OPTIMIZATION STUDY OF METHANOL ENGINE EXHAUST SYSTEM

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ARTICLE DETAILS

ABSTRACT

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From the engineering application perspective, methanol is an ideal alternative, renewable, environmentally and economically attractive fuel. In the 1990s, the southwest research institute proposed a high compression ratio SI methanol engine program which provides a new idea for the development of high power and high efficiency methanol engine. The study of the optimization for the exhaust system is the key scientific guidance to the development of the SI methanol engine, promoting the rapid maturity of the technology so as to meet the market demand. In this study, the effects of exhaust parameters such as lengths, diameters and angles of exhaust pipes has been studied based on the one-multidimensional GT-Power model. The results showed that as the exhaust main length was 100mm, heat release ratio reached peak and CO emission was lowest. The most suitable exhaust main diameter was 49mm. The most suitable exhaust manifold angle was 140°.

INTRODUCTION

Because of low cost, convenience, and mature technology, methanol is suitable for replacement fuel for petroleum. While methanol is burning, it may produce unburden methanol, formaldehyde and formic acid and other unregulated emissions. Wang Yang of Tianjin University^[1] had researched the performance of methanol engine. Yao Chunde^[2] from Tianjin University and Zhang Qingfeng of Chongqing University and so on also promoted the development of the study^[3]. Southwest Research Institute^[4,5] had researched burning methanol on high compression ratio engine, which supplies reference for the study after that. If optimizing the performance by traditional test, it needs a large amount of human resources and high cost. So it's necessary to emulate simulation model for the optimizing and lower cost, shorten time, and propose the most appropriate parameter.

1 Simulation model building of work process of ignition methanol engine

1.1 1-d simulation model building of ignition methanol engine

In order to analyze and calculate the performance of engine, its necessary to building simulation model by GT-POWER. It is developed by GTI Co. of USA. It can be used for simulation and calculation for engine^[6]. Also it can be used to do analysis of both transient and steady state^[7].

(1) Building work process simulation model

First divide the complex engine into several simple subsystems. Then build relevant physical model by simulation model of diesel engine work process supplied by GT-POWER.

(2) According to knowledgeable of thermodynamic, heat and mass transfer theory, and fluid mechanics, quantitative mathematical describe the simplified physical model. Then input data and information into relevant module. So preliminary simulation model of engine work process is built.

(3) The simulation model of ignition methanol engine is built on the base of single cylinder. According of the structure parameters of engine (Tab.1), Fig.1 shows simulation model of engine work process. This model has been made a verification and analysis^[8], so it can be used to optimize and analyze the engine performance.

Tab.1 Methanol engine

Fig.1 Simulation model of ignition methanol engine

2 Simulation study of spark ignition engine performance

Item	Parameter
Engine style	Water-cooling, 4-cylinder, in-line, 4-stroke, turbo
Cylinder diameter(mm)	100.0
Stroke (mm)	127.0
Displacement (L)	3.99
Firing order	1-2-4-2
Combustion mode	Spark ignition
Combustion chamber style	ω style
Compression ratio	17.5
Rated power/speed (Kw/(r/min))	83/2600
Peak torque/speed (Nm/(r/min))	410/1600
Idle speed (r/min)	650

2.1 The effect of exhaust main length on engine performance

Fig.2 shows 1-cylinder pressure of different exhaust main length. We can propose that the highest pressure in the cylinder occurred at almost the same time, which is within 8-9° after the top dead center of crank angle. Cylinder pressure increases gradually as the increase of exhaust main length. When the exhaust main length reaches 100mm, the pressure reaches maximum. Then the peak pressure decreases gradually as increase of exhaust main length.

Fig.3 shows heat release rate of different exhaust main pipe length. Fig.4 shows the CO emission of different exhaust pipe length. From two figures, we can propose that heat release rate reaches the peak at 100mm of exhaust main length. At the same CO emission reaches the lowest. The length over or under 100mm leads the lower heat release and higher CO emission. Finally this makes the power and torque reduce, and fuel to increase.

Fig.2 1st cylinder pressure of different exhaust main length

Fig.3 Heat release rate of different exhaust main length

Fig.4 CO emission of different exhaust pipe length

2.2 The effect of exhaust main diameter on engine performance

Fig.5, 6, 7 show cylinder pressure, heat release, and CO emission respectively with different exhaust main length. Fig.2-1 shows that cylinder pressure increases with the increasing of exhaust main diameter. It reaches the peak when exhaust main length is 49mm. Then it reduces gradually. The cylinder pressure may reach peak at almost same time within 8-9° crank angle after top dead center. Fig.2-5 and 2-6 show that the heat release ratio reaches peak and CO emission reaches the lowest when exhaust main diameter is 49mm. Heat release ratio will decrease and CO emission will increase because of higher or lower than 49mm. And it will lead to much lower power and fuel increasing.

Fig.5 Pressure of different exhaust main diameter

Fig.6 Heat release rate of different exhaust main diameter

Fig.7 CO emission of different exhaust pipe diameter

2.3 The effect of exhaust manifold length on engine performance

Fig.8 shows the 1-cylinder pressure with different exhaust manifold length. From which we can find that the peak pressure appears 8-9° after the top dead center. As the increasing of exhaust manifold length, pressure increases gradually. When the exhaust manifold length is 40mm, the pressure reaches peak. When the length is more than 40mm, the pressure decreases gradually. Fig.9 and 10 show that heat release ratio reaches peak and CO emission is lowest when the exhaust manifold length is 40mm. Higher or lower will lead to lower heat release ratio and higher CO emission. Finally it leads to lower engine power and heat release ratio.

Fig.8 1st cylinder pressure of different exhaust manifold length

Fig.9 Heat release rate of different exhaust manifold length

Fig.10 CO emission of different exhaust manifold length

2.4 The effect of exhaust manifold diameter on engine performance

Fig.11 shows the 1-cylinder pressure with different exhaust manifold diameter. From which we can know that the peak pressure appears 8-9° after the top dead center. As increasing of exhaust manifold length, pressure increases gradually. When the exhaust manifold length is 40mm, the pressure reaches peak. When the length is more than 40mm, it decreases gradually. Fig.12 and 13 show that heat release ratio reaches peak and CO emission is lowest when the exhaust manifold length is 40mm. Higher or lower will lead to lower heat release ratio and higher CO emission. Finally it leads to lower engine power and heat release ratio.

Fig.2-11 1st cylinder pressure of different exhaust manifold diameter

Fig.12 Heat release rate of different exhaust manifold diameter

Fig.13 CO emission of different exhaust manifold diameter

2.5 The effect of exhaust manifold angle on engine performance

Fig.14, 15, 16 show the 1-cylinder pressure, heat release, and CO emission figure with different exhaust manifold angle. From which we can propose that the peak pressure appears 8-9° after the top dead center. As increasing of exhaust manifold angle, pressure increases gradually. When the exhaust manifold angle is 140°, the pressure reaches peak. When the angle is more than 140°, it decreases gradually. Fig.15 and 16 show that heat release ratio reaches peak and CO emission is lowest when the exhaust manifold angle is 140°, Higher or lower will lead to lower heat release ratio and higher CO emission. Finally it leads to lower engine power and heat release ratio.

Fig.14 Pressure of different exhaust manifold angle

Fig.15 Heat release rate of different exhaust manifold angle

Fig.16 CO emission of different exhaust manifold angle

2.6 The effect of exhaust port flow length on engine performance

Fig.17, 18, 19 show 1-cylinder pressure, heat release, and CO emission figure with different port flow length. From which we can propose that the peak pressure appears 8-9° after the top dead center. As increasing of exhaust manifold angle, pressure increases gradually. When the exhaust manifold angle is 85mm, the pressure reaches peak. When the angle is

more than 85mm, it decreases gradually. Fig.18 and 19 show that heat release ratio reaches peak and CO emission is lowest when the exhaust manifold angle is 85mm. Higher or lower than 85mm, especially 75mm, will lead to lower heat release ratio and higher CO emission. Finally it leads to lower engine power and heat release ratio.

Fig.17 Pressure of different port flow length

Fig.18 Heat release rate of different port flow length

Fig.19 CO emission of different port flow length

2.7 The effect of exhaust port flow diameter on engine performance

Fig.20, 21, 22 show 1-cylinder pressure, heat release, and CO emission figure with different port flow diameter. From which we can propose that the peak pressure appears at 8-9° after the top dead center. As increasing of port flow diameter, pressure increases gradually. When the port flow diameter is 40mm, the pressure reaches peak. When the diameter is more than 40mm, it decreases gradually. Fig.21 and 22 show that port flow diameter reaches peak and CO emission is lowest when the port flow diameter is 40mm. Higher or lower than 40mm, especially 38mm, will lead to lower heat release ratio and higher CO emission. Finally it leads to lower engine power and heat release ratio.

Fig.20 Pressure of different exhaust port diameter

Fig.21 Heat release rate of different exhaust port diameter

Fig.22 CO emission of different exhaust port diameter

3. Conclusion

With 1-D simulation software GT-POWER, this paper has done the performance simulation calculation on four-cylinder, straight line, SI engine, and studied the impact of power, economic, and emission with different exhaust parameters. The main conclusion are as follows:

- (1) When exhaust main length is 100mm, heat release ratio reaches peak and CO is lowest. More or less than 100mm leads to higher CO emission, lower heat release ratio, and also results in power decreasing and fuel increasing;
- (2) The most suitable exhaust main diameter is 49mm. Other diameter leads to pressure and heat release reducing, and CO emission and fuel consumption increasing.
- (3) The most suitable exhaust manifold angle is 140°. Other angle leads to pressure and heat release reducing, and CO emission and fuel consumption increasing.
- (4) When exhaust port length increases to 85mm, heat release ratio reaches peak, and CO emission is lowest. Higher or lower than 85mm results in power reducing and increasing fuel. Especially when 75mm, the power reaches lowest and fuel reaches highest.
- (5) When exhaust port flow diameter is more or less than 40mm, especially 38mm, heat release and pressure reach lowest, and CO emission reaches peak. This makes the engine lower power and higher fuel.

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