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Study on Dual-Spark Ignition Rapid Combustion Characteristic of Opposed-Piston Two-Stroke GDI Engine

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Abstract

The mixture formation and combustion process of an opposed-piston two-stroke (OPTS) gasoline direct injection (GDI) engine was carried out by numerical simulation. The effects on in-cylinder combustion and engine performance in different ignition ways of dual-spark ignition have been compared and analyzed. The dual-spark ignition system were installed on cylinder liner could make the in-cylinder combustion more stable and faster. It was benefit for increasing the thermal efficiency and avoiding the knock. Compared with single-spark ignition, dual-spark ignition could shorten flame propagation distance and accelerate flame propagation. Compared with single-spark ignition and synchronous dual-spark ignition models, the rapid combustion period of asynchronous ignition model was shorter, which was helpful to fast burning. In 6000r/min and 15kW full load case, the best ignition angle step of asynchronous ignition was about 10º crank angle (CA). When the initial ignition angle was the same, the ignition angle step of asynchronous ignition was smaller and the antiknock was worse.

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Keywoeds: opposed-piston; dual-spark ignition; rapid combustion; knock

1. Introduction

Energy conservation and emissions reduction have been referred to a higher strategic. The car industry faced with unprecedented challenges due to its high energy consumption and pollution emissions. In order to keep a sustainable development, the car industry will develop in the direction of zero emission electric drive car in the future. Range-extender pure electric vehicle was a transitional technology, which could overcome the limitation of traditional electric vehicle charging time and improve the travel distance of pure electric vehicles, by adding an additional energy storage component [1]. Small generating set, as a form of implementation of extender, was used for online supplement energy, which has a small

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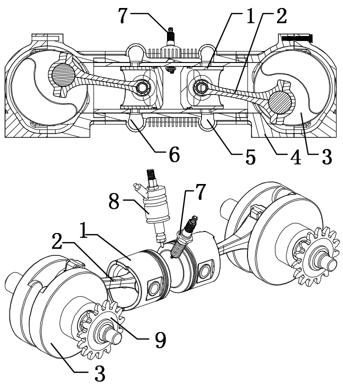
displacement, high power density and compact structure [2]. OPTS-GDI engine has some advantages in being pure electric vehicles extender or motor power, since it was equipped with simple structure, compact, high power density, as well as good balance. OPTS-GDI engine adopted uniflow scavenging and GDI technology to realize the separation of injection and scavenging process, and adopted dual-spark ignition to speed up the combustion [3, 4]. Dual-spark could make the flame front to travel from two points in the cylinder and short the effective distance of each flame. In order to make the in-cylinder combustion more stable and faster, it was necessary to match the number of spark plugs and ignition phase difference for the OPTS-GDI engine.

2. OPTS-GDI engine

Figure 1 showed OPTS-GDI engine was equipped with the GDI system and uniflow scavenging system, and its injector and spark plug were installed on cylinder liner. The crank-rod mechanisms were placed on both sides of cylinder body and a chain transmission mechanism was designed to realize synchronization working of opposed piston. On both sides of cylinder liner there were gas ports, intake ports on one side and exhaust ports on the other side. Intake ports were used to deliver exhaust gas out from cylinder. There were two pistons placed in cylinder liner, the combustion chamber was formed when the two pistons moved to the most closed position. The structure parameters were shown in Tab.



1-piston, 2-connecting rod, 3-crank, 4-engine-block, 5-scavenging port, 6-exhaust port, 7-spark plug, 8-injector, 9-chain wheel

Figure 1. opposed-piston two-stroke GDI engine

Table 1. engine specifications

Parameters	Value (*unit*)
Compression ratio	10.5
Speed	6000 (r/min)
Power	15 (kW)
Bore	56 (mm)
Stroke	49.5 (×2) (mm)
Exhaust timing	103-243 (ºCA)
Scavenging timing	123-250 (ºCA)
Scavenging pressure	0.13 (MPa)
Exhaust back pressure	0.1 (MPa)
Injection quantity	13.8 (mg/cycle)
Injection duration	1.8 (ms)
Injection advance timing	100 (ºCA)
BSFC	276 (g/kW.h)

3. Modeling and Simulation

In this paper, AVL-Fire software has been applied to build the simulation model of CFD, and the validity of the model was verified. The computational grid comprised of 249528 cells at scavenging process and 47961 cells at compression process after rezone. The initial conditions and piston motion were extracted from the one dimensional GT-Power software simulation model.

3.1. Study on the number of spark plugs

The variation of combustion process with the number of spark plugs was shown in Figure 2 and 3. Figure 2(a) showed with the increasing of the number of spark plugs, flame development duration decreased gradually, and rapid burning duration decreased and then increased and reached its minimum at three spark plugs. Figure 2(b) showed with the increasing of the number of spark plugs, the total speed of combustion was faster, but this change was not obvious when the number of spark plugs was more than three. Figure 3 showed when the number of spark plugs was more than three, the variation of flame surface density with the number of spark plugs was not obvious at 180ºCA and 190ºCA, so the dual-spark ignition could make sure of rapid combustion.

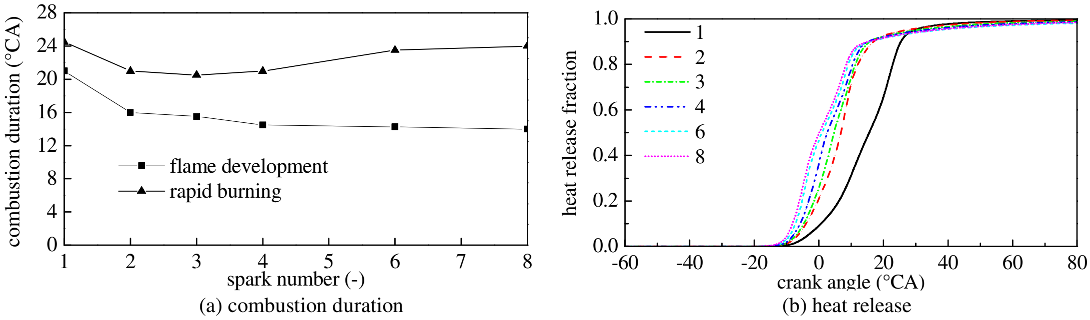


Figure 2. variation of combustion process with the number of spark plugs

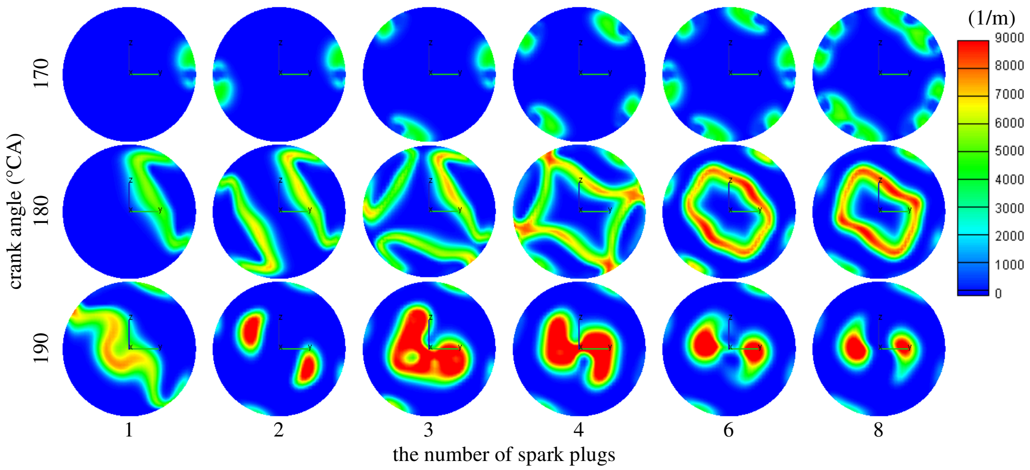
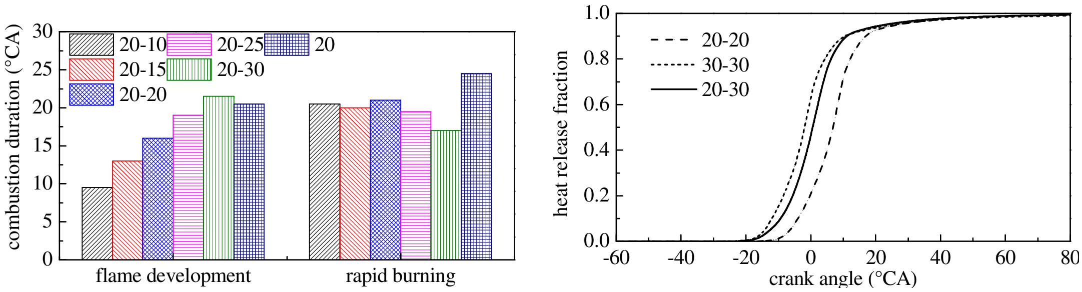


Figure 3. variation of flame surface density with the number of spark plugs

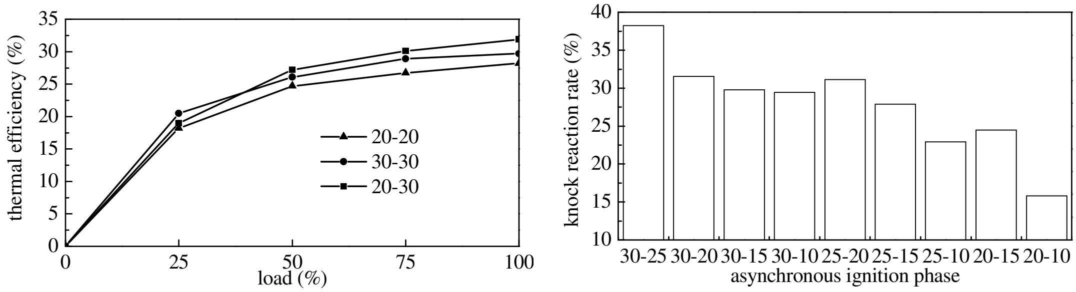
3.2. Study on the phase difference of ignition

Results obtained from the simulation on single and double plug modes with different ignition timings, example, 20º-20ºCA, 20º-30ºCA, 30º-30ºCA before top dead center (TDC) and so on were presented in Figures 4 and 5. With the advance of ignition timing, flame development duration increased gradually, and rapid burning duration decreased and showed its minimum at ignition timings of 20º-30ºCA before TDC. This was due to the fact that the combustion of the unburned mixture was lower temperature and pressure. At the same time, when the asynchronous ignition phase was 20º-30ºCA before TDC, the 50% of heat release was at 0ºCA (TDC) and the thermal efficiency might reach the maximum in other kinds of ignition phase. With the delay of ignition timing, knock reaction rate increased. If the asynchronous ignition initial angle was the same, the smaller the step, the worse the antiknock.



(a) combustion duration (b) heat release

Figure 4. variation of combustion process with the phase difference of ignition



(a) thermal efficiency (b) knock reaction rate

Figure 5. variation of combustion process with the phase difference of ignition

4. Conclusion

- Dual-spark ignition was most obvious to realize rapid combustion for the OPTS-GDI engine.
- With the increase of the asynchronous ignition phase difference, flame development duration increased gradually and rapid burning duration was decreased.
- With the delay of ignition timing and the increase of the asynchronous ignition phase difference, the knock reaction rate was decreased.
- Brake thermal efficiency was the highest at asynchronous ignition timings of 20º-30ºCA before TDC.

References

[1] E. D. Tate, etc. The Electrification of the Automobile: From Conventional Hybrid, to Plug-in Hybrids, to Extended-Range Electric Vehicles, *SAE paper* 2008-01-0458.

[2] Zhou Su, Niu Jigao, Chen Fengxiang. A Study on Powertrain Design and Simulation for Range-extended Electric Vehicle. *Automotive Engineering*, 2011, 11 p.924-929.

[3] Zhong cun de yang, Zhu yuwen. Research on multi-spark ignition engine.*Vehicle Engine*, 1987, 03 p.35-41.

[4] Du weiming. Development and Study on Key Technologies of 8AYT10 GDI Engine. *Jilin University*, 2013.

Biography

Fukang Ma recieved Master's degree in mechanical engineering from North University of China (NUC) in 2007. He is also pursuing Ph.D in the area of Combustion Engineering in Beijing Institute of Technology. He has 11 years of teaching and currently working as lecturer in the school of Mechanical and Power NUC.