Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2021, 8(10):74-79

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Effect of Ignition Advance Angle on Overall Performance of Aviation Piston Gasoline Engine

Chenxi Qiu, Jingbin Hu, Hong Ji, Yuanjin Dong, Fanyan Meng, Baoli Wang, Jian Meng, Bin Zheng*

School of Transportation and Vehicle Engineering, Shandong University of Technology, Zibo City, Shandong Province, China

Abstract In order to analyze the effect of ignition advance angle on the overall performance of a four-stroke aviation piston gasoline engine, a simulation model was established by using GT-Power to study the dynamic performance, economy and emission characteristics of the engine at 5500r/min at full load. The results show that when the ignition advance angle increases from 15°BTDC to 36°BTDC, the engine power and torque increase first and then decrease, and the engine effective fuel consumption decreases first and then increases, indicating that the thermal efficiency increases first and then decreases, nitrogen oxide emissions increase. When the ignition advance angle is 30°BTDC, both engine power and torque to reach the maximum value, which is 81.11kW and 140.83N·m. When the ignition advance angle is 27°BTDC, the maximum in-cylinder explosion pressure is 7.88MPa, the maximum pressure rise rate is 0.387MPa/(°CA), the engine power is 80.65kW, the torque is 140.03N·m, the effective fuel consumption rate is 226.07g/kW·h, and the indicated thermal efficiency is 36.44%. At this time, the engine works more stably, with good economy and the dynamic performance is better.

Keywords ignition advance angle, aviation piston engine, dynamic performance, economy; emission characteristics

Introduction

The aviation piston engine is mainly suitable for fixed-wing aircraft, rotary-wing aircraft and UAV, etc. The aviation piston engine is selected as the power, which has obvious advantages in economy and practicality. Due to the development history and technical maturity of the aviation piston engine, most of the domestic light power devices are gasoline engines [1-2]. When the flight altitude of UAV increases, it is difficult to ignite the engine, dynamic performance declines and economy deteriorates due to the decrease of environmental pressure and temperature [3-4]. Under the same air-fuel ratio and engine speed, the reasonable ignition advance angle can make the engine have better dynamic performance and fuel economy. Jiang Nan used GT-Power software to study the intake system of a certain two-stroke aviation piston engine. By analyzing the pressure difference between inlet and outlet of the intake system and the outlet flow coefficient, he believed that the designed intake structure could improve the output power of the engine [5]. Taking a small two-stroke piston engine as the research object, Cai established a simulation model and analyzed the influence of ignition advance angle on the engine. The results show that the ignition advance angle has the maximum output power at 15°CA, and the output power of the engine increases with the increase of ambient pressure [6]. Yang used the Jialing JH600 engine as a prototype and used Fire to simulate the combustion and emission process of a hydrogen fuel engine. The study found that as the speed increases, the corresponding optimal ignition advance angle also follows. Under the optimal ignition advance angle, ignition delay period is shorter, the constant volume combustion sex is good, and get larger indicated work [7]. Ma established a pressurized natural gas engine model with GT-Power, and studied the influence of different compression ratio and ignition advance angle on the dynamic performance, knock time and knock index of natural gas engine. The research showed that with the increase of ignition advance angle, the possibility of engine knock increased and the start time of knock is advancing [8]. Jamrozik established a CFD model to study the effect of ignition advance angle on the engine. The results show that when the ignition advance angle was too large, the combustion in the cylinder would be abnormal [9]. Watanabe studied the influence of inlet temperature on the output power of a two-stroke piston engine and obtained the corresponding relationship between inlet temperature and output power. Studies show that when the intake temperature is within the range of 4.5°C and 40°C, the increase of temperature will decrease the output power, and if the air in the engine's external environment is heated to the same temperature as the intake air, the output power will decrease more [10]. Binjuwair studied the effect of different ignition timing on engine performance under two grades of gasoline, and the results showed that with the increase of ignition timing, braking power of the two fuels increased and brake fuel consumption decreased [11]. Zhen studied knock of methanol engine with high compression ratio by using multidimensional numerical simulation method, and the results showed that with the increase of EGR rate, knock intensity was greatly suppressed and the pressure peak was reduced and delayed [12].

In summary, the ignition parameters have a great impact on all aspects of piston engines. The current research direction is mainly about the effects of ignition parameters on engine dynamic performance and knocking. However, there are few studies on ignition parameters of four-stroke aviation piston gasoline engine under high speed and full load, combining dynamic performance, economy and emission. In this paper, GT-Power software is used to build a calculation model of the whole machine, and systematically study the effect of ignition advances angle on the dynamic, economy and emission performance of four-stroke aviation piston gasoline engines, and provide theoretical support for the follow-up research on four-stroke aviation piston gasoline engines.

Model Building

GT-Power is suitable for the simulation and analysis of ignition piston engines [13]. Use GT-Power to establish a one-dimensional engine simulation model, including the initial environment of intake and exhaust, intake system, in-cylinder system, crankcase, exhaust system, and turbocharger system. The ambient temperature of the engine is 290K and the pressure is 0.1MPa. The main parameters of the engine are shown in Table1. Assuming that the gas entering the cylinder is an ideal gas, the ideal gas state equation can be satisfied. The established GT-Power simulation model is shown in Figure1.

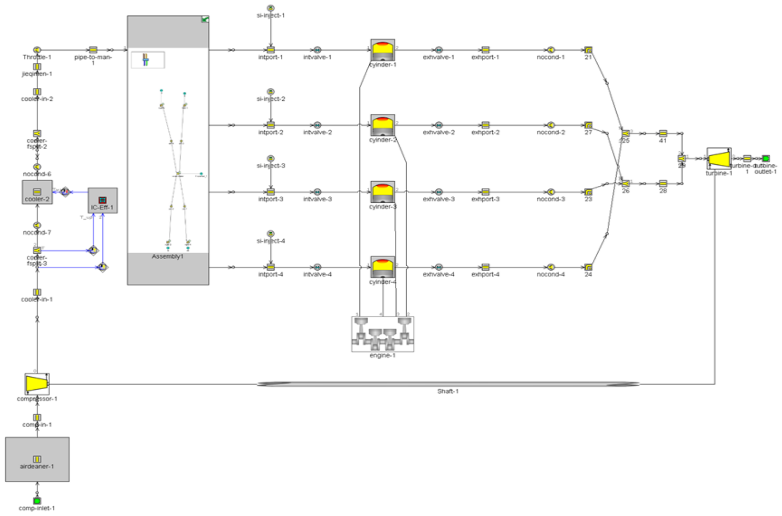


Figure1: Complete engine model

Table1: Engine specifications

Item	Parameter
Bore	79.5mm
Stroke	61.0mm
Connecting rod length	106mm
Displacement	1.2L
Compression ratio	9.0
Pressurization method	Exhaust gas turbocharging

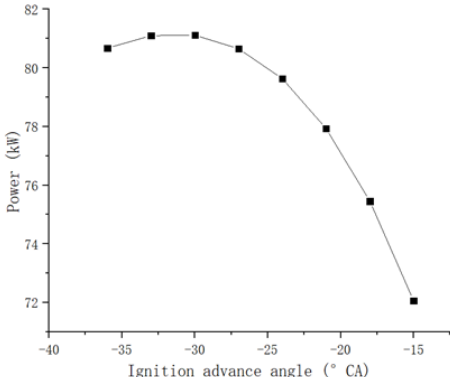
The engine speed was set at 5500r/min, the throttle valve was fully open, and other conditions remained unchanged. Analyze the changes of dynamic performance, economy and emission characteristics from 15 °BTDC to 36 °BTDC. The step size was 3°CA and a total of 8 points were used for simulation calculation.

Calculation Results and Analysis

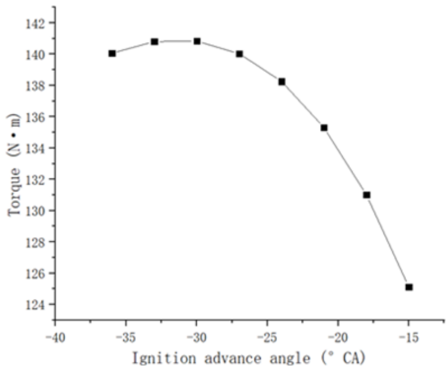
Effect of Ignition Advance Angle on Engine Dynamic Performance

The comparison curves of engine power and torque under different ignition advance angles are shown in Figure 2. It can be seen from Figure 2(a) that with the advance of ignition advance angle, engine power firstly increases and then decreases. When the ignition advance angle increases from 15°BTDC to 36°BTDC, engine power firstly increases from 72.06kW to 81.11kW, and then decreases to 80.67kW, the power reaches the maximum, when the ignition advance angle is 30°BTDC. As shown in Figure 2(b), Engine torque increased from 125.12N·m to 140.83N·m and then decreased to 140.06N·m, and the torque is also reaching maximum torque at an ignition advance angle of 30°BTDC. When the ignition advance angle is too small, most of the mixture combustion occurs in the process of the piston descending, the volume of the mixture combustion keeps increasing, which makes the maximum burst pressure in the cylinder decrease, the combustion rate of the mixture decreases, causing a part of the expansion work to be lost; As the contact area between the mixture and the cylinder wall increases, the heat loss to the cylinder wall increases, resulting in a significant decrease in engine power and torque. Ignition advance angle is too large, the mixture combustion too early, mixture is not fully compressed, during the upward process of the piston, the volume of mixture combustion and decreases, the temperature in cylinder and the cylinder pressure is too high, the maximum explosion pressure in cylinder appears near the TDC makes the piston upward need to overcome more resistance, causing compression negative work increases, resulting in a decrease in engine power and torque.

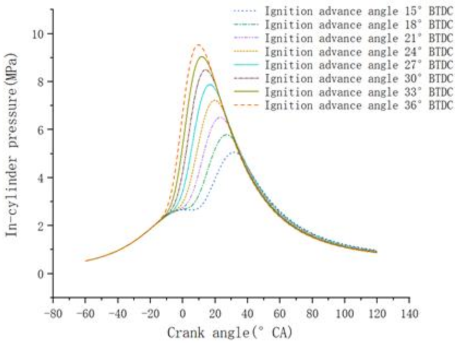
When the ignition advance angle is 30°BTDC, the power and torque of the engine reach the maximum, and as shown in Figure 2(c) and Figure 2(d), the maximum explosion pressure in the cylinder reaches 8.5MPa, the maximum pressure rise rate has reached 0.44MPa /(°CA). For the ignited gasoline engine, the pressure rise rate is generally in the range of 0.2-0.4MPa/(°CA), where the engine works smoothly and has good dynamic performance [14]. At this time, the in-cylinder pressure and pressure rise rate of the engine are high; it is not conducive to the stable output of the engine and reduces the service life of the engine. When the ignition advance angle is 27° BTDC, the maximum explosion pressure in the cylinder is 7.88MPa, the maximum pressure rise rate is 0.387MPa /(° CA), the engine power is 80.65kW, and the torque is 140.03N·m. Compared with the ignition advance angle of 30°BTDC, the engine power and torque decreased by 0.57% and 0.57% on the premise that the maximum explosion pressure in cylinder decreased by 7.3% and the pressure rise rate decreased by 12.0%. Comprehensively considered, the engine ignition advance angle of 27 ° BTDC is more appropriate.



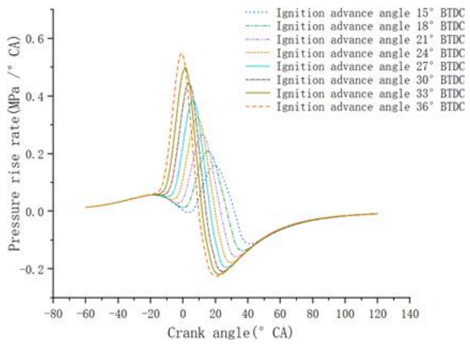
(a) Engine power



(b) Engine torque



(c) In-cylinder pressure



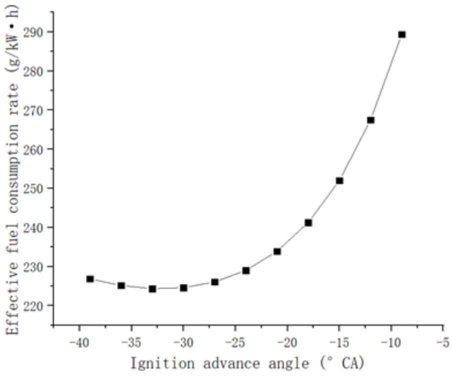
(d) Pressure rise rate

Figure 2: Effect of ignition advance angle on dynamic performance

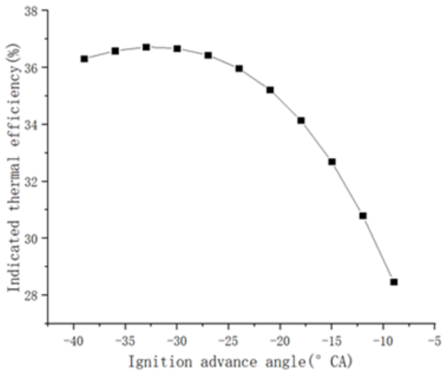
Effect of Ignition Advance Angle on Engine Economy and Emission Characteristics

As shown in Figure 3(a), with the increase of ignition advance angle, the effective fuel consumption rate of the engine firstly decreased significantly and then increased slightly. The effective fuel consumption rate decreased from 251.97g/kW·h to224.34g/kW·h and then increased to 225.15g/kW·h. The minimum effective fuel consumption is 224.34g/kW·h when the ignition advance angle is 33°BTDC. As shown in Figure 3(b), with the increase of ignition advance angle, the indicated thermal efficiency of the engine first increases and then decreases. It also reaches the highest indicated thermal efficiency (36.72%) when the ignition advance angle is 33°BTDC.When the ignition advance angle is too small, the heat loss of the mixture to the cylinder wall increases and the thermal efficiency decreases. The fuel consumption per unit work increases, making the engine fuel consumption rate increase, economy decreases. When the ignition advance angle is too large, the piston needs to overcome greater resistance, resulting in an increase in the negative work of compression, a decrease in the thermal efficiency of the engine and a decrease in the fuel consumption rate. When the ignition advance angle is 27°BTDC, the effective fuel consumption rate of the engine is 226.07g/kW·h, indicating a thermal efficiency of 36.44%, compared with 33 ° BTDC of ignition advance angle, the effective fuel consumption rate of the engine increases by 0.77%, indicating a thermal efficiency decreases by 0.76%, and the engine economy changes little.

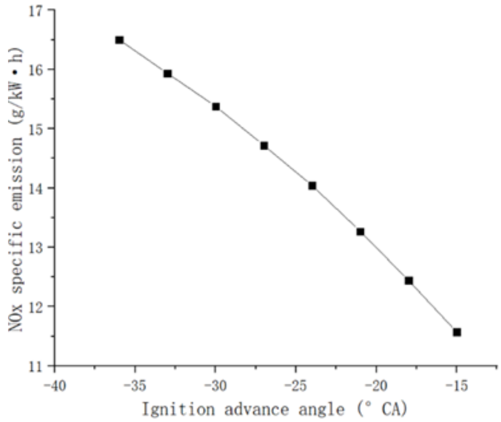
Nitrogen oxide emission of engine at different ignition advance angles is shown in Figure3(c), nitrogen oxide emission increases with the advance of ignition advance angle at high rotational speed. When the ignition advance angle changes from 15°BTDC to 36°BTDC,nitrogen oxide specific emissions increased from 11.6g/kW·h to 16.5g/kW·h. Because with the increase of ignition advance angle, most of the fuel burns before the compression TDC, the maximum explosion pressure and the maximum combustion temperature in the cylinder increase continuously. The residence time of the burned gas at high temperature also increases with the increase of ignition advance angle, both of which increase the formation of nitrogen oxides. So delaying the ignition advance angle can reduce NOx generation. When the ignition advance angle is 27°BTDC, the NOx emission ratio is 14.72g/kW·h.



(a) Effective fuel consumption rate



(b)Indicated thermal efficiency



(c) NOx specific emission

Figure 3: Effect of ignition advance angle on engine economy and emission characteristics

Conclusion

In this paper, a simulation model of a four-stroke aviation piston gasoline engine is established by GT-Power. Under the condition of engine speed of 5500r/min and the throttle valve was fully open, the dynamic performance, economy and emission characteristics of the engine was analyzed, and the following conclusions were drawn:

(1) With the increase of ignition advance angle, the engine power and torque increase first and then decrease, the effective fuel consumption rate decreases first and then increases and the engine indicated thermal efficiency increases first and then decreases. Nitrogen oxide emissions have been rising.

(2) Under the simulated conditions, when the ignition advance angle is 27°BTDC, the maximum explosion pressure in the cylinder is 7.88MPa, the maximum pressure rise rate is 0.387MPa/(°CA), the engine power is 80.65kW, the torque is 140.03N·m, and the effective fuel consumption rate is 226.07g/kW·h. Indicative thermal efficiency is 36.44%, and NOx specific emission is 14.72g/kW·h. At this time, the engine is in a stable working state, with good power performance and economy, and low nitrogen oxide emission.

Acknowledgment

The authors wish to thank Shandong Provincial Natural Science Foundation, China (ZR2017LEE019 and ZR2013EEQ005) for their support of this study.

References

[1]. Lu Dongliang, Zheng Jun, Hu Chongbo, Bian Shaochun. Research on the development status of general aviation piston engine [J]. Internal combustion engine and accessories, 2019, No. 284 (08): 70-72

[2]. Feng guangshuo, Zhou Ming. Technical route analysis of heavy oil aviation piston engine [J]. Journal of Tsinghua University (Natural Science Edition), 2016,56 (10): 1114-1121

[3]. Hu Chunming, Hao Mengmeng. Optimization of intake and exhaust system of UAV piston engine [J]. Journal of Aeronautical dynamics, 2018, 33 (04): 1009-1016. Li Binglin. Simulation calculation and Experimental Research on ignition advance angle of piston kerosene engine [D]. Nanjing University of Aeronautics and Astronautics, 2011

[4]. Yang Fei, Chen Wei, Zhang Chen, et al. Comparison of applicability of piston aeroengine burning biological aviation coal and RP-3 fuel [J]. Biomass chemical engineering, 2019, 053 (006): 15-21.

[5]. Jiang Nan. Design and analysis of intake system of aviation piston engine [D]. Nanjing University of Aeronautics and Astronautics, 2013

[6]. Cai Juan. Overall performance analysis and optimization of a small aviation kerosene piston engine [D]. Nanjing University of Aeronautics and Astronautics, 2015

[7]. Yang Yakun. Effect of ignition advance angle on combustion and emission characteristics of hydrogen fuel engine [D]. North China University of water resources and hydropower

[8]. Mazhen. Numerical simulation and research of natural gas engine based on GT power [D]. Shandong University of technology

[9]. Jamrozik A, Tutak W, Kociszewski A, et al. Numerical simulation of two-stage combustion in SI engine with prechamber [J]. Applied Mathematical Modelling, 2013, 37(5):2961-2982.

[10]. Watanabe I, Kuroda H. Effect of Atmospheric Temperature on the Power Output of a Two-Stroke Cycle Crankcase Compression Gasoline Engine[C]// Sae International Congress & Exposition. 1981.

[11]. Saud A. Binjuwair, Abdullah M. Alkhedhair, Ahmed A. Alharbi, et al. Combustion and Emission Analysis of SI Engine Fuelled by Saudi Arabian Gasoline RON91 and RON95 with Variable Compression Ratios and Spark Timing [J]. Open Access Library Journal, 2017, 4: 4184.

[12]. Zhen X, Wang Y, Xu S, et al. Study of knock in a high compression ratio spark-ignition methanol engine by multi-dimensional simulation [J]. Energy, 2013, 50 (Feb.):150-159.

[13]. Gamma Technologies. GT-Power User's Manual [Z]. Version 7.3.

[14]. Wang Jianxin, Shuai Shijin. Principle of automobile engine [M]. Tsinghua University Press, 2011