Experimental Investigation on LHR Extended Expansion DI Diesel Engine Emission Controlling Injection Timing

A.Siva Kumar, K.Vijaya Kumar Reddy, E.Ramjee

Abstract: Fossil fuels are depleting rapidly because of incremental consumption rate due to population growth and necessary comforts on par with civilization. In this connection, the conventional fuels especially petrol and diesel for internal combustion engines, are getting exhausted at an alarming rate. In order to conserve the fossil fuels or to plan for survival of technology in future it is essential to plan for alternate fuels. Further, these fossil fuels cause serious environmental problems as they release toxic gases into the atmosphere at high temperatures and concentrations. Some of the pollutants released by the internal combustion engines are HC, CO, NOx, smoke and particulate matter. The predicted global energy consumptions are double by 2030 and quadruple by 2100. In view of this, an attempt is made to study a Low Heat Rejection (LHR) concept as one of the measures. The ignition delay will vary as the injection timing of the engine is varied. The variation in the injection timing will be effecting the performance and exhaust emissions of the engine strongly. The experimental results of the effects of variation in injection timings on the emission of LHR extended expansion engine is presented and analyzed.

Key words: Injection Timing, Emission and LHR Extended Expansion Engine.

I. INTRODUCTION

LHR is one of the extensively used concepts for diesel engines, which results in low fuel consumption and increasing thermal efficiency but with higher amount of NO_x for the same power output [1].

The stringent regulation on emission control with reduced fuel consumption has made diesel engine designers to concentrate more on valve timing modification to improve fuel economy and reduced exhaust gas emission. Normally diesel engines have higher compression ratios and their expansion ratios are somewhat lower than the compression ratios. The extended expansion cycle with a short compression stroke is one of the few remaining engine concepts that are available for improving engine performance and reducing fuel consumption. The complete operation is based on having high expansion ratios and the low effective compression ratio [2-3]. The decrease in the compression ratio can be achieved by closing the inlet valve either before the BDC or after the BDC.

The timings of the inlet/exhaust valve are controlled by cam and cam shaft action it can be pre opened or it can be closed lately. But in LHR engines the late valve closing displays an advantage over early valve closing (inlet) which affects its volumetric efficiency. This is basically a part of the gas dynamic, where gas is filled and emptied based on the breathing process of the LHR engines. Better heat transfer is also achieved with late intake valve closing (LIVC). These engines with extended expansion stroke and short compression stroke are known as the Extended Expansion cycle [4-6].

The advantages of Extended Expansion cycle are many aside from more power and efficiency over the conventional engine such as lower compression temperature for lower cylinder component stress, fuel knock deterrent, lower peak pressure, lower exhaust pressure, lower compression work and greater expansion work.

The net result of extended expansion alone is an improvement in fuel consumption and efficiency. It is further improved by making the Extended Expansion Engine a Low Heat Rejection type. The Extended Expansion cycle concept was achieved, in this case by closing the valve late. In the Extended Expansion cycle the inlet valve closes at 60° after BDC whereas in the conventional engine inlet valve closes at 45° after BDC. It has been chosen to achieve an effective compression ratio of at least 15:1 and a ratio of ER to compression ratio is of about 1.2 [7-9].

A Low Heat Rejection (LHR) engines employs suitable insulation coatings such as a ceramics etc., to the cylinder and piston. Due to the insulation provided on the required surfaces of the cylinder, the amount of heat loss to the coolant is reduced and hence results in high combustion chamber temperatures. This leads to some problems such as high NO_x emissions and exhaust blow-down losses.

The blow-down losses are mainly associated with the difference in pressure between the engine cylinder and exhaust pipe prevailing at the beginning of the exhaust stroke. This can be overcome by using a concept called extended expansion cycle, in which the expansion ratio is greater than that of the compression ratio.

This higher expansion ratio can be achieved by late closing of intake valve. The above described extended expansion cycle is shown in Fig.1 form as below:

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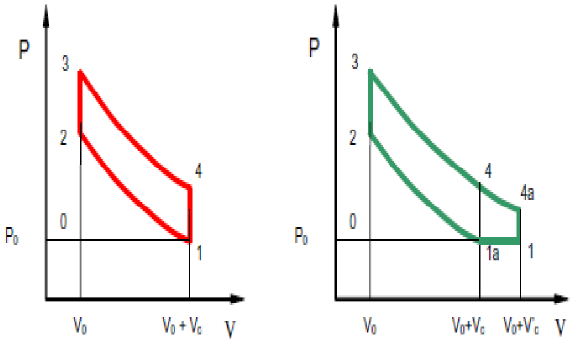

Fig: 1 Extended Expansion Cycle applied to Diesel Engine

Fuel injection timing is an important parameter that affects the combustion and exhaust emissions in diesel engines. The ignition delay will vary as the injection timing is varied. If earlier is the injection of the fuel, lower is the initial temperature and pressure causing increased in ignition delay [10]. And if later is the injection of the fuel (closer to TDC), the temperature and pressure will be higher decreasing the ignition delay period. Hence variation in the injection timing will be effecting the performance and exhaust emissions of the engine strongly. In this paper the investigations made on test engine at different injection timings for various exhaust emissions are presented and analyzed.

II. EXPERIMENTAL SET UP

An experimental set-up is developed to conduct tests on a four cylinder, four stroke water cooled DI Diesel engine. The test engine is coupled with eddy current dynamometer. In addition to this, fuel measuring burette, air flow measuring U-tube manometer are also fitted to the test engine set up. A provision is also made to mount a piezoelectric pressure transducer flush with the cylinder head surface to measure the cylinder pressure. The experimental set-up layout is shown in Fig. 2. The equipment and instrumentation used in this work is briefly described below.

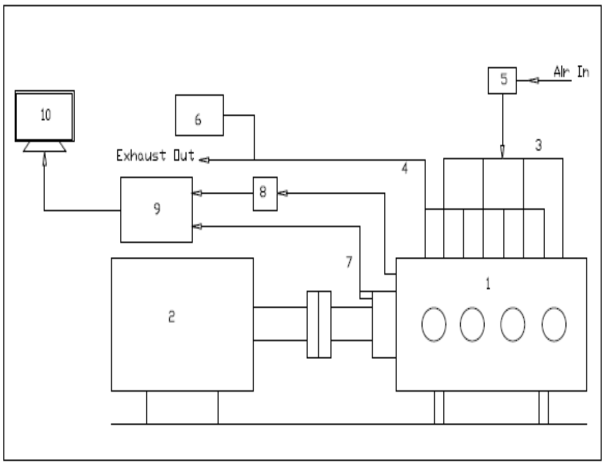

Fig: 2 Experimental Set up Layout

1. Engine 2. Eddy current dynamometer 3. Inlet line 4. Exhaust line 5. Air surge tank 6. Exhaust gas analyzer 7. Crank angle encoder 8. Charge Amplifier 9. CRO 10. Computer

A. SPECIFICATIONS OF THE TEST ENGINE

Bore, mm	111
Stroke length, mm	127
Connecting rod length, mm	251
Compression ratio	15:1
Displacement volume, liter	4.9134
Maximum power, HP	75
Injection pressure, bar	200
Inlet Valve Open(IVO)	8° bTDC
Inlet Valve Closing(IVC)	45° aBDC
Exhaust Valve Open(EVO)	45° bBDC
Exhaust Valve Closing(EVC)	12° aTDC
Injection timings, degrees	8° bTDC

Exhaust emissions are measured by five gas exhaust emission analyzer of model "5G-10, PLANET EQUIPMENT". The measuring method adopted for CO, HC and CO_2 was by NDIR and for NO_x and O_2 was by electrochemical bench.

III. RESULTS AND DISCUSSIONS

A. Nitric Oxide Concentration

The NO_x formation is invariable dependent on cylinder mean temperatures, the oxygen concentration and residence time for the reaction to take place. Fig 3 shown emission of NO_x for conventional, LHR and LHR (EEE) engines at different injection timings. When injection timing is advanced increase in NO_x emission are observed for all the engines. As the cylinder temperatures achieved in LHR engine is high may be the reason for producing higher NO_x concentration than conventional and LHR (EEE) engines. The NO_x concentration level is lower in case of LHR (EEE) because of its ability to reduce temperatures during the combustion cycle.

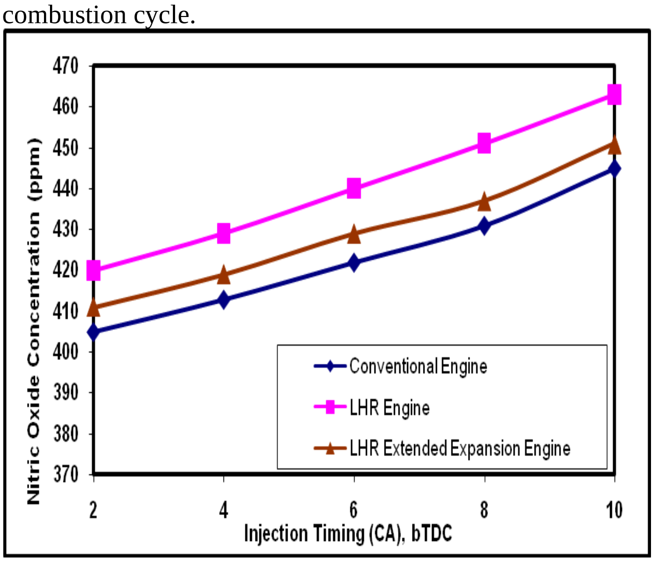

Fig.3 Comparison of Nitric Oxide Concentration for Conventional, LHR and LHR (EEE) engines for different Injection Timings.

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B. Unburned Hydrocarbon

As the diesel engine faces with serious problem of unburned hydrocarbons at light loads. UBHC emissions consists of incompletely burned fuel may be because of poor fuel distribution, low exhaust temperature, lean fuel air mixture regions and crevices in the engine cylinder. The influence of injection timing on UBHC emission for conventional, LHR and LHR (EEE) engines can be noted clearly from the Fig 4. As the injection timing is advanced the UBHC emission level is falling for all the engines. The reason of lower UBHC level may be due to high temperatures developed in advancing the injection timing which causes earlier combustion.

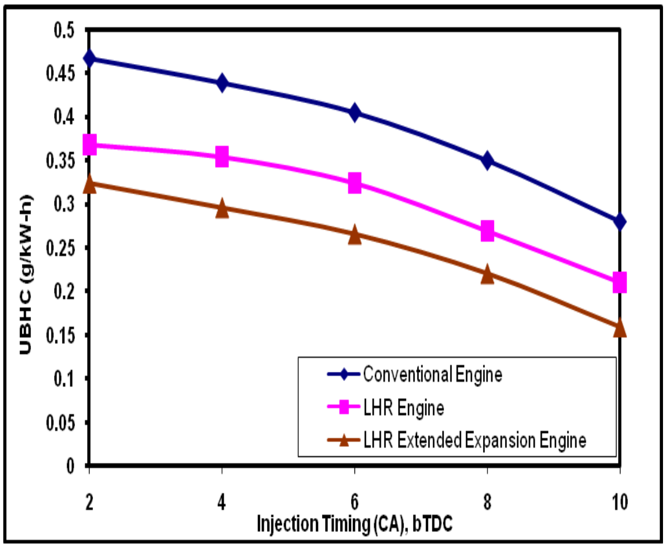

Fig.4 Comparison of UBHC for Conventional, LHR and LHR (EEE) engines for different Injection Timings.

C. Exhaust Gas Temperature

The Exhaust Gas Temperatures are mainly dependent on peak temperatures developed in the engine cylinder and heat transfer rate to cooling. In LHR Engine due to thermal coatings naturally the heat transfer rate to cooling water is reduced considerably. Hence the operating temperatures in LHR Engine will be higher, this leads to higher EGT. As the injection timing is advanced the start of combustion is earlier and peak temperatures achieved in lesser time may be the reason for increase in EGT in all the engines as noted from Fig5.

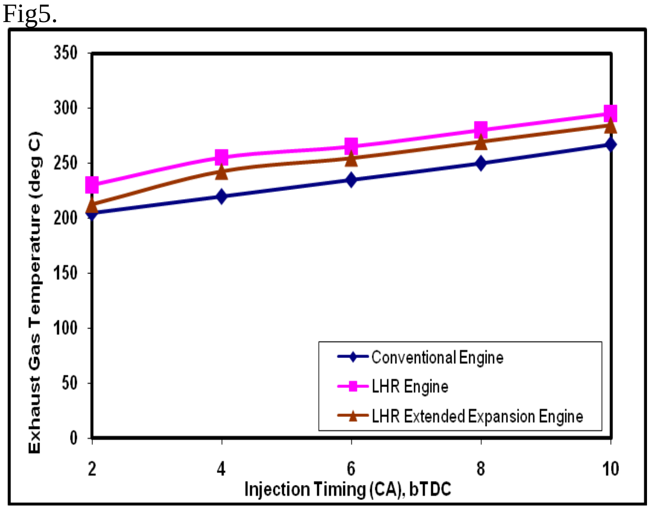

Fig. 5 Comparison of Exhaust Gas Temperature for Conventional, LHR and LHR (EEE) engines for different Injection Timings.

D. Carbon Monoxide

Carbon monoxide is the intermediate product in the combustion of hydrocarbon fuel so its emission results from incomplete combustion. CO emission greatly dependent on air-fuel ratio. The CO emission from conventional, LHR and LHR (EEE) engines for different injection timings are shown in Fig 6. It is observed from the figure that retarding the injection timing caused the increase of CO emission for all the engines.

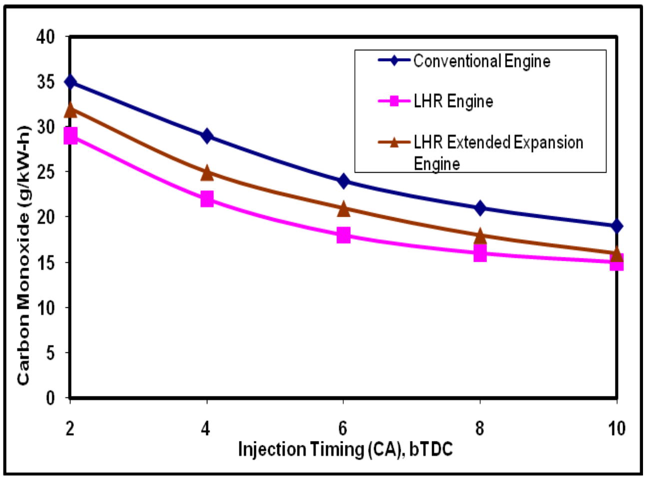

Fig.6 Comparison of Carbon Monoxide for Conventional, LHR and LHR (EEE) engines for different Injection Timings.

E. Smoke

The deficiency of oxygen locally in diesel engine cylinders leads to formation of smoke. As the air-fuel ratio decreases the oxygen deficiency decreases leading to the smoke formation. Advancing the injection timing has shown reduction in smoke in the exhaust. The earlier injection leads to higher temperatures during the expansion stroke and more time in which oxidation of soot particles occurs. Fig 7 shown smoke percentage variation against injection timings of conventional, LHR and LHR (EEE) engines.

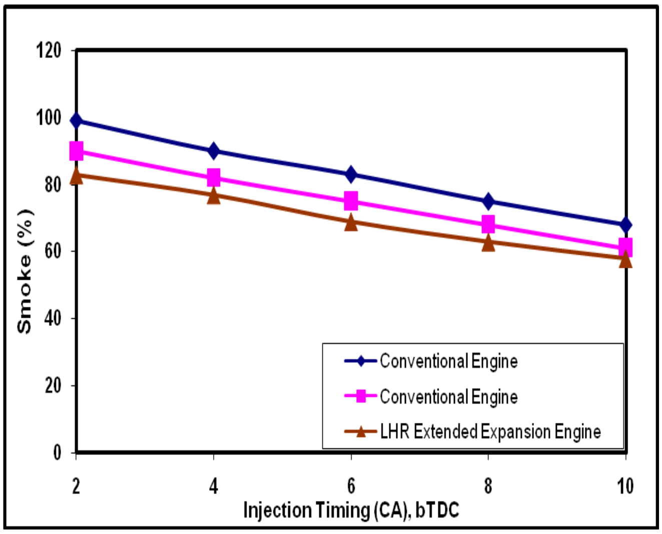

Fig.7 Comparison Of Smoke For Conventional, LHR And LHR (EEE) Engines For Different Injection Timings.

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IV. CONCLUSIONS

The experiments are conducted on conventional diesel engine in the beginning, later which is converted into LHR engine. The experimentation procedure is repeated on LHR engine. Then LHR engine is operated on Extended Expansion cycle by modifying the inlet cam. All the results of experiments mentioned above are reported and discussed below.

- As the cylinder temperatures achieved in LHR engine are high due to NO_x emission in the exhaust. The ability of the Extended Expansion Engine to maintain lower temperatures leads to lesser NO_x concentration level in the exhaust.
- As the injection timing is advanced the UBHC emission level are decreased due to earlier combustion.
- With the advancement in the injection timing the start of the combustion earlier achieving peak temperatures in lesser time may be the reason for increased EGT as the injection timing increases.
- Retarding the injection timing causes the increase of CO emission for all the engines. CO emission level in LHR engine is lowered compared to LHR Extended Expansion Engine and conventional engine for all the injection timings.
- Advancing injection timing resulted in reduction in smoke exhaust. Earlier injection leads to higher temperatures during the expansion stroke and due to more time available the oxidation of soot particles occurs. The LHR Extended Expansion Engine gives lower smoke level in exhaust than LHR and conventional engine.

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