Exhaust Gas Recirculation- A Review

Rashi Koul
Department of Mechanical & Automation Engineering
Amity University, Haryana, India

Abstract— Exhaust gas emission systems also called in short as EGR now-a-days have been commercialized as a NOx reduction method for a wide range of diesel engines. In internal combustion engines EGR is a nitrogen oxide (NOx) emissions reduction technique used in petrol/gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders [1]. This dilutes the O2 in the incoming air stream and provides gases inert to combustion to act as absorbents of combustion heat to reduce peak in-cylinder temperatures. NOx is produced in a narrow band of high cylinder temperatures and pressures. A number of considerations must be taken into account when designing EGR systems including: deposit accumulation, contaminants, engine lubricant, system packaging and more.
Key words: Exhaust Gas Recirculation (EGR), Diesel Engines, No_x Emissions, Exhaust Heat, Gasoline, Palm Oil, Jatropha Oil

I. Introduction

In a gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder. In a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture [1]. Because NOx forms primarily when a mixture of nitrogen and oxygen is subjected to high temperature, the lower combustion chamber temperatures caused by EGR reduces the amount of NOx the combustion generates (though at some loss of engine efficiency) [2]. Gases re-introduced from EGR systems will also contain near equilibrium concentrations of NOx and CO. Now-a-days, modern engines in different countries now require exhaust gas recirculation to meet emissions standards. It depends upon the chemical properties of different fuels that limit how much EGR may be used. For example methanol is more tolerant to EGR than gasoline.

Renewable and alternative fuels such as diesel oil blends of palm oil, jatropha etc; from sustainably available feedstock sources have been the vital subject of research in recent years for replacing current petroleum fuels. These alternate fuels are suggested for opposing the adverse effects contributed by the present use of petroleum fuels in transportation and power generation [1, 2].

II. Efficiency of Gasoline Engine Using EGR

In a typical automotive spark-ignited (SI) engine, 5% to 15% of the exhaust gas is sent back to the intake as EGR. The maximum quantity is limited by the need of the up applications can cause misfires and partial burns. Although EGR does measurably slow combustion but the same can be compensated by advancing the spark timing which helps in preventing long delay periods. The impact of EGR can increase the efficiency of an engine but it mostly depends upon the specific engine design but sometime it can lead to a compromise between efficiency and NOx emissions. There are various mechanisms which can lead to the increase in efficiency using EGR. Some of them are as follows:

- Reduced throttling losses. The addition of inert exhaust gas into the intake system means that for a given power output, the throttle plate must be opened further, resulting in increased inlet manifold pressure and reduced throttling losses [5].
- Reduced heat rejection. Lowering the peak combustion temperatures not only reduces NOx formation but also reduces the loss of thermal energy to combustion chamber surfaces. It results in availability of thermal energy which is converted to mechanical work during the expansion stroke.
- Reduced chemical dissociation. The lower peak temperatures result in more of the released energy remaining as sensible energy near TDC (Top Dead-Center), rather than being bound up (early in the expansion stroke) in the dissociation of combustion products. This effect is minor compared to the first two.

EGR is usually not employed at high loads because it would reduce peak power output and it happens because it reduces the intake charge density. EGR is also omitted at idle (low-speed, zero load) because it would cause unstable combustion, resulting in rough idle.

Since the EGR system recirculates a portion of exhaust gases but over the time, the valve gets clogged with the carbon deposits present in the exhaust gases. Due to this the replacement becomes necessary for smooth and effective operation.

The effects of EGR on combustion and emissions under different hydrogen ratios were studied based on an engine with a gasoline intake port injection and hydrogen direct injection. It was studied that the peak cylinder pressure increases by 9.8% in the presence of a small amount of hydrogen [3]. The heat release from combustion is more concentrated, and the engine torque can increase by 11% with a small amount of hydrogen addition. Nitrogen oxide (NOx) emissions can be reduced by EGR dilution. Hydrogen addition offsets the blocking effect of EGR on combustion partially, therefore, hydrogen addition permits a higher original engine EGR rate, and yields a larger throttle opening, which improves the mechanical efficiency and decreases NOx emissions by 54.8% compared with the original engine [4]. The effects of EGR on carbon monoxide (CO) and hydrocarbon (HC) emissions are not obvious and CO and HC emissions can be reduced sharply with hydrogen addition. CO, HC, and NOx emissions can be controlled at a lower level, engine output torque can be increased, and fuel consumption can be reduced significantly with the co-control of hydrogen addition and EGR in a hydrogen gasoline engine.

III. Performance and Emission

The performance and emission parameters have been compared for palm biodiesel and mineral diesel under EGR and normal modes in the experimental works and numerical study at same test conditions. In understanding the effect of EGR on engine performance, the brake specific fuel consumption (BSFC) and exhaust gas temperature (EGT) were measured and calculated at full load condition with a constant engine speed of 2500 rpm. The full load condition was chosen since the point is achieved minimum air-fuel ratio with maximum smoke emission. This condition provides more significant differences when comparing different fuels at similar test condition.

It is obtained from the study that palm biodiesel produces a 5.6% higher exhaust gas temperature than mineral diesel. This effect is due to the higher excess oxygen content in methyl ester that leads to improved combustion efficiency with higher cylinder temperature [3]. In the case of EGR mode, it is found that the exhaust gas temperatures for mineral diesel and palm biodiesel are 2.8% and 1.6 % lower than normal modes. Similar finding noticed with the results obtained by Rajesh Kumar et al. [5]. Their studies also concluded that most different types of fuel produce lower exhaust gas temperature significantly with EGR mode at various speeds and loads. The decrease in the exhaust gas temperature may be associated with the exhaust gasses recirculate and combine with the fresh air charge in the intake manifold [4]; eliminating the enriched oxygen content, then swirl back in the cylinder to be burned again. This condition will lead to increase in the incomplete fuel burning rate which attributes to lower thermal efficiency and more fuel to be consumed.

For palm biodiesel, the CO emission is lesser than for the mineral diesel because of a complete burning is occurred inside the cylinder due to the more availability of the oxygen content in palm biodiesel as compared to that of mineral diesel [4]. Whenever there is excess oxygen content as in palm biodiesel it helps toconvert CO to CO2. However, it is obtained from the results that 9.7% and 24.5% increase in the CO emission for mineral diesel and palm biodiesel when employed EGR at full load. CO emissions percentage is increased for both fuels with EGR mode due to the insufficiently supplied oxygen in the inlet charge that mixing with recirculating exhaust gas and thus it causes incomplete fuel burning.

Two additional conditions contribute to the NOx formation which more oxygen content in the fuel and the reactions occur in the residence time. Since palm biodiesel is used for the testing, the listed conditions are a favour to the biodiesel combustion as compared to mineral diesel. The exhaust emissions were compared to mineral diesel and palm biodiesel under EGR and normal modes at full load condition with a constant engine speed of 2500 rpm. Exhaust emissions include oxides of nitrogen (NOx), carbon monoxide (CO), carbon dioxide (CO2) and unburned hydrocarbons (UHC) were measured during the testing. An increase in cylinder temperature is mainly attributed to the higher formation level of NOx emission [10].. Hence, palm biodiesel combustion contributes higher NOx emission than mineral diesel. This consequence is mainly attributed higher oxygenated nature content in methyl ester, which leads to higher oxidized flammable combustion in the cylinder and increases exhaust temperature simultaneously. Also, the higher oxygen content in biodiesel may be associated with the early injection timing in the combustion due to the difference in the compressibility of the different fuels in the cylinder.

IV. Conclusion

The reviewed work had concluded some significant results during the test fuels, mineral diesel and palm biodiesel operated with two different modes (EGR and normal) in a diesel engine at full load at 2500 rpm. The findings concluded as follows:

– With the employment of an EGR system, using palm biodiesel there is an increase in fuel economy at a specific engine speed.
– Whenever EGR is employed with both test fuel, it is found out that there is a decrease in the exhaust temperature.
– NOx emission is reduced significantly when the EGR is applied with increase in CO and unburnt hydrocarbon emissions are obtained for both test fuels.

Production of bio-fuel from plant materials is a major step toward harnessing one of the world's most-prevalent, yet least-utilized renewable energy resources [3] the main aim of the present investigation was to produce bio-diesel from jatropha oil by using different methods. The resulting biodiesel has almost the same chemical structure as traditional diesel and burns the same way in diesel engines. This comparison helped us to figure out that with certain modifications in the chemical properties of the bio-diesel, it can replace the existing endangered diesel fuel completely so as to use it as 100% in CI engines [2].

India, with its huge waste/non-fertile lands, has taken a well noted lead in the cultivation as jatropha can be grown in such parts. Since the knowledge-base/expertise for jatropha has been inadequate in India, there is an ardent need for setting up specialized extension service centres for its cultivation and propagation and conversion to bio-diesel and taking it on a larger scale for the betterment of environment.

References

[1] https://www.dieselnet.com/tech/engine_egr_sys.php
[2] Hong W., Xuan T., He Z., Wang Q., Li D., Zhang X., Huang Y.Y., “Experimental study of combustion and emission characteristics of diesel engine with diesel/ second-generation biodiesel blending fuels”, Energy Conv. Manaagement, 2016; 121:241-250.
[3] Yunus khan T.M., Badruddin I.A., Badarudin A., Banapurmath N.R., Salman Ahmed N.J., Quadir G.A., Al-Rashed A.A.A.A., Khaleed H.M.T., Kamangar S., “Effects of engine variables and heat transfer on the performance of biodiesel fueled IC engines”, Renew. Sustain. Energy Rev., 2015; 44:682-691.
[4] Takase M., Zhao T., Zhang M., Chen Y., Liu H.,Yang L., Wu X., “An expatiate review of neem, jatropha, rubber and karanja as multipurpose non-edible biodiesel resources and comparison of their fuel, engine and emission properties”, Renewable and Sustainable Energy Reviews, 2015; 43:495-520.
[5] Mangus M., Kiani F., Mattson J., Tabakh D.,Petka J., Depcik C., Peltier E., Stagg-Williams S., “Investigating the compression ignition combustion of multiple biodiesel/ULSD (ultra-low sulfur diesel) blends via common-rail injection”, Energy, 2015; 89: 932-945.