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Numerical Research of Instantaneous Combustion Process In-Cylinder of Large Dual Fuel Engine

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Abstract. In the study, the AVL-FIRE software had been adopted to numerical effect analysis on combustive process of the engine. The result shows that numerical simulation results are consistent with the tested pressure, ignition point of ignition diesel is 2 ° CA ATDC, ignition point of natural gas is 2.25 ° CA ATDC. During the combustion process, the position of the highest temperature in-cylinder has changed, first, between the natural gas and the diesel nozzle, second, before the natural gas nozzle, at the last, moving from the natural gas nozzle to the center of the cylinder.

Introduction

Natural gas is rich in reserves, excellent emissions and good economy, so the field of alternative fuel in the engine occupies an extremely important position, is being the world's unprecedented attention[1 ~ 4]. The activation energy of natural gas is higher, the transmission speed of the layered flame is slower, maximum flame propagation speed is 33.8cm / s, only about 2/3 of the gasoline-air laminar flame propagation speed. The slow flame propagation rate leads to an increase in the burning time, so the natural gas engine with large boreholes tends to have insufficient combustion. Domestic and foreign research scholars on the natural gas engine combustion process research found that: the combustion chamber structure of the air flow within the tank and the combustion process has a very important effect [5 ~ 6]. In this paper, the combustion process of a large bore dual fuel engine cylinder is numerically studied, and the transient combustion process in cylinder is analyzed in detail.

Calculation model

Modeling and meshing was by using AVL-FIRE software. The calculations assumed that the initial state of the cylinder pressure and temperature in cylinder were uniform. Throughout the calculation process, the cylinder is closed system, heat transfer process was according to a given wall temperature boundary conditions calculations. The calculation was took into account the integral compression and power stroke, beginning with the scavenging port closed time and end with the exhaust valve open time, top dead center was 360°CA.The technical specifications of the engine had given in Table.1.

Table1. Technical specifications of engine

Item	Parameter
Bore (mm)	500
Stroke (mm)	2000
Rated rotate speed (r/min)	108
Rated power (kW)	7800
Fuel system type	Direct Injection
Method of aspiration	Turbo-charging
Maximum cylinder pressure (MPa)	16.17
Charge air pressure (MPa)	0.387
Charge air temperature (K)	305
Coolant	water

Model validation

The results data is obtained by simulation of AVL FIRE software. To ensure the accuracy and reliability of the results of the calculation model, the data used for initial conditions of calculation model is obtained in the experiment. The comparison of cylinder pressure is shown in the Figure 1, between measure value and simulation value in the pure diesel mode and dual fuel mode.

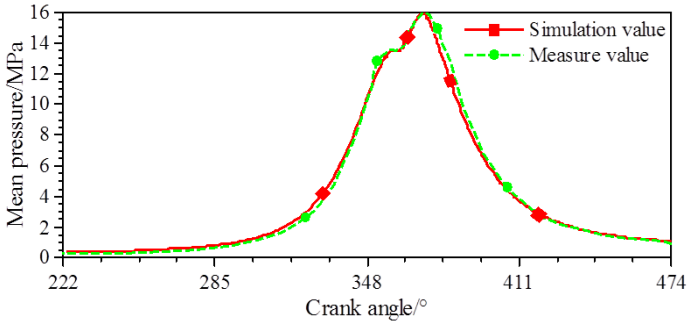

Fig 1 The comparison of cylinder pressure

Combustion process analysis

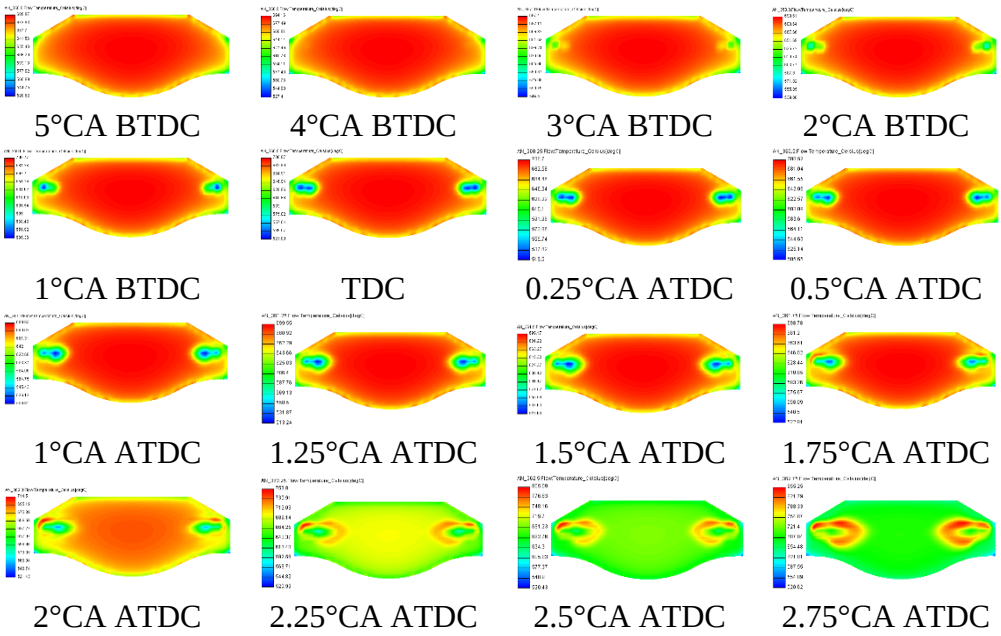

Fig.2 Temperature changes near top dead center in-cylinder

The ignition mode in the dual fuel mode is diesel ignition. Ignition diesel and natural gas were injected into the cylinder at 6 ° CA BTDC and 4 ° CA BTDC, respectively. Figure 2 shows the in-cylinder temperature distribution of 5 ° CA BTDC ~ 3.5 ° CA ATDC after in-cylinder injection. As can be seen from the figure, the temperature of 5 ° CA BTDC ~ 4 ° CA BTDC is relatively uniform, Of the upper and lower corners of the local low temperature, mainly in the cylinder axial air movement due to the role of inertia in the combustion chamber sidewall at the upper and lower corners relative to the smaller density of air caused. At this point there is no near the nozzle in the low temperature, because the natural gas has not yet begun to inject the cylinder, and ignite the diesel fuel to the cylinder is very small, did not cause significant changes in the temperature inside the cylinder. 3 ° CA BTDC, the in-cylinder temperature has four temperature drop points in the cylinder, except for the low temperature at the upper and lower corners of the side wall of the combustion chamber, due to the increase in the amount of diesel fuel injected and the start of the injection of natural gas, Where two "yellow" temperature drop areas near the cylinder axis are ignition diesel, and two "green" temperature drop areas near the cylinder wall are natural gas. The ignition of diesel fuel in the form of liquid into the cylinder, a small range in the nozzle tip of the local low temperature, leading to this phenomenon is due to the injection of diesel fuel temperature is lower than the average temperature in the tank at the same time just jet out diesel to evaporate Heat, further reducing the ambient gas temperature. Natural gas is injected directly into the cylinder in the form of gas. The natural gas inlet temperature is 45 ° C and the cylinder temperature is very large. Therefore, there is also a local low temperature in the small range of the front end of the natural gas nozzle. Since the natural gas injected into the cylinder is larger than the injected Diesel fuel is much larger, so the temperature around the natural gas nozzle is lower than the temperature around the diesel nozzle. With the development of natural gas and diesel injection process, natural gas and diesel oil gradually spread to the main injection area in front of the nozzle, and the low temperature region caused by the jet gradually developed toward the cylinder axis. In the process of the cylinder in the overall temperature along with the piston before the top deadline and the top dead center after the downlink, gradually increased and fall. At 2 ° CA ATDC, the cylinder temperature suddenly rises to 715 ° C at 699 ° C from 1.75 ° CA ATDC and the cylinder temperature change is 16 ° C. A partial warming phenomenon occurs between the natural gas nozzle and the diesel fuel nozzle, which is caused by the ignition of diesel fuel. At 2.25 ° CA ATDC, the cylinder temperature is further increased to 760 ° C at 7 ° C from 2 ° CA ATDC and the in-cylinder temperature change is 45 ° C due to the ignition of the diesel, Of the natural gas caused by ignition. Therefore, the ignition period of the diesel is 8 ° CA (6 ° CA BTDC ~ 2 ° CA ATDC), and the natural gas is 6.25 ° CA (4 ° CA BTDC ~ 2.25 ° CA ATDC). It is more clear that the ignition point of the ignition diesel is 2 ° CA ATDC and the ignition point of the natural gas is 2.25 ° CA ATDC.

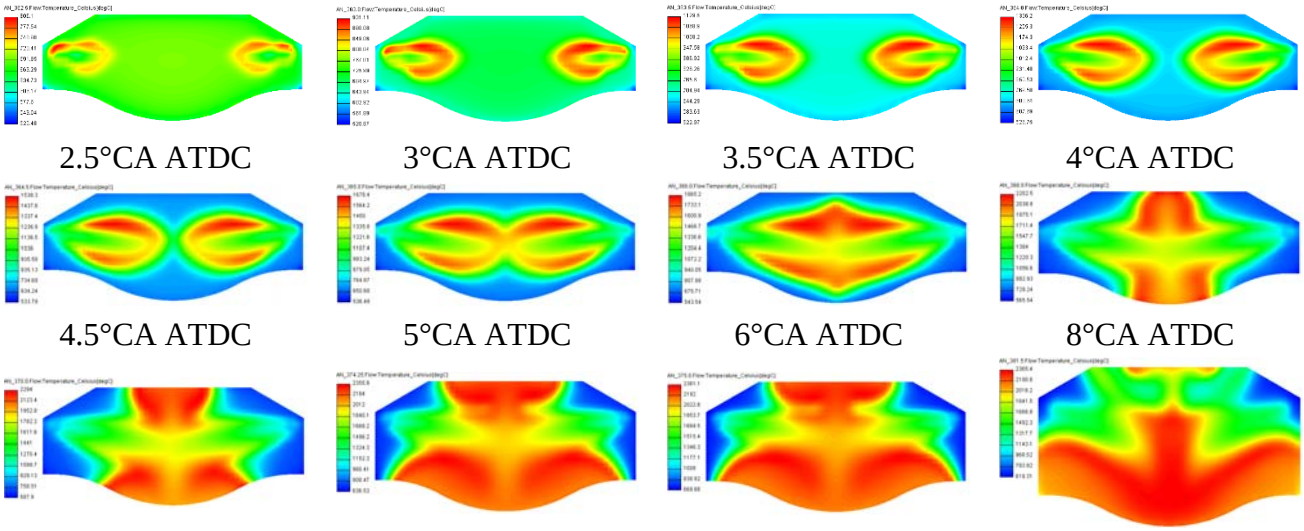

Fig.3 Combustion temperature changes process

Figure 3 is the dual fuel under the cylinder temperature distribution, can be seen from the figure, dual fuel mode, the flame of the law of development: the nozzle near the fire, the flame along the jet direction to the cylinder center development, then front flame After the intersection of the center, along the cylinder axial development of combustion, which is pure diesel mode flame development law is more consistent with the pure diesel fuel is the initial location and 14 ° CA ATDC after the flame propagation speed, natural gas initial fire location Natural gas nozzles and diesel nozzles between the jet and the front of the fire at the same time, while the diesel mode for the nozzle after the first fire. After 14 ° CA ATDC, the flame in the dual fuel mode travels more slowly than the pure diesel mode in the radial direction, and the flame occupies almost 80% of the combustion chamber. The position of the highest temperature in the cylinder has gone through the process of moving between natural gas and diesel nozzles, before the natural gas nozzle, moving from the natural gas nozzle to the center of the cylinder.

Summary

In the large dual-fuel engine, ignition point of ignition diesel is 2 ° CA ATDC, ignition point of natural gas is 2.25 ° CA ATDC. During the combustion process, the position of the highest temperature in-cylinder has charged, first, between the natural gas and the diesel nozzle, second, before the natural gas nozzle, at the last, moving from the natural gas nozzle to the center of the cylinder.

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