Research on Effects of fuel pyrolysis to performance of internal combustion engine

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Abstract: A new power cycle is proposed for improving the efficiency of internal combustion engine (ICE), which is throughout regenerative cooling to enhance the heat value of fuel, thenmake the combustion condition in ICE better. The scheme is proved to be feasible by means of thermodynamic and combustion analysis. An experimental platform is built to conduct re-cooled experiment, the results demonstrate that fuel releases heat absorbed from cooling process in combustor can reduce the heat loss and fuel consumption of ICE effectively.

Keywords: Internal combustion engine (ICE),Regenerative cooling

1. Introduction

There are low combustion efficiency and high pollutant emission problems with conventional internal combustion engines. For example, the combustion of gasoline engine (GE)is premixed homogeneous spark-ignited combustion (PHSIC) with low compression ratio and low thermal efficiency. While the combustion of conventional diesel engine (DE) is diffusive combustion, which means the fuel and air can’t mix sufficiently because of short mixing time. The combustion of DE is divided into high-temperature flame zone and high-temperature over-thick zone. There is a great deal of soot and NO_x in the exhaust. Generally, the exhaust of ICE has a high temperature from 400□ to 700□, it consumes about 25% to 45% heat of the calorific value of fuels. In that case, it’s a general measure to improve the cycle efficiency by utilize the waste heat fully and reasonably.

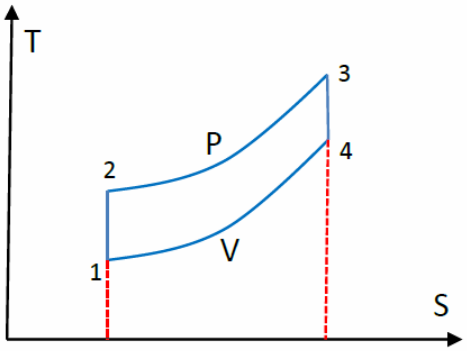
Table 1 Power utilization of ICE

	Effective work	Exhaust	Cooling process
GE	25%-30%	26%-35%	12%-27%

DE	30%-40%	20%-30%	15%-35%

To solve the problem of low waste-heat utilization and difficult in improving the combustion efficiency of ICE, a new power cycle is proposed to improve the efficiency of ICE. This cycle can improve the calorific value of fuel by regenerative cooling and make the combustion regime inside ICE better. Meanwhile, fuel releases the heat absorbed from cooling process in combustor, which can lower the heat loss and fuel consumption of ICE.

2. Theoretical verification



Fiugre.1. Temperature-entropy diagram of Isobaric heating cycle of ICE

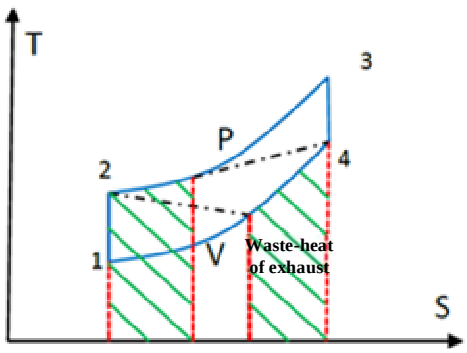


Figure.2. Temperature-entropy diagram of Isobaric heating cycle of ICE with regenerator

The compression ratio(ε) of gasoline engine(GE) is within ±2 of 7, let us assume the compression ratio(ε) equals to 7, while the pressure rise ratio(λ) equals to 2.5, and the mechanical efficiency(η) equals to 0.7. Because the combustion gases of GE is a mixture of multiple atomic, the isentropic exponent is from 1.32 to 1.18 generally, here we assume γ_0=1.35,heat recovery coefficient ζ=1.Similarly, the compression ratio of diesel engine(DE) is from 13 to 20, assuming the compression ratio(ε) equals to 16, the pre-expansion ratio(ρ) equals to 2.5,the mechanical efficiency(η) equals to 0.7,heat recovery coefficient ζ=1. The isentropic exponent is within ±0.1 of 1.39 because the combustion gases of DE is a mixture of multiple atomic. Hence, γ_0=1.39.The Reheating Regenerative Cycle increase the efficiency of GE and DE from 34.6%, 40.7% up to 42.4% and 45.4 respectively.

3. Confirmatory experiment

Pyrolysis experiment system is used to analysis the performance of fuel pyrolysis as sown in Figure 3.

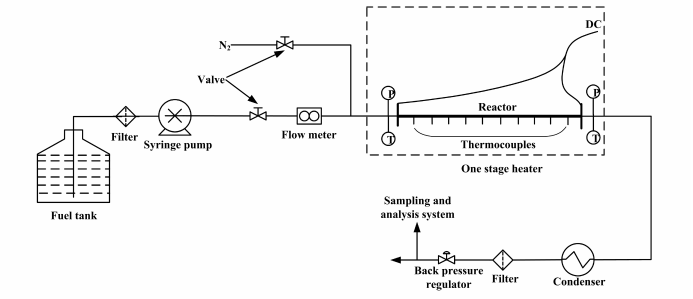
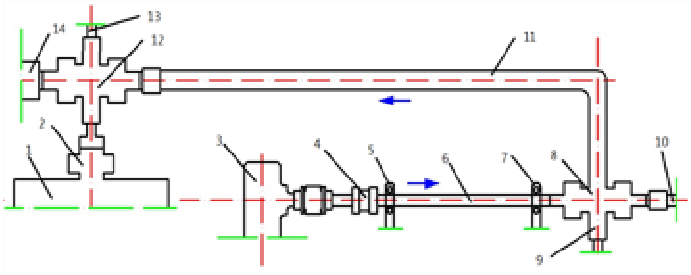


Figure.3.Experimental system of high temperature pyrolysis



1-Cylinder liner of ICE, 2-Nozzle, 3-Fuel injection pump, 4-Insulation device, 5-VDD, 6-Heating pipeline, 7-GND, 8,12-Four-way excuse, 9,13-Pressure sensor, 10,14-Temperature sensor, 11-Cooling pipeline,

Figure.4.Schematic diagram of the ICE regenerative cooling experiment platform

The ICE regenerative cooling experiment platform is a confirmatory experimental system. In order to simulate the process of fuel endothermic, a means of electric heating is used and the fuel is sprayed into the combustor the spray nozzle as shown in Fig.4.

4. Experimental results and discussion

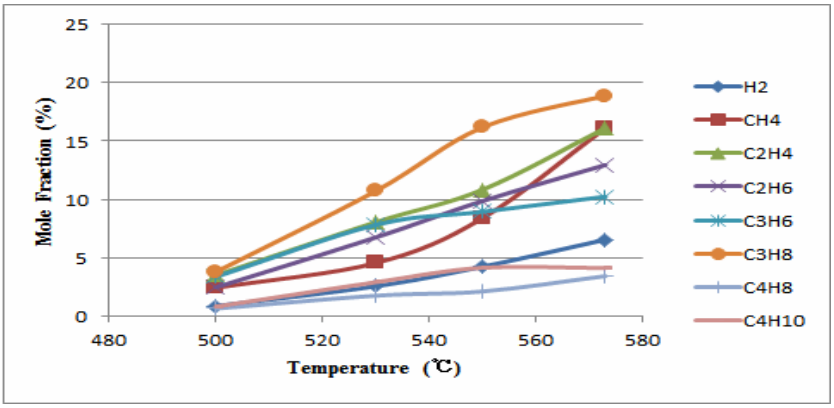


Figure.5. Distribution of gaseous products

The content of CH_4 and H_2increases with the temperature rise and smooth gradually in high-temperature zone. The co-combustion characteristics of H_2 improve the combustion regime a lot. Second, hydrogen has strong catalysis to the carbon-oxygen reaction, which makes the combustion conduct more completely. Third, the small molecule hydrocarbons such as compounds of C2 and C4 remain high, which benefit the improvement of effect of the spray. Finally, there is less acetylene compounds in the

gaseous products. The increase of acetylene compounds will lead to higher degree of unsaturation of hydrocarbon fuel and higher hydrogen content.

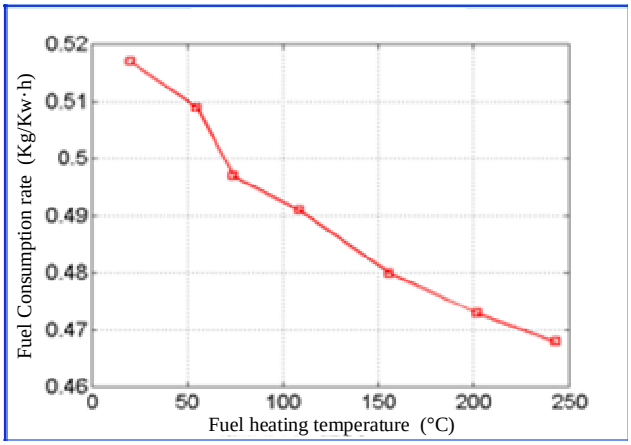


Figure.6.Relationship between Fuel consumption rate and inlet temperature

The fuel consumption ratedecreases with the temperature rise, which means the rise of fuel temperature enhance the thermal efficiency and the combustion efficiency of internal combustion engine (ICE), thus it proves that this system can decrease fuel consumption indeed.

5. Summary

In this work, a new power cycle is proposed for improving the efficiency of internal combustion engine (ICE), which is throughout regenerative cooling to enhance the heat value of fuel, then make the combustion condition in ICE better. We can learn by thermodynamic analysis that utilizing the waste-heat by regenerative cooling can improve the efficiency of ICE notably. Moreover, the combustion analysis indicates that the increase of gas molecules after pyrolysis can reduce exhausted pollutant heavily, which proves the feasibility of this scheme. Regenerative cooling experiment has been conducted on a self-built experimental platform. The results indicatethe process that fuel releases heat absorbed from cooling process in combustor can reduce the heat loss and fuel consumption of ICE effectively.