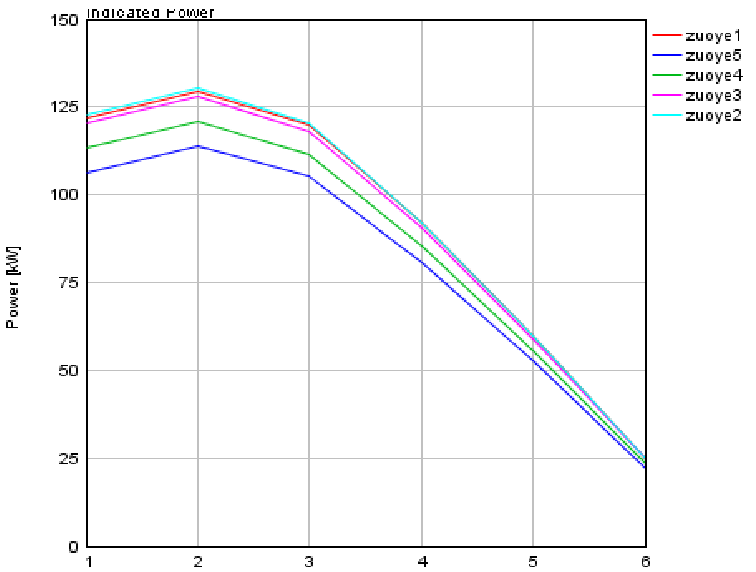


Fig.3 Influence of air-fuel ratio on torque

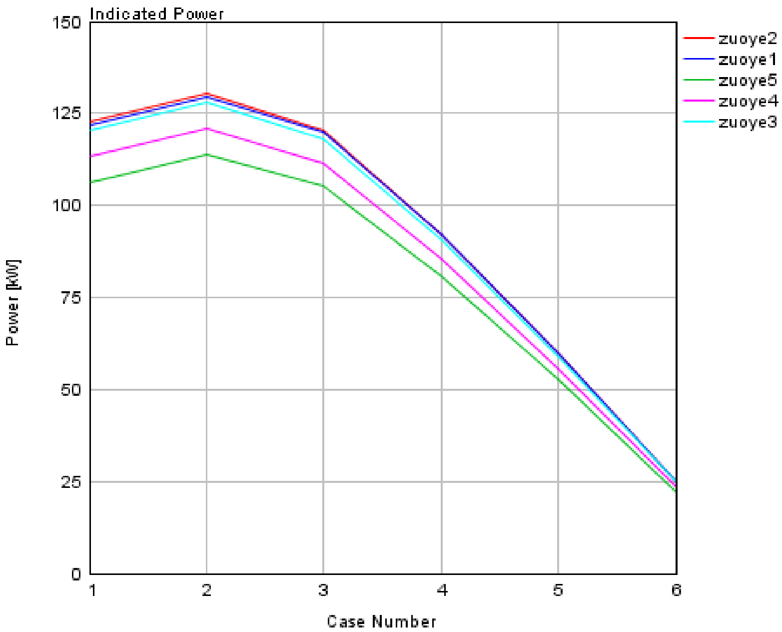


Fig.4 Influence of air-fuel ratio on power

From Fig. 3, it can be seen that the torque shows the trend of increase with the increase of the air-fuel ratio when the air-fuel ratio is in 1-2, and the amplification is approximately 10%, while it shows the trend of decrease with the increase of the air-fuel ratio when the air-fuel ratio is in 2-3, and the decreasing percentage is approximately 11.2%. In addition, the torque decreases gradually, and the decreasing percentage is increasing with the increase of the air-fuel ratio when the air-fuel ratio is in 3-6.

From Fig. 4, it can be seen that the power increases firstly and then decreases with the increase of air-fuel ratio, and shows the trend of increase with the increase of air-fuel ratio when the air-fuel ratio is in 1-2, and the amplification is 9.85%. It decreases gradually with the increase of air-fuel ratio when the air-fuel ratio is in 2-3, and the decreasing percentage is about 10.15%. In addition, the power decreases gradually, and the decreasing percentage is increasing with the increase of air-fuel ratio when the air-fuel ratio is in 3-6.

From these two figures, we can infer that the smaller the air-fuel ratio is, the greater the torque and power of the engine become under the same engine speed. However, the combustion is relatively incomplete, and the emissions of oxycarbide and nitric oxide will be accordingly increased when the air-fuel ratio is smaller. The curve graph is shown as follows.

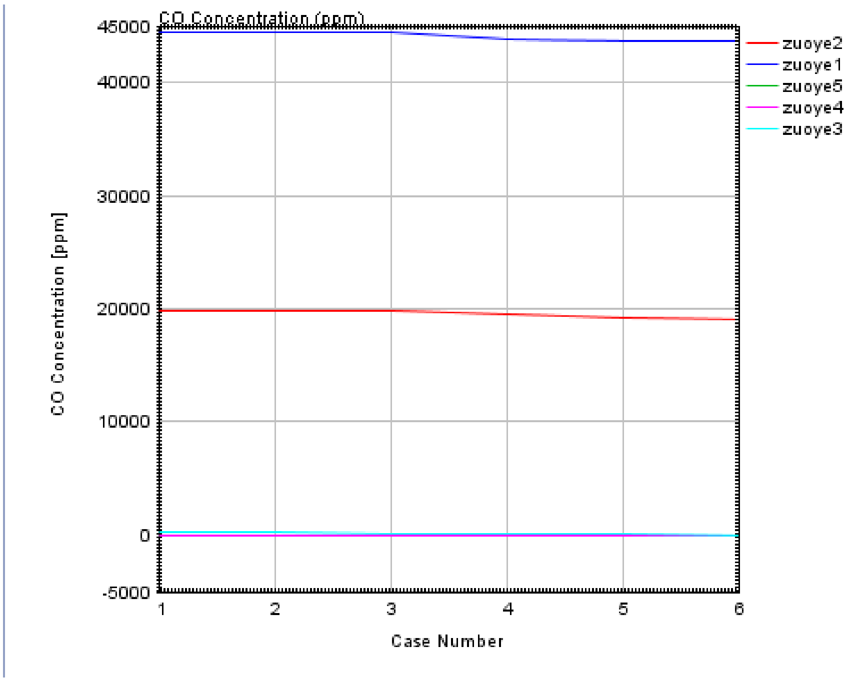


Fig.5 Influence of different air-fuel ratios on carbon monoxide emission

The above figure could not completely show the influence of five different air-fuel ratios on carbon monoxide emission, but it is obvious that the emission of carbon monoxide is much greater than that of any others under the smaller air-fuel ratio.

4. CONCLUSION

In the process of optimizing engine model, the influence of exhaust pipe length and air-fuel ratio on engine performance is mainly investigated. The change of the exhaust manifold length has little influence on the engine performance, and the manpower and material resources required for re-designing the exhaust manifold are large. In consideration of a precondition of cost optimization, the exhaust manifold might not be re-designed.

The air-fuel ratio has great influence on the engine performance, and the conclusions and theoretical conclusions obtained are relatively acceptable. In the optimization process, the influence on any other parameters like emission shall also be considered apart from that on dynamic performance.

ACKNOWLEDGEMENTS

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