

Impact of Exhaust Gas Recirculation on the Performances of Diesel Engine

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ABSTRACT

"Worldwide emission regulation has been tightening year after year. Numbers of researchers are trying to work out combinations of key technologies to meet the forth-coming emission norms. Exhaust gas recirculation (EGR) for diesel engine to reduce oxides of nitrogen is chosen for present work. The emphasis is given on oxides of nitrogen (NOx). Experiments were carried out on computerized single cylinder four- stroke diesel engine with eddy current dynamometer (10 BHP 7.4 KW)."

"Exhaust gas re-circulation set-up is developed. It consists of EGR cooler; air filters box, rota-meter, exhaust control valve, pressure gauge and temperature indicator etc. Engine set-up was modified and coupled with EGR setup. Exhaust gas recirculation system was tested with different EGR percentage. i.e. 0 %, 8 %, 12 %, 15 % & 23 %. Effect of EGR on smoke, NOx and other performance parameters like smoke opacity, brake thermal efficiency, specific fuel consumption were studied. There is considerable reduction in oxides of nitrogen (NOx)."

I. INTRODUCTION

"The emission problem is now reached at alarming level. The toxic gases emitted to atmosphere by automobiles are liable to cause harm to human health, other living organisms, plants and environment by entering into bio-logical system."

"Diesel engine commonly known as compression ignition (C.I.) engine is widely used as power source. Exhaust gas emitted from compression ignition (C.I.) engine, is a mixture of many undesirable constituents known as pollutants.

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Diesel engine is better power source due to higher efficiency, performance, reliability and fuel economy than spark ignition (S.I.) engine and hence is preferred over spark ignition engine in commercial application."

"In diesel engines NOx formation is temperature dependent phenomenon & takes place when the temperature in the combustion chamber is 2000 k. To reduce NOx emission in the exhaust, it is necessary to keep combustion temperature under control. Exhaust gas recirculation is the effective technique for nitrogen oxides (NOx) reduction."

II. EXHAUST GAS RE-CIRCULATION SYSTEM

"Exhaust gas recirculation means re-circulating exhaust gas to the engine. Intermixing the incoming air with re-circulated exhaust gas, lowers the adiabatic flame temperature and reduces the excess oxygen. The exhaust gas increases the specific heat of the mixture and lowers the peak combustion temperature. NOx formation progresses faster at higher temperatures. EGR serves to limit the formation of NOx."

III. EXPERIMENTAL SETUP

Computerized single cylinder four stroke diesel engine with eddy current dynamometer was used. It is water cooled, vertical four stroke compression ignition engine. Other equipments used were as under

- AVL make smoke meter for smoke opacity measurement.
- AVL make five gas analyzer for measurement of HC, CO and NOx.
- Temperature indicator for measurement of EGR gas temperature.
- Rota meter for EGR flow rate.

Specification of the engine

- Compression ratio – 17.5 : 1
- Bore – 102 mm
- Stroke – 116 mm
- Power – 10 BHP (7.4 KW)
- Length of arm – 180 mm
- Maximum torque – 32 N-m
- RPM – 1500

IV. EXPERIMENTATION

Engine jacket cooling water flow rate was kept constant at 300 kg/hr. The speed of the engine was kept constant (1500 rpm)

The following parameters were measured.

- Smoke opacity of exhaust at different EGR rates with AVL make smoke meter.
- NOx: with the AVL make five gas analyzer.
- Temperature of EGR gas with temperature Indicator.
- Air flow and fuel flow by digital indicators.
- EGR flow rate with Rota meter.

The trials were conducted on computerized single cylinder 4-stroke kirloskar diesel engine with eddy current dynamometer to evaluate the performance of EGR system. The performances parameters were compared with EGR and without EGR for same engine output conditions. Known quantity of exhaust gas is re-circulated into the combustion chamber with air. And is achieved with manually controlled EGR valve. The exhaust gas comes out at very high temperature and pressure. It is pulsating in nature. The experimental EGR system is shown in figure (V). Several components of this EGR system have been designed and fabricated.

“An EGR cooler is designed and fabricated to reduce the temperature of exhaust gas. Gate valve is used to control the flow of exhaust gas. Valves are used to control the inlet and outlet water supply to the cooler. An air filter was fabricated to restrict moisture and dust particles of exhaust gas which come out from EGR

cooler. Air filter is fitted with a rota-meter for volumetric flow rate measurement. Digital Temperature Indicator is used to measure the temperature of exhaust gas. A Bourdon’s pressure gauge is used to measure the pressure and it is mounted on exhaust manifold. Digital control panel is provided to acquire data such as torque, fuel, air, water flow of engine and calorimeter. Thermocouples are provided at the intake, exhaust manifold and other test points along the EGR route. An AVL smoke-meter is used to measure the smoke opacity of the exhaust gas. A five gas analyzer is used to measure the exhaust pollutants such as O₂, CO, CO₂, HC and NOx.”

V. CALCULATION OF THE EGR RATE

When the impact of EGR on the emissions is assessed, it is essential to know the EGR ratio.

$$\% \text{ EGR} = \frac{M_{\text{EGR}}}{M_i} \times 100$$

Where: M_{EGR} = mass of EGR
 M_i = mass of total intake mixture

VI. RESULTS

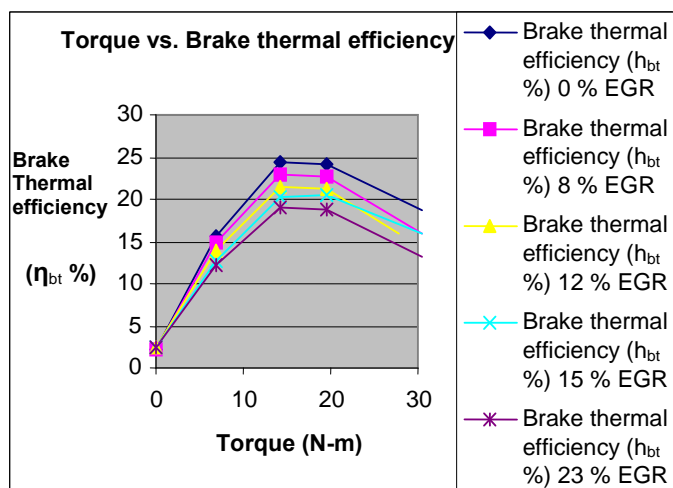


Figure (I): Torque Vs. Brake thermal efficiency

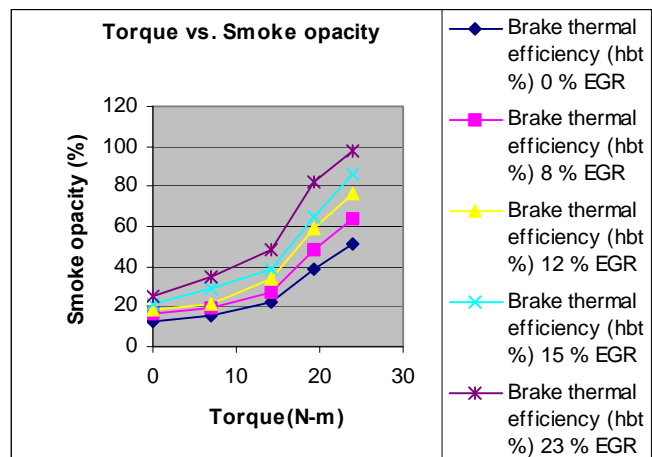


Figure (II): Torque Vs. Smoke opacity

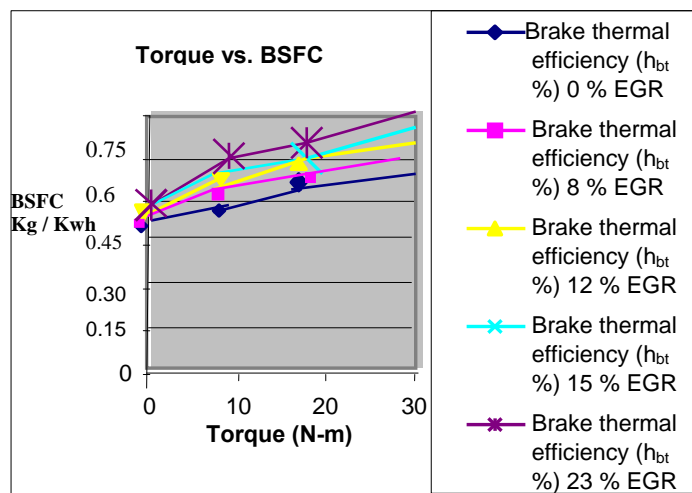


Figure III: Torque Vs. BSFC

Table I: Effect of EGR on NO_x

Sr. No.	% EGR	NO _x (ppm Volume)	Reduction in NO _x (ppm Volume)
1	0	376	0
2	8	327	49
3	12	290	86
4	15	243	133
5	23	178	198

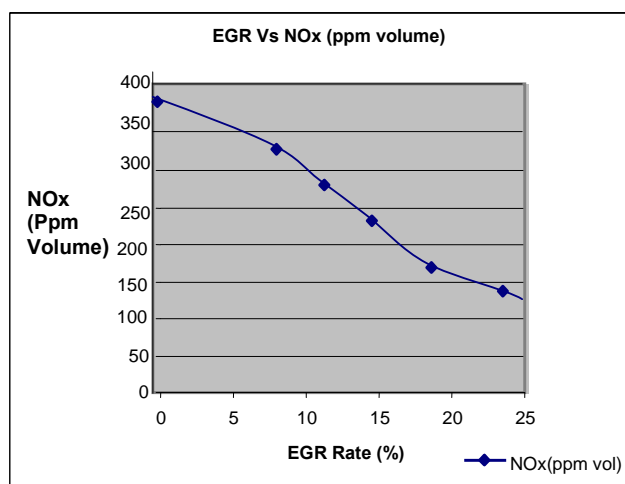


Figure (IV): EGR Rate vs. NO_x

VII. DISCUSSIONS

Figure (I) show variations of brake thermal efficiency with torque at different EGR rates. It is observed that with increasing rates of EGR at different torque there is marginal decrease in brake thermal efficiency. This may be due to the oxygen deficiency at higher load, which leads to incomplete combustion.

Figure (II) shows that the smoke emission increases with the increase in EGR rates for different torque. This significant increase in smoke is due to

- Exhaust Gas Re-circulation reduce the overall air/fuel ratio which enhances the increase in particulates.
- Re-circulated exhaust gas contain particulates which further contribute in raising smoke level.

Figure (III) shows variation of brake specific fuel consumption with torque at different EGR rates. It is observed that with increasing EGR at different torque there is marginal increases in BSFC.

Figure (IV) shows variation of NO_x concentration with different EGR. It indicates that with increase in EGR the concentration of NO_x decreases, as the exhaust gas absorbs some energy and hence lowers the peak combustion temperature.

VIII. CONCLUSION

The conclusions are as under

- Brake thermal efficiency decreases with increasing EGR rates. However, this decrease is marginal.
- The concentration of smoke density increases.
- Brake specific fuel consumption increases marginally with increasing exhaust Gas Re-circulation rates at high load.
- The exhaust gas recirculation (EGR) has definite impact on NO_x reduction.

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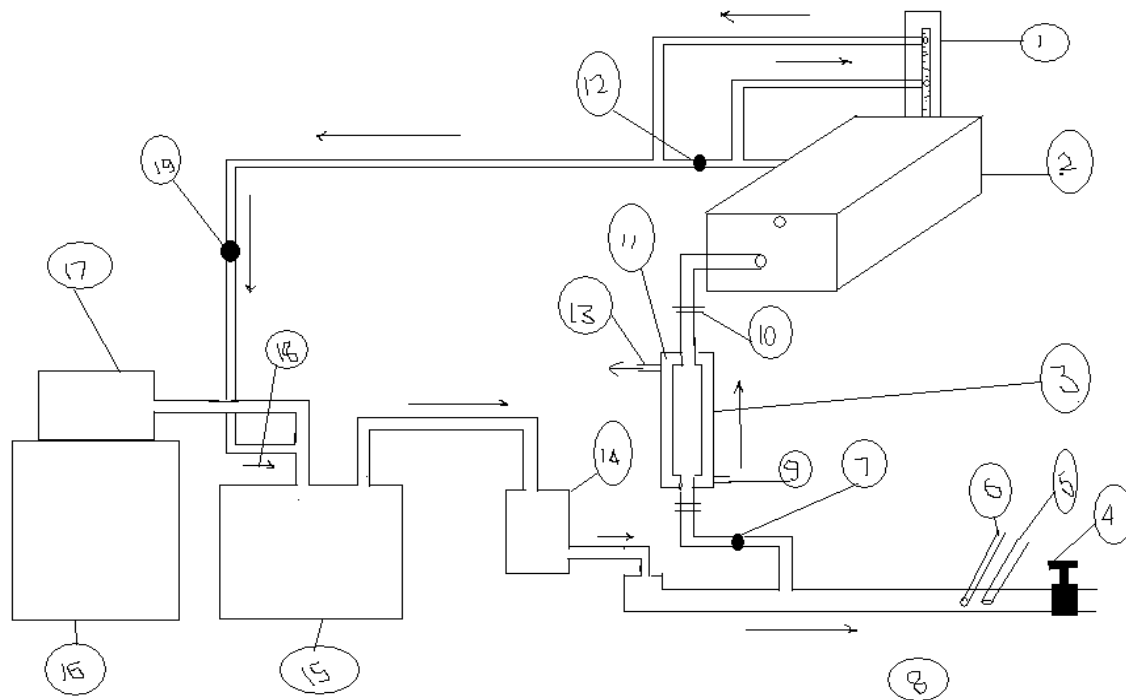
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Figure (VI):- Exhaust gas recirculation set up



Figure (VII):- Exhaust gas recirculation set up coupled with engine



COMPONENTS OF EXPERIMENTAL SETUP

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|-----|----------------------------------|-----|----------------------------------|
| 1. | Rota meter | 11. | Water surrounds the Hot Gas Pipe |
| 2. | Air box | 12. | Gate Valve (2) |
| 3. | Air Filter Box | 13. | Water Outlet from EGR Cooler |
| 4. | EGR Cooler | 14. | Exhaust Gas Calorimeter |
| 5. | Exhaust Control Valve | 15. | Digital Indicator Panel |
| 6. | AVL Five gas Analyzer Ball Valve | 16. | Air Box |
| 7. | AVL Smoke meter Ball Valve | 17. | (Air + % of Exhaust Gas) Inlet |
| 8. | Gate Valve | 18. | Air Inlet control Valve |
| 9. | Exhaust Pipe line | 19. | Digital Temperature Indicator |
| 10. | Water Inlet to EGR Cooler | 20. | Pressure Gauge |

Figure (V): Line diagram of computerized single cylinder four stroke Diesel engine with Exhaust gas Re-circulation system EGR system