Timed Turbulence Assistance in CI Engine Combustion for Fuel Economy and Lower Emissions

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Abstract

Objectives: This paper aims at improving fuel economy and lowering the smoke level of CI Engine. Methods/Analysis: In CI Engines smoky exhaust and sluggish after burning (burning after the end of injection) results due to incomplete combustion of the products cracked during rapid combustion and gradual combustion in locally over-rich regions. Turbulence improves mixture formation and accelerates after burning reducing smoke. A present study employing turbulence assistance approach aims at improving fuel economy and lowering the smoke level. Findings: While high-pressure secondary air is the turbulence provider, timing is achieved through microprocessor programming and related hardware. Timed turbulence closer to TDC helps in combustion and hence improved thermal efficiencies at all loads. Timed turbulence away from TDC during expansion accelerates ‘After burning’ and reduces ‘smoke emission’. Encouraging results of the experiments with single and twin injections per cycle are reported. Also, the timing of turbulence has been optimized. Applications/Improvements: Timed turbulence may be attempted in auxiliary diesel power plants and in combined gas and diesel power plants for fuel economy and lower emission.

Keywords: CI Engine, Emissions, Fuel Economy, Timed Turbulence

1. Introduction

Automobile emissions account for 20 to 30 percentages of air pollutants, altering the ecological balance. Diesel exhaust contains toxic and harmful gasses, particulate and soot. These cause several health disorders. Attempts to combat diesel engine emissions include modified engine design, component modification, after treatment, fuel reformation, fuel conditioning, use of additives, advanced injection technologies, alternate fuels, bio-diesel, blends, emulsions, turbocharging and supercharging. Recently various research on improving emissions and fuel economy has been undertaken.

Rapid combustion and gradual combustion in Compression Ignition (CI) engine are associated with thermal cracking of fuel. The cracked molecules contain a smaller number of carbon atoms. The reaction of cracked products is limited by the extent of oxygen availability. Due to widening the gap between cracking rate and oxygen supply pure carbon remains. The result is sluggish after burning (burning after an end of injection) and smoky exhaust arising out of incomplete combustion of the cracked products in locally over-rich regions. Turbulence improves mixture formation and accelerates ‘after burning’ reducing smoke.

Secondary air jet admission is employed to provide turbulence. Single air injection or twin air injections per cycle during expansion were tried using microprocessor controlled solenoid valve. Effect of timing, the turbulence on fuel economy (brake thermal efficiency) and smoke density have been studied in the present work and optimized.

2. Methods and Materials

2.1 Turbulence Assistance in CI Engine

Fuel is usually injected starting around 10° to 20° before Top Dead Centre (bTDC) and terminated at about 10°
after Top Dead Centre (aTDC) allowing only a small duration of about 30° crank rotation (0.0059 seconds at 850 rpm and still smaller fraction at high speeds) around TDC for combustion to take place. Mixing with air, vaporization and burning all should be over in a very short duration. Hence incomplete combustion of cracked products causes smoky exhaust.

Turbulence means disturbance that is violent and uneven movement of air or fluid. If one fluid is super imposed over the other or the same then turbulence is created. While inherent turbulence depends on the design of manifold passage, combustion chamber and engine speed, one created using external sources depends on fluid-jet interaction.

2.2 Microprocessor (µp) based Secondary Air Admission

Compressed air jet at 7 bar was used to create turbulence during expansion in the cylinder. Electronic circuit and microprocessor programming were used to time the air admission. The electronic circuit consists of sensing, ON-OFF, µp kit and solenoid valve.

A glomming lamp and a LDR transistor are kept on either side of the disk (Galvanized iron disk with holes at 10° intervals mounted on crankshaft). When the lamp, light and LDR align each other through a specified disk hole (specific crank angle), the microprocessor is signaled and on/off circuit is directed to open the solenoid valve to inject air into the cylinder. Microprocessor program and the hardware keep the solenoid valve closed at all other instants of the cycle.

Load and emission tests were carried out on Field Marshall 4 stroke single cylinder water cooled vertical diesel engine of rating 5.88 KW at 850 rpm fitted with mechanical brake drum loading arrangement. The experimental setup is shown in Figure 1.

Preliminary trials were carried out to ascertain the suitability of 7 bar air pressure for the various instants 10° bTDC TO 60° aTDC of air admission over a wide range of load conditions. Nevertheless this pressure has been reported as optimum in an earlier study.

Figure 2. Brake thermal efficiency vs. actual percentage load.

3. Results and Discussion

In Table 1, the results of six different load tests (4 cases of single injection and 2 cases of twin injections) carried out with turbulence assistance at varying instants through 7 bar secondary air are compared with results of conventional operation without turbulence assistance. Smoke
levels were measured in Hartridge Smoke Units (HSU) using Netal make smoke meter.

![Figure 3. Smoke density vs actual percentage load.](image)

As found in Table 1 and Figures 2,3, turbulence assistance through microprocessor timed high pressure external air admission during expansion (single or twin) at all crank angles tried yield higher thermal efficiencies and lower smoke levels compared to the results of conventional operation without turbulence assistance.

Among the six trials higher thermal efficiencies and lower smoke densities at all loads are yielded with single time air admission at 10° aTDC, twin admissions at 10° aTDC and 40° aTDC. Among the four cases of single air injections 10° aTDC timing gave higher efficiencies and 40° aTDC lower emissions. Among two cases of twin injections 10° aTDC and 40° aTDC combination gave both higher efficiencies and lower emissions.

4. Conclusion

Timed turbulence closer to TDC (10° aTDC) helps in combustion and hence improved thermal efficiencies at all loads. Timed turbulence away from TDC (40° aTDC) during expansion accelerates ‘After burning’ and reduces ‘smoke emission’. Twin injection at 10° aTDC and 40° aTDC is optimized for lower smoke emissions and thermal efficiency much closer to the highest one. Hence timed turbulence may be attempted in auxiliary diesel power plants and in combined gas and diesel power plants for fuel economy and lower emission.

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6. References

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