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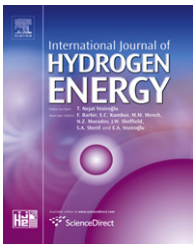

Research on optimal control to resolve the contradictions between restricting abnormal combustion and improving power output in hydrogen fueled engines

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ABSTRACT

In this paper, based on experiment result in a hydrogen fueled engine, pre-ignition and transforming process from pre-ignition to backfire of the hydrogen fueled engine was analyzed. Moreover, mechanism of pre-ignition and backfire of hydrogen fueled engines was studied by analyzing chain reaction. The analysis shows that the temperature, pressure and rate of pressure rise have great influence on pre-ignition and backfire. And based on thermodynamic relations of heat release rate, both pre-ignition and backfire were also analyzed. Finally, optimization control model which has multi-variables, multi-objectives and multi-constraints was established. And the simulation was carried out through the genetic algorithm. Results have shown that the excess air ratio and ignition advance angle can be adjusted by weighted coefficients to optimize the power output and restrict the abnormal combustion. Thus, a useful method is shown to resolve the contradictions between restricting the abnormal combustion and improving hydrogen fueled engine's power output.

1. Introduction

Hydrogen fueled engine will be widely used for its low environment pollution and high combustion efficiency [1–3]. However, there are significant differences of physicochemical properties and combustion characteristics contrasting hydrogen fuel with traditional fuel, it makes hydrogen fueled engine more prone to pre-ignition, backfire and other abnormal combustion, which leads to decrease hydrogen fueled engine performance and even cause engine to flame out. The study shows that sometimes pre-ignition and backfire of hydrogen fueled engine turn into each other and promote each other [2], it makes investigation into abnormal combustion in hydrogen fueled engine very complex and difficult.

Theoretical and experimental research conducted on abnormal combustion of hydrogen fueled engine have been still few for a long periods[1–3]. Shoichi Furuhama analyzed systematically abnormal combustion phenomena, such as pre-ignition and backfire, of hydrogen fueled engines by lots of experiments through the change of running parameters and structure performances of hydrogen fueled engines, and studied the method of restricting abnormal combustion through the use of methods such as different spark plugs and different injection mode [2]. J.T.Lee etc surveyed on the cause of hydrogen fueled engine's backfire and found that occurrence of backfire is associated with the combustion chamber crevice volumes, backfire can be controlled by improving the crevice volume[3], and the research focused on the improvements of the structural design. In this paper, based on

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combustion chemical reaction kineticsthe mechanism of pre-ignition and backfire of premixed hydrogen fueled engines were studied, the relationship of the transformation between pre-ignition and backfire was analyzed through the thermodynamic. And the influence parameters of pre-ignition and backfire was also analyzed. Finally, a method is shown to resolve the contradictions between restricting abnormal combustion and improving power output in hydrogen fueled engine by optimal controlling operating parameters such as excess air ratio and spark advance angle

2. Experimental study on abnormal combustion

This test was carried out in a modified, single-cylinder, four-stroke hydrogen fueled engine [2,4]. The engine is water-cooled horizontal type its displacement is 482cc, bore is 85 mm, stroke is 85 mm, compression ratio can be changed from 4.8 to7.93.

Figs. 1 and 2 respectively show the comparison of the cylinder pressure and rate of pressure rise when hydrogen fueled engine are normal combustion (excess air factor is 1.8) and pre-ignition (excess air factor is 1.26) at the speed of 1700 rpm.

It can be visually seen from Figs. 1 and 2 that the phases of curves of cylinder pressure and rate of pressure rise of pre-ignition are earlier than that of normal combustion (the crank angle corresponding to maximum combustion pressure becomes earlier), the largest value of the combustion pressure and the value of rate of pressure rise are larger than that of normal combustion. Though indicator diagram area is larger than that of normal combustion, the area of increasing amount almost appear in the compression stage that the piston uplift before top dead center, and before the largest pressure of normal combustion. Thus, this larger indicator diagram area is not beneficial to hydrogen fueled engine's performance.

Fig. 3 shows the intake manifold pressure and cylinder pressure curve in hydrogen fueled engine at the speed of 2100 rpm when backfire happens. From Fig. 3,we can find that

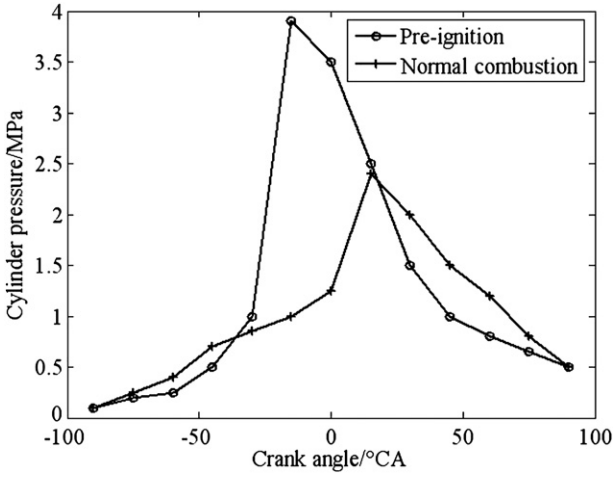

Fig. 1 – Comparison of cylinder pressure between normal combustion and pre-ignition.

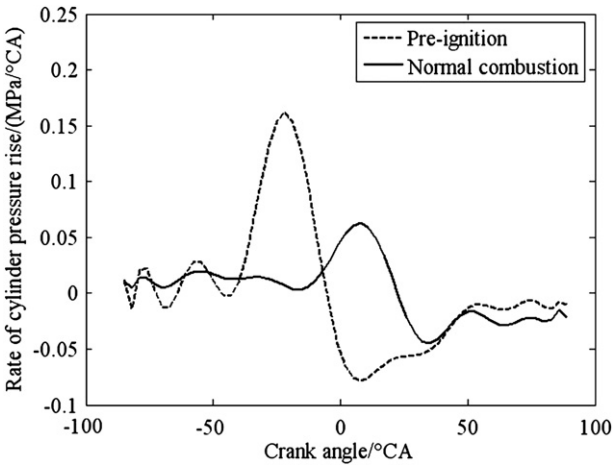

Fig. 2 – Comparison of rate of cylinder pressure rise between normal combustion and pre-ignition.

ignition in the mixture of combustion chamber started in point A, then, fresh mixture of intake manifold was also ignited so that low intake manifold pressure in point B suddenly increased with volatility.

It can be seen from Fig. 4 that after pre-ignition occurred, the mixture pressure increased too quickly, and pre-ignition became more and more serious with hydrogen fueled engine carrying out the work of the cycle, that is, the ignition continued to advance, and the maximum pressure continuously reduced, and the crank angle corresponding to highest temperature in the initial stage of cylinder compression step by step moved forward, and the temperature of mixture in the initial stage of cylinder compression step became higher and higher so that the higher and higher temperature of mixture would benefited to ignite the fresh charge by the high temperature exhaust gas or incandescent spot in cylinder after intake valve opened, and backfire happened, the highest pressure of hydrogen fueled engine further declined intake manifold pressure suddenly increased.

3. The research on abnormal combustion mechanism

Studying the abnormal combustion phenomena, it can be concluded that the reasons for abnormal combustion

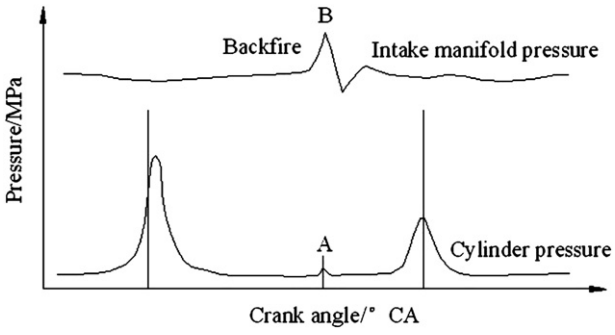

Fig. 3 – Cylinder pressure and intake manifolds pressure when backfire happens.