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ESTIMATION THE INFLUENCE OF INTERNAL RESIDUAL GASES ON PEAK FIRING TEMPERATURE AND NO_X EMISSION OF A V-TWIN ENGINE

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ABSTRACT

The exhaust residual gases and effective release energy are known as essential factors, which influence engine performance and emission characteristics. Herewith we estimated the effect of residual gas on peak pressure rise, effective release energy, and engine emissions. It is complicated to determine the residual gas ratio, the effective release energy under the various testing conditions from the experiments. Through combined experimental and simulation methods we eliminated certain above drawbacks. From results of the research, we thoroughly investigated the effects of engine speed, air-fuel ratio, valve overlap, combustion duration, intake port diameter-bore ratio, and bore-stroke ratio on the internal exhaust residual gases recirculation. We also found that the increase in the exhaust residual gas ratio from 1% to 5% was due to the peak firing temperature decrease from 2900 K to 1250 K, the peak pressure rise decrease from 8 to 5.5 bar/deg, the effective release energy decrease from 0.85 to 0.53 kJ, the NOx emission reduction from 11.3 to 2.12 g/kwh and the engine brake torque decrease from 20.3 to 9 Nm.

Keywords: residual gas, effective release energy, peak firing pressure rise, peak firing temperature, emission characteristics.

1. INTRODUCTION

From the historical trend of research on the factors which affect the mass of exhaust residual gas in the cylinder, the effects of residual gas on engine performance, and engine emission characteristics. Past researchers attempting to control the amount of residual gas trapped in the cylinder and used new techniques to measure exhaust residual gas, such as Variable Valve Timing technologies, and an exhaust gas prediction method

Lei Zhou *et al.* [1] evaluated a single-cylinder, four-stroke Ricardo E6 to study the influence of exhaust gas recirculation on the engine combustion characteristics under low load conditions. The intake valve timing and exhaust valve timing were used to adjust the exhaust residual gas ratio. They found that under partial load conditions, when the exhaust residual gas ratio was small, the heating effect was the main influence on the burning rate, but when the exhaust residual gas ratio was larger, the burning rate was reduced. Under idle conditions, the combustion stability and fuel consumption were improved with a larger residual gas ratio. Jun Yang *et al.* [2, 3] presented a statistical dynamic model with stochastic properties that was developed to control the exhaust residual gas in gasoline engines. In further research they used that model to study the effect of the transient residual gas fraction on engine performance. Their results showed that the exhaust residual gas fraction has a sensitive effect on misfiring, NOx emission, the heat release rate, and engine knocking.

Our research utilized an SI V-twin engine which had two separate camshafts, one for controlling the intake valve and the other for controlling the exhaust valve. Our studies with changing valve timing were conducted without the limited experimental conditions described above. As a result, our simulation model produced more accurate predictions and we were able to thoroughly assess and discuss those parameters which have sensitive effects on exhaust residual gas.

2. EXPERIMENTAL SETUP

Figures 1 and 2 shows the schematic of the small-SI engine testing system and experimental setup. The conditions of the experimental included a compression ratio of 11.8:1.0, and an air-fuel ratio of 13.6. The temperature of environment ranged from 29.5 to 30 deg C. Air was used for coolant, the engine oil temperature was maintained at 80 deg C; when the engine was running and the opening throttle angle was 90 degrees

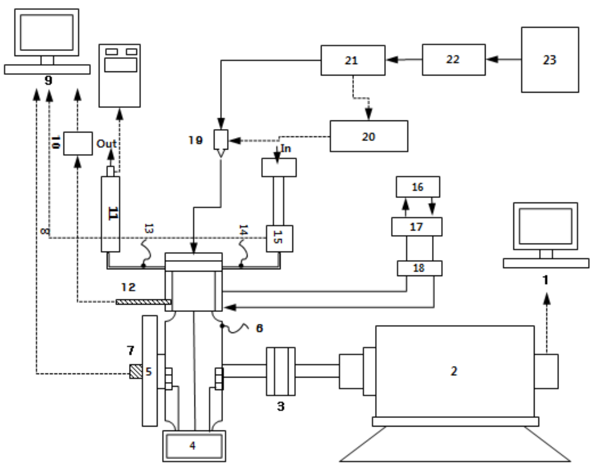

Figure-1. The schematic of the V-twin engine testing system.

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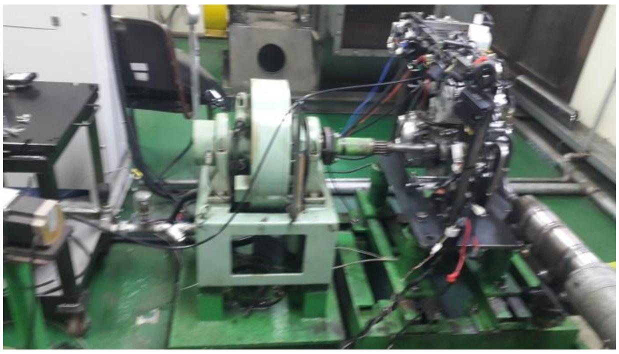

Figure-2. Engine experimental system.

3. APPLIED ENGINE

The applied engine specifications are shown in Table-1.

Table-1. Engine specifications.

Parameter	Unit	Value
Engine model	-	Four stroke, spark ignition
Number of cylinder	-	2
Compression ratio	-	11.8:1
Bore	mm	57
Stroke	mm	53.8
Connecting rod	mm	107.9
Intake valve	-	2
Exhaust valve	-	2
Cooling system	-	Air cooled

4. SIMULATION MODEL SETUP

The AVL-Boost is well known as effective and useful simulation software of internal combustion engine field. AVL-Boost software allows researchers simulate all type of combustion engine as well as: SI - engine [4-7], CI engines [8], turbocharged diesel engines, and alternative fuels engines.

The simulation model of researching small-SI engine is showed in Figure-3.

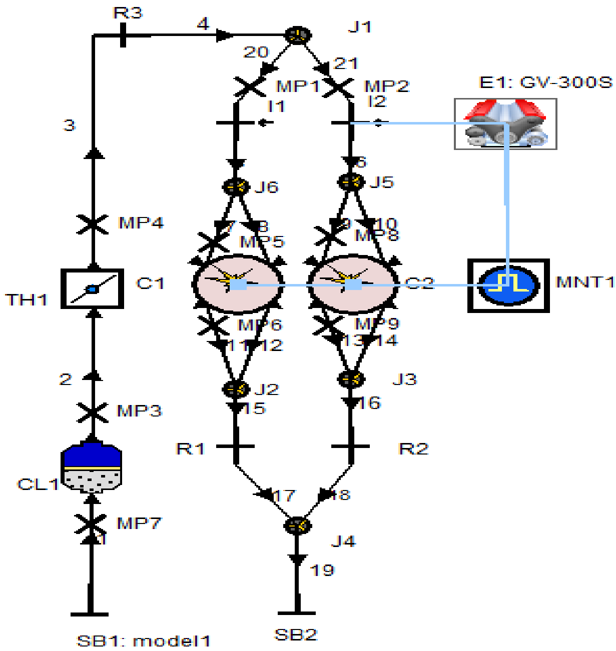

Figure-3. Simulation model.

The elements in the simulation model describe for engine parts of researching engine. Those simulation elements are used to define researching engine's parts characteristics. The simulation condition of steady state or transient state is permitted to select in the engine element E1. The monitor element MNT1 is an extra element because this part is not in researching engine. This monitor element helps researcher is able to select observing output data as well as engine torque, residual gas ratio, effective release energy, etc. And the selected observing output data is able to shows in transient results. The element SB1and SB2 is system boundary of intake and exhaust pipe. Element CL1 is the air cleaner of the system. The opening of the throttle angle is set in element TH1, in this research the throttle is kept for opening 100%. The pressure loss in the intake and exhaust pipe (1, 2, 3…21) is described by element restriction R1, R2, R3. The element junction J1, J2, J3, J5, and J6 help to collect or to distribute the flow in the pipe. By using measuring element MP1, MP2 on the intake and exhaust pipe to determine the flow characteristic as well as: air mass flow, flowing velocity, air flow temperature. Injector I1 and I2 provides fuel in to cylinder C1 and C2 of the engine.

5. RESULTS

The exhaust residual gas ratio has a significant effect on peak firing temperature and peak firing pressure rise. As shown in Figures 4 and 5, the peak firing temperature and peak firing pressure rise decreased when the exhaust residual gas increased. This is because the increase in exhaust residual gas in the cylinder was due to a diluted and less homogeneous air-fuel mixture and an increased area that lacked fuel or oxygen. As a result, when the residual gas ratio increased from 1% to 5%, the peak firing temperature decreased from 2900 K to 1250 K and the peak pressure rise decreased from 8 to 5.5 bar/deg.

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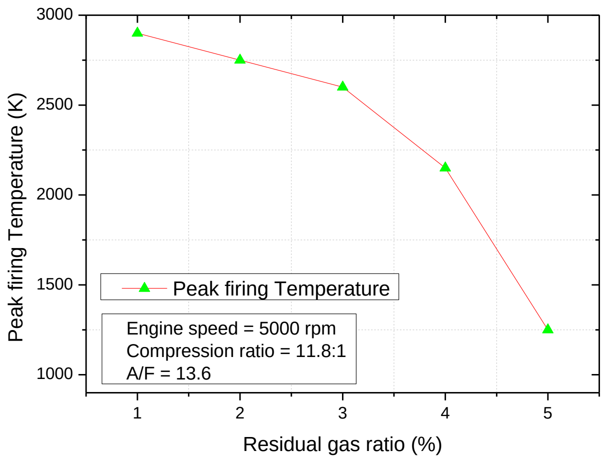

Figure-4. Peak firing temperature.

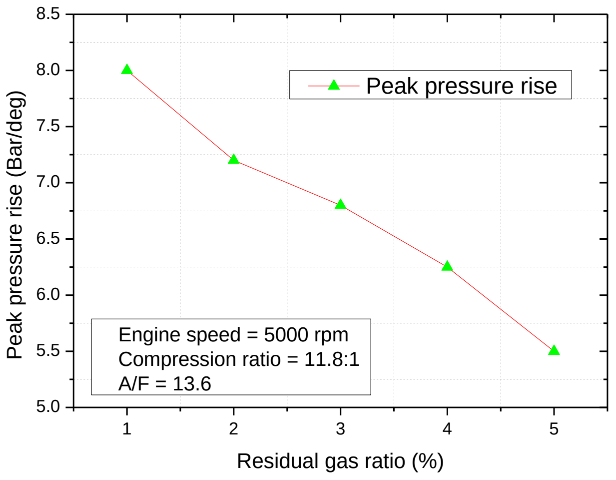

Figure-5. Peak firing pressure rise.

In the combustion stroke of the internal combustion engine, the chemical energy of fuel trapped in the cylinder is released into heat energy. A certain amount heat energy is lost from heat transfer, pumping loss, and energy that is not effectively released in the cylinder (but instead goes into the combustion products), and the remaining energy is the effective release energy. The heat transfer loss and combustion duration have a large effect on the effective release energy. We observed a decline in effective release energy (Figure-6) as the exhaust residual gas increased. In this study, the effective release energy decreased from 0.85 KJ to 0.53 KJ when the residual gas ratio increased from 1% to 5%.

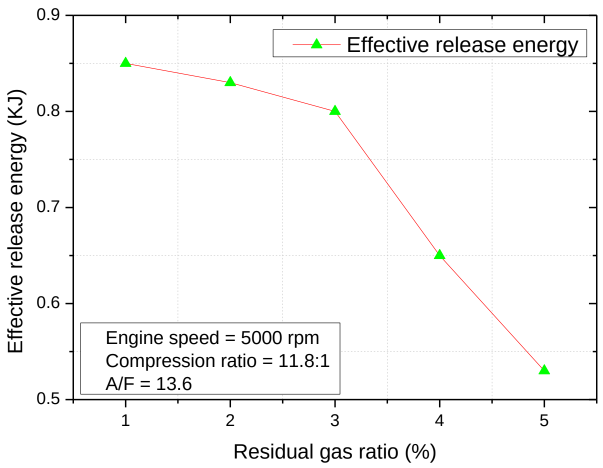

Figure-6. Effective release energy.

Figure-7 shows the NOx emission versus residual gas ratio. The NOx emissions tend to decrease with an increasing residual gas ratio for two reasons. First, an increased residual ratio is associated with a decreased peak firing temperature. And second, an increase in the residual gas is caused by a diluted air-fuel mixture and a lower level of oxygen concentrate. The decreased oxygen concentrate leads to decreased NOx emissions in the combustion stroke. In our study, these two factors explain why the NOx tended to decrease with an increasing residual gas ratio. The minimum NOx emission was 2.12 g/kWh at a 5% residual gas ratio.

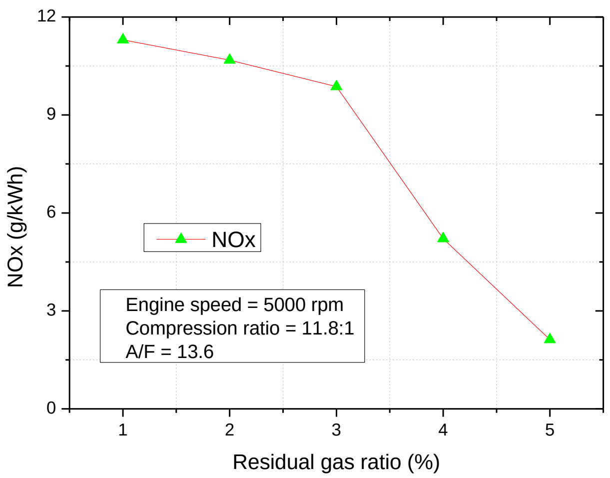

Figure-7. NOx emission versus residual gas ratio.

Figures 8 and 9 show the CO and HC emissions versus residual gas ratio. An increased residual gas ratio leads to a diluted air-fuel mixture and increased areas lacking oxygen. In this study, the dilution of the air-fuel mixture and the lack of oxygen increased the unburned HC and CO emissions from 3.65 to 18.2 g/kwh and from 139 to 450 g/kwh, respectively.

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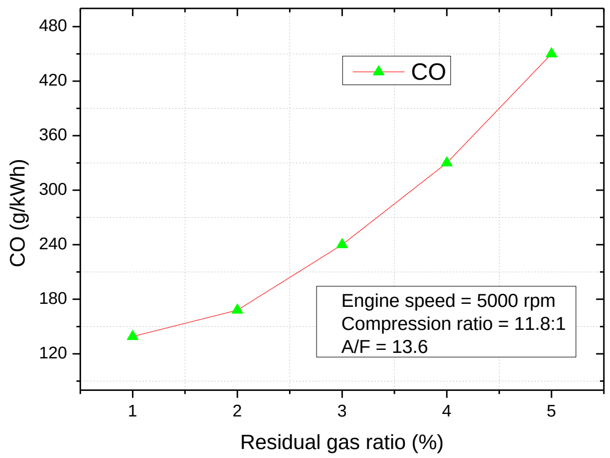

Figure-8. CO emissions versus residual gas ratio.

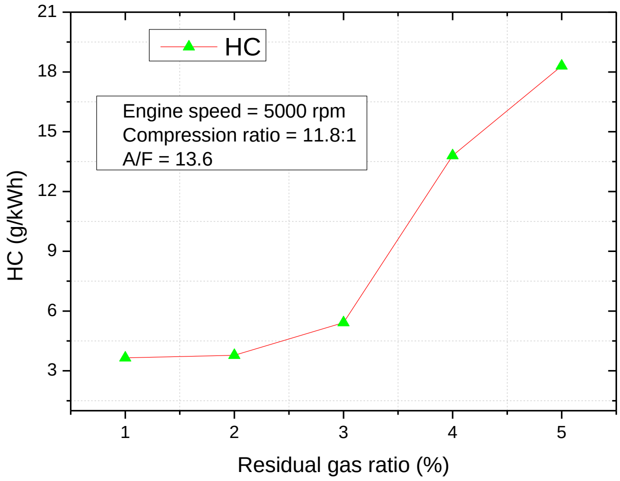

Figure-9. HC emissions versus residual gas ratio.

6. CONCLUSIONS

The exhaust residual gas ratio had a significant effect on the peak firing temperature and peak firing pressure rise. When the residual gas ratio increased from 1% to 5%, the peak firing temperature decreased from 2900 to 1250 K and the peak pressure rise decreased from 8 to 5.5 bar/deg. An increase in the exhaust residual gas in the cylinder was due to a longer burn time, lower peak firing pressure rise, and lower peak firing temperature, which in turn caused a lower effective release energy. The effective release energy decreased from 0.85 KJ to 0.53 KJ when the residual gas ratio increased from 1% to 5%. The NOx emission tended to decrease as the exhaust residual gas increased because an increase of residual gas in the cylinder led to a decreased peak temperature and less oxygen concentrate. Thus, the NOx emission declined from 11.3 to 2.12 g/kwh when the exhaust residual gas increased from 1% to 5%. An increased residual gas ratio led to a diluted air-fuel mixture and larger areas that lacked oxygen. The dilution of the air-fuel mixture and the lack of oxygen were due to increases in unburned HC and CO emissions from 3.65 to 18.2 g/kwh and from 139 to 450 g/kwh, respectively.

REFERENCES

[1] Lei Zhou, Jianxiong Hua, Feng Liu, Fengnian Liu, Dengquan Feng, Haiqiao Wei. 2018. Effect of internal exhaust gas recirculation on the combustion characteristics of gasoline compression ignition engine under low to idle conditions. Energy. 164: 306-315.

[2] Jun Yang, Kota Sata, Junichi Kako, Akira Ohata, Tielong Shen. 2013. Statistical Model and Control of Residual Gas Mass in Gasoline Engines. IFAC Proceedings Volumes. 46(21): 594-599.

[3] Kota Sata, Junichi Kako, Jun Yang, Akira Ohata, Tielong Shen. 2013. Effect of Transient Residual Gas Fraction for Gasoline Engines. IFAC Proceedings Volumes. 46(21): 588-593.

[4] Nguyen Xuan Khoa, Ocktaeck Lim. 2020. Comparative Study of the Effective Release Energy, Residual Gas Fraction, and Emission Characteristics with Various Valve Port Diameter-Bore Ratios (VPD/B) of a Four-Stroke Spark Ignition Engine. Energies. 13 (6):1330.

[5] Nguyen Xuan Khoa, Ocktaeck Lim. 2020. Effective release energy, residual gas, and engine emission characteristics of a V-twin engine with various exhaust valve closing timings. Journal of Mechanical Science and Technology. 34 (1): 477-488.

[6] Nguyen Xuan Khoa, Ocktaeck Lim. 2021. The Internal Residual Gas and Effective Release Energy of a Spark-Ignition Engine with Various Inlet Port–Bore Ratios and Full Load Condition. Energies. 14 (13): 3773.

[7] Nguyen Xuan Khoa, Ocktaeck Lim. 2020. The effects of bore-stroke ratio on effective release energy, residual gas, peak pressure rise and combustion duration of a V-twin engine. Journal of Mechanical Science and Technology. 34: 2657-2666.

[8] Jose Antonio Pagán Rubioa, Francisco Vera-Garcíab, Jose Hernandez Graub, Jose Muñoz Cámarab, Daniel Albaladejo Hernandezb. 2018. Marine diesel engine failure simulator based on thermodynamic model. Applied Thermal Engineering. 144(5): 982-995.