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ORIGINAL ARTICLE

Effect of Exhaust Gas Recirculation in a Spark-Ignition Engine

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ABSTRACT

In This paper we examine the effect of exhaust gas to air manifold on nitrogen oxides in different loads, the exhaust smoke temperature, brake specific fuel consumption, volumetric efficiency, and thermal efficiency. Analysis of this research show that increasing exhaust gas to air manifold get to decrease engine thermal and volumetric efficiency and then increasing exhaust smoke temperature.
***Key-words**: EGR, Volumetric efficiency, Nitrogen oxide, Specific fuel consumption, air Pollution*

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INTRODUCTION

For reducing air Pollution by vehicles, the different methods and systems can be used for controlling of pollution. Returning some of exhaust gas to air manifold in EGR System cause to be decreasing engine temperature and then decreasing nitrogen oxides. EGR is one of the important methods for controlling nitrogen oxides in exhaust spark-ignition engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. Intermixing the incoming air with re-circulated exhaust gas dilutes the mix with inert gas, lowering the adiabatic flame temperature and (in diesel engines) reducing the amount of excess oxygen. The exhaust gas also increases the specific heat capacity of the mix lowering the peak combustion temperature. Because NOx formation progresses much faster at high temperatures, EGR serves to limit the generation of NOx. NOx is primarily formed when a mix of nitrogen and oxygen is subjected to high temperatures. Recirculation is usually achieved by piping a route from the exhaust manifold to the inlet manifold, which is called external EGR. A control valve (EGR Valve) within the circuit regulates and times the gas flow. Some engine designs perform EGR by trapping exhaust gas within the cylinder by not fully expelling it during the exhaust stroke, which is called internal EGR. EGR can also be used by using a variable geometry turbocharger (VGT) which uses variable inlet guide vanes to build sufficient backpressure in the exhaust manifold. For EGR to flow, a pressure difference is required across the intake and exhaust manifold and this is created by the VGT. EGR Percent increasing until combustion temperature and flame speed be enough for good engine performance [1]. The advanced gasoline engines actuates with ratio of estocumetric air-fuel mixture. When EGR aren't used mass of inlet air-fuel mixture to engine cylinder can be control engine torque and engine power, but while EGR method is used, if out put torque have fix then, imprisoned mixture mass would be fix in cylinder. The inlet mass cylinder should be added to imprisoned air- fuel mixture. Thus, total imprisoned inlet mass (air- fuel mixture together with EGR mass) should be increased because of fixing outlet power and torque. When engine volume is fix, imprisoned mixture mass increasing only by increasing mixture density and that cause more opening intake valves [2].

EXHAUST GAS RECIRCULATION TO INLET MANIFOLD

Fig.1 showing exhaust gas recirculation to air manifold. A filter with dimensions 15×15×30 cm^3 use for smoke transferring and particulating trap. A thermocouple install on EGR pipe and near of inlet air manifold for measuring smoke recirculation temperature. A part of EGR pipe is made of anti rust steel and flexible steel to prevent from transfer vibrations and engine vibration to exhaust system and for install of measurement devices. Also to prevent gases temperature drop from EGR pipe, this pipe is insulated by glass insulators [3].

DETERMINING RATE OF ENGINE INLET AIR

To measure volumetric efficiency, measuring for consumption value of inlet air is necessary. In ideal conditions, the measurement instrument should not be in front of air flow. Unless, engine inlet air be increase in compare with ideal condition. Orifice and tank method is suitable method for measuring engine inlet air, and this method is cheaper than others. At first, engine inlet air crossing from an orifice plate, and pressure drop in two sides of orifice plate have direct relation with engine inlet air value. Fig. 2 showing orifice method for measuring engine inlet air. It is important to know, damping oscillation of inlet air pressure could be duty of tank. By calculations, fit orifice diameter consider 52.4 mm, tank volume 0.33 m^3. Dimensions 60×70×80 cm determined base on tank volume.

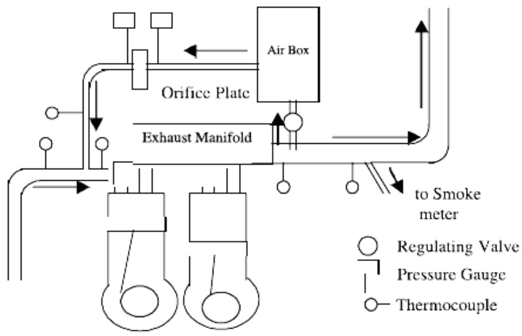

Fig.1 Line diagram of the proposed EGR

Orifice diameter and tank volume calculated in steady current while air flow is unsteady. For decreasing oscillation range of air stroke to minimum value, a big damper tank should be among orifice plate and engine. Also the tank connects to engine intake by a short flexible hose. In this research a spark-ignition engine that has four cylinders and four strokes with capacity 1.3 lit and maximum speed 630 $^{rad}/_{s}$ used. To manufacture tank, after plates slice carefully, welding has done. In central part of any disk and on the two side of tank a hole is made with diameter 15 cm. There are two aims for making hole, one is installation of orifice plate according calculated orifice diameter and another aim is installation flexible pipe for connecting tank to motor manifold. [4]

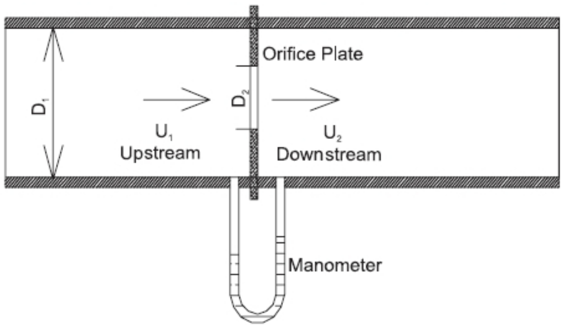

Fig.2 a schematic diagram of orifice meter

Determining exhaust smoke percent to air manifold

Exhaust gas recirculation percent is a percentage amount of total intake mixture that it is returned to inlet manifold. [5]

$$\text{EGR\%} = \frac{m_{EGR}}{m_i} \times 100 \qquad (1)$$

That:

$$m_i = m_a + m_f + m_{EGR}$$

m_a: Inlet air mass
m_f: Specific fuel consumption
m_{EGR} =Smoke recirculation mass that it is almost more than 30
In other words, exhaust gas recirculation is based on EGR to fresh mixture ratio. [6]

$$\text{EGR\%} = \frac{m_{EGR}}{m_a + m_f} \times 100 \qquad (2)$$

Some times EGR is defined by volume rate of returned gas to total inlet mixture into cylinder.

$$EGR\% = \frac{m_{EGR}}{m_a+m_f+m_{EGR}} \times 100 \quad (3)$$

In this research, calculating of turning smoke is done by orifice and differential pressure in upstream and downstream (according to fig.2).

Measuring engine fuel consumption

The companies try to produce vehicles with less fuel consumption. The Vehicles with upper brake power have more fuel consumption. Therefore, it is impossible to compare two different power engine with fuel consume. Specific fuel consumption is important for comparing and it is fuel consumption to brake power ratio. We know that, fuel consumption to indicator power ratio is called indicator specific fuel consumption. According to figure 4, a glass vessel was used for measuring engine fuel consumption. This is calibrated and its total volume is 100 cc. under the vessel is connecting to fuel system by a plastic hose. Fuel flow is controlled by stop cock in vessel end. By this vessel, it is easy to calculate fuel consumption volume in specific time. By this, rate of engine fuel consumption is calculating by under formula.

$$Q = V/t \quad (4)$$

That:

Q: Rate of fuel consumption (m^3/s)

V: Volume of fuel consumption (m^3)

t: Time of consuming fuel (s)

Also, fuel mass flow is determined by flow formula.

$$\dot{m}_f = Q \times \rho \quad (5)$$

That:

$\dot{m}_f$=fuel mass flow (kg/s)

Q=rate of fuel consumption ($m3/s$)

ρ =fuel density ($kg/m3$)

It is important to know, needing value of density is $0.75\, Kg/m^3$ and $45\, Mj/Kg$ for fuel heating value.

Measuring brake power

Brake power of engine is based on torque and crank angular velocity. A dwell tachometer has been used for determining crank angular velocity. Also hydraulic dynamometer uses to measure engine crank shaft moment. (Fig. 3 and Fig. 4)

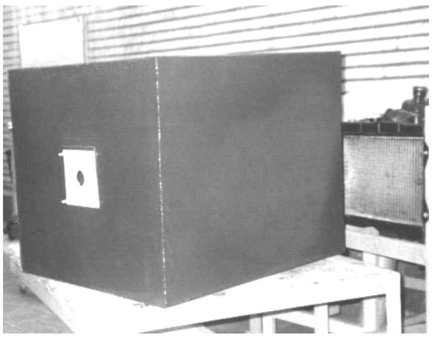

Fig.3 manufactured tank

Fig.4 measuring time of engine fuel

Analysis of exhaust gas

Analysis of combustion products is done by four-gas analyses system. (Fig.5) This system is able to measure amount of carbon oxide, unburned hydrocarbon and nitrogen oxides in exhaust smoke. For sucking smoke into system at time of measuring pollutants and too sucking air into analyzer because of leak test, a pump and filter are used. An analyzer has a specific metal pipe for setting in exhaust pipe. The system should be checked before testing. One of the important cases is caulking from pump to exhaust. That been called manifold leakage test. Four-gas analyses system show any pollutants percentage on monitor after analysis of received smoke. [7]

Fig. 5 Four-gas analyzer system

RESULTS AND DISCUSSION

After preparing equipment, different examination was done. And the effect percent of exhaust returned on nitrogen oxides, fuel consumption, engine volumetric efficiency, exhaust smoke temperature, measuring thermal efficiency is shown by different rate of returned smoke. [8]

The effects returned smoke percent to air manifold on Nox gas

Now, the effect of exhaust smoke returned of exhaust smoke returned of Nox gas is considered with different load. Increasing smoke recirculation percent cause decreasing nitrogen oxide formation. In different load percent and different EGR is shown by Fig. 6. It is clear that maximum decreasing nitrogen oxides is in 10-15 percent of EGR. Less loads had less nitrogen oxides formation. And it is because of decreasing engine temperature in fewer loads. [9]

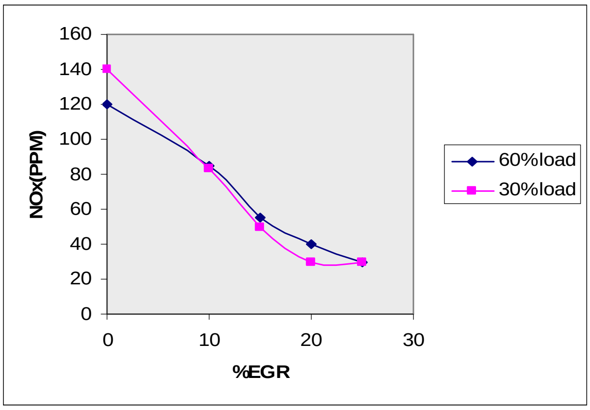

Fig.6 smokes returned percentage effect to inlet manifold on Nox at different loads

The effects Percentage of exhaust gas recirculation to air manifold on thermal efficiency

The results of this topic are seen in fig.7.Research shows that decreasing exhaust gas temperature doesn't much influence on thermal efficiency and to EGR Value doesn't much effect. While, there are %15 thermal efficiency drop in EGR Partially. Good mixing of air and fuel in spark-ignition engine increasing mixed temperature and so increasing pressure that it would be reason of decreasing thermal efficiency partially.

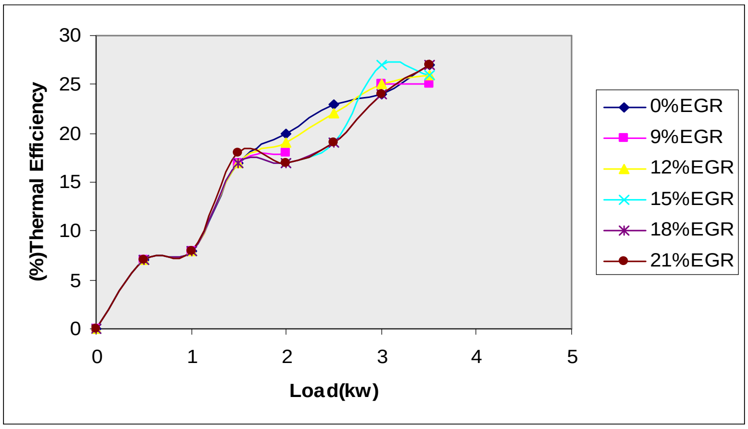

Fig.7 smokes returned percentage effect to inlet manifold on thermal efficiency at different percentage of EGR

The effects Percentage of exhaust gas recirculation to air manifold on specific fuel consumption

This part is examining exhaust smoke to air manifold on brake specific fuel consumption and results from that had shown in Fig.8. As you seen, specific fuel consumption independent on EGR and It is decreasing with increasing engine load.

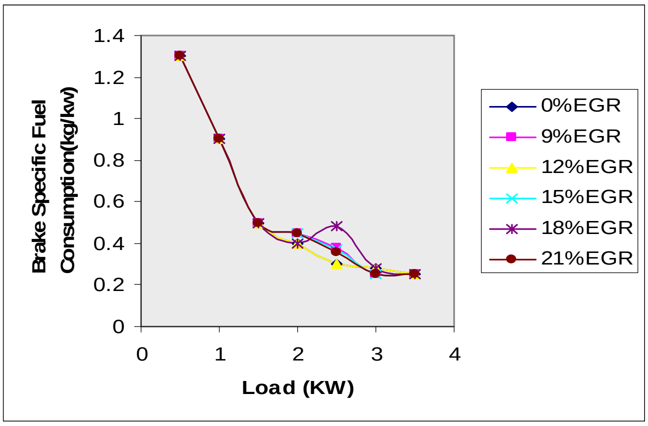

Fig.8 smokes returned percentage effect to inlet manifold on specific fuel consumption at different percentage of EGR

The effects Percent of exhaust gas recirculation to air manifold on volume efficiency

Engine volumetric efficiency is a important parameter in this research. Smoke could be expanded inlet air in combustion chamber. Air expansion in combustions chamber get inlet air limited by this engine volumetric efficiency would be decrease. In ordinary state, always volumetric efficiency of spark-ignition is less than 100 percent. Turbocharger or super charger is using for increasing volumetric efficiency in heavy vehicles. By this, volumetric efficiency would be more than 100 percent. Using after cooler, cause increase volumetric efficiency. In this research supercharge system shouldn't be used. The effects percent of exhaust gas on volumetric efficiency are shown by fig. 9. It is clear that volumetric efficiency is dropping with increasing EGR, Percent.

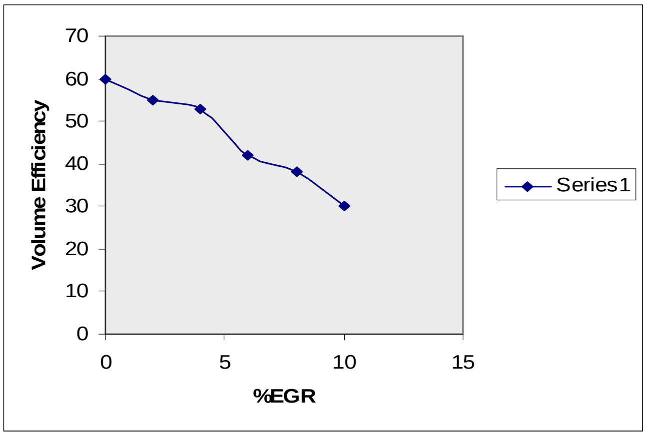

Fig.9 smokes returned percentage effect to inlet manifold on volumetric efficiency at different percentage of EGR

The effect percent of exhaust gas recirculation to air manifold on exhaust smoke temperature

Studying exhaust smoke is important for producing nitrogen oxides and chemical reaction in catalyst exchanger. Digital thermometer measured exhaust gas temperature with different loads and process. The results from examination are represented in fig.10. In fixed loading, while EGR Percent is increasing, exhaust gas temperature is decreasing continually and we know, in any determined percentage of returned smoke, smoke temperature increasing with increasing engine load. It is to remind that returning smoke to air manifold get decreased combustion temperature and this case have direct effect on smokes.

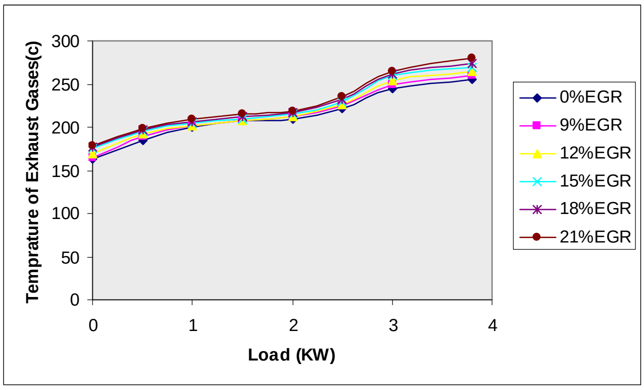

Fig.10 smokes returned percentage effect to inlet manifold on exit smokes temperatures from exhaust at different loads

CONCLUSION

According to done examination, the effects exhaust gas returned on some parameters are considered. These parameters are exhausted gas temperature, thermal efficiency, specific fuel consumption, and volumetric efficiency and nitrogen oxides values. The results show that usage to EGR method get decreased nitrogen oxides and using this method, decrease exhaust gas temperature and then nitrogen oxides would be decrease in combustion chamber. So, high temperature of combustion is important reason for nitrogen oxides formation and so, thermal efficiency and specific fuel consumption undependend on EGR Value significantly. Vicinity heat smokes with inlet air, cause to be expanding air. Air expansion in combustion chamber get decreased engine inlet air suction stroke. By lessening inlet air value, indicator power and brake power and finally volumetric efficiency would be decreased. It is important to know reduction of returned smoke temperature have negative effect on catalyst exchanger function. Thus this investigation, it is be suggested to use a heat element in catalyst exchanger.

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