Essay: EXPERIMENTAL SETUP OF LP EGR SYSTEM FOR NOx and PM EMISSION

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LP EGR loop is one of the method to further reduce NOx while maintaining PM Emissions at low level. When variable geometry turbine (VGT) get closed there are chances of higher boost pressure allowing a high rate of supplemental EGR. The study discusses about the influence of boost pressure and injection pressure on combustion which gives optimal pressures for each operating point in terms of NOx and PM Emissions. It also includes the study of increased boost pressure by closing VGT veins in LPL EGR. NOx PM trade off gets worst when compared to constant boost pressure for EGR at constant A/F ratio. Low pressure EGR is used by varying the EGR rate the gas flow through the turbine is unchanged. Higher boost pressure can be achieved

when VGT veins are closed which increases the dilution ratio while maintaining a suitable in-cylinder oxygen quantity for PM emissions. This is the main reason why LP EGR is mostly studied by manufactures for future automotive diesel engines. The study mainly focuses on NOx and PM Emission reduction by LP EGR loop.

The study is conducted on 2.0-liter water cooled HSDI diesel engine. The test setup and engine specification is shown in Figure 1 [3].

OPERATING POINTS AND RESULTS

The engine is equipped with the combination of HP EGR loop and LP EGR loop. The two operating conditions studied in this experiment are load and speed. The EGR results increases with the decrease in O2 concentration in inlet and decrease of boost pressure O2 of in-cylinder decreases. During the middle load operation, the load for above conditions, critical value of air rises. This increases the PM, CO, HC Emissions and specific fuel consumptions. This is the reason for these operating conditions NOx emission reduction is difficult.

Effect of Boost Pressure on NOx Emissions

Boost pressure can be increased by LP EGR loop by varying LP EGR rate. In this study for A and B operating points four level of boost pressure are studied which gave the optimal pressure in terms of NOx and PM Emissions. The boost pressure is increased by closing VGT veins.

A. Operating Point, A
Effect of boost pressure on varying EGR on NOx emissions for operating point A is shown in Figure 6[3]. For a given boost pressure the increase of EGR rate results in the decrease of EGR rate. There are two condition for which the NOx emissions are affected because of boost pressure. The first one is, the boost pressure increases results in higher in-cylinder oxygen quality that increases NO formation rate. Second is increase of in-cylinder trapped which results in decrease of local temperatures at particular flame temperature that control NOx formation.

B. Operating Point, B
Figure 7[3] shows the effect of boost pressure with varying dilution ratio on NOx emissions. Contrary to operating point A boost pressure increases at a given dilution ratio increases NOx emissions which shows there is no unique trend of NOx emission with varying boost pressure.

Effect of Injection Pressure on NOX Emission.

As the injection pressure increases there is much negative impact on NOx emissions for low dilution ratio and little impact at higher dilution ratio which is shown in Figure 12[3]. Often due to the increase in speed there is a rush of fuel entering the combustion chamber leading to increase in NOx emission. Also due to the rush of fuel entering the combustion chamber at higher rate the local combustion temperature increases leading to higher NOx emissions.

REVIEW 3:

DEVELOPMENT OF LOW PRESSURE LOOP EGR SYSTEM

From the above methods we know that LPL is an effective technique of reducing NOx emission and fuel consumption of diesel engines. When the system of LPL EGR is combined with NOx storage and reduction catalyst (NSR) further the emission levels can be lowered. Because of the change in air-fuel ratio due to EGR gas recirculation from either NOx reduction control or diesel particulate filter (DPF) regeneration, the issue of combustion fluctuations has to be overcome. The study explains about the reduction of combustion

fluctuations by developing LPL EGR control logic. Recirculation time needs to be estimated to control the combustion fluctuations. Initially recirculation delay is found, where it shows that recirculation delay becomes longer when the LPL EGR flow rate or engine speed is low. On the other hand, even if the engine speed changes, the delay was found to be proportional to the number of engine cycles. Recirculation delay was estimated by the model, which showed a good correlation with actual measurements.

EGR PERFORMANCE:

From the study 8.98% of total EGR rate is equal to 10.24% of conventional rate which is defined as a percentage of exhaust mas. NOx formation is effected by recirculation of exhaust gas into the engine intake in two ways. Firstly, there is a reduction in the peak combustion temperature due to reduced oxygen supply (main reason) and high heating capacity of exhaust gases (secondary reason) which results in lower NOx formation. Secondly, due to the mixing with hot exhaust it increases the inlet air temperature which increases the peak combustion temperature. At high engine load any amount of EGR results in some reduction of NOx.

NOx concentration reduction with application of EGR is shown in [1] figure 4. The road tailpipe concentration was back calculated using dilute exhaust measurement. This effect take place at low exhaust mass flow which accounts for 4.2% of total NOx removal efficiency. Now a day's trends being with increase EGR rate at low loads there are more chances of reduction in NOx. Certainly, in cooperating a valve would make such a system active. The two ways to improve the passive system are:
• At low loads shutting down the EGR flow.
• Removal of condensed water vapor increases the efficiency of EGR cooler.
The operating condition of EGR shown in one figure 5 [1] allows 35% of total NOx reduction by recirculating particulate free exhaust and maintain the key engine parameters. As per the study for 4% of NOx reduction per 1% of total EGR rate.

The two different line one being 12-foot-long truck exhaust while other is 6-foot line bus exhaust were tested with same pickup unit located downstream of main soot filter. The 6-foot line having the written point temperature 100℃ more than the 12- foot line which resulted in higher EGR pickup temperature. This is because the 12- foot line has 2 times larger heat transfer area. The 12 – foot line has a mass rate of 0.23% more than 6-foot line which is a substantial reduction considering mass rate of 1.5 to 3.5 % at a given speed.

At low load conditions increase in temperature can be achieved via active EGR rate control which allows larger amount of Gas being recirculated into engine intake. On DDC series 50 engine which is at full load steady state condition was experimented where both NO and NO2 were substantially reduced by EGR. Figure 8[1] shows reduction of NO2 concentration with EGR. NO emissions were lowered due to decrease in NO production during combustion. There was a slower oxidation of NO to NO2 because of reduced NO and O2 content in the exhaust. In the figure 9[1] effect of EGR on percentage of NO in total NOx is shown.

EMISSION RESULTS:

For the M11 Engine proposed EGR system allowed for 8.98% total mass recycle rate and there by reduced NOx by 35.1%. Apart from NOx total hydro carbons were reduced by 34.6% and total particulate emissions reduction due to soot filter was 84.9% and increase in CO is 2.9% relative to baseline engine. A fuel penalty of 3.2 was observed

For DDC Series 50 Engine proposed EGR system allowed for 14.9% total mass recycle rate and thereby reduce NOx by 40.1% (2.7% of NOX per 1% of EGR rate) with Total Particulate Matter reduction of 88.4%. Apart from NOx total hydro carbons were reduced by 60.2% and increase in CO is 10.8% relative to baseline engine. A fuel penalty of 2.3% was observed.

As many of the off road engines do not require sophisticated control passive LPL EGR will be the appropriate

NOx control solution because of this M11 engine was further tested at conditions of 370 HP @ 1800 RPM. The test result showed reduction of NOx- 42.3%(3.5% of NOx per 1% of EGR rate). The study leads to a conclusion that LPL system can exhibit a better fuel efficiency due to the following reasons:
• The proposed LPL EGR does not require an artificially created differential pressure.
• The proposed EGR allows for lower Engine inlet temperature.

In this study the main focus was on the advantages of proposed LPL EGR system when compared to conventional EGR system. It also showed the ways to improve NOx control and engine performance. NOx control can be done by:
• Improvement of the design line
• Improve fuel Injection strategy
• Enhance efficiency of EGR cooler that shows to use water cooler currently employed on various HP systems.
• At high Loads the recirculation rate without artificially enhanced EGR flow allows for effective NOx control.

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