Emission Control Technologies in Compression Ignition Engines

The need to control emissions comes as a result of new standards proposed by the EPA (Environmental Protection Agency). The Draft RIA (Draft Regulatory Impact Analysis) provides economical, technical, and environmental analysis for compression ignition engine (Jackson, 2012). The anticipated reduction is meant to reduce emission of gases that have a negative impact on the environment, which includes hydrocarbons (HC), oxides of Nitrogen (NOx), particulate matter (PM) and carbon monoxide (CO).

In 2002, the regulatory board adopted verification procedure that involved in-Use Strategies to help reduce emissions from diesel engines (Jackson, 2012). The verification procedures defined a clear process, which manufacturers handling emission control equipments can follow, and demonstrate reduction capabilities in their control technologies. There are several technologies that are currently available and useful in controlling diesel particulate matter from portable diesel engines Some examples of control technologies that can be employed includes fuel oxidation catalyst, fuel particulate filter, selective catalyst reduction system, exhaust gas recirculation, alternative diesel fuel systems, and fuel additives (Mahgoub, Sulaiman & Karim, 2012). Majority of these methods are currently being verified by the ARB portable diesel engines and on-road vehicles. Currently, the only technology that has been verified by ARB for off-road engine use is the diesel oxidation catalyst.

Fuel particulate filters reduce fuel PM emissions through the process of filtration. This technology has demonstrated great efficiency, and has been used to reduce diesel PM by almost 90% (Mahgoub, Sulaiman & Karim, 2012). There are several classes for fuel particulate filters, which include active, passive, and flow-through.

Passive fuel particulate filters make use of catalytic material that enables the trapped PM to be oxidized or burned-off at lower temperatures. In order for this system to be effective, the exhaust must maintain a minimum temperature when the engine is operating for certain duration (Mohanamurugan & Sendilvelan, 2010). Otherwise, there will be accumulation of diesel or fuel PM in the filter causing operation problems. There are several fuel particulate filters that have been verified for on-road purposes. However, there are no fuel particulte filters that have been verified for application on the portable engines.

Active fuel particulate filter function the same as passive fuel filters but differ in the sense that they oxidize by using heat from the engine exhaust. Flow through the filter (FTF) technology is a current technology that is being employed to reduce PM emissions. In this method, the exhaust is allowed to move through certain media, such as wire mesh with high density causing turbulent flow conditions (Mahgoub, Sulaiman & Karim, 2012).

Various emission control strategies have been employed on land-based nonroad, locomotives, and on-highway engines. The strategies used to reduce exhaust emission include better fuel control, combustion optimization, exhaust gas recirculation, after-treatment, and improved charge air characteristic.

**Combustion Optimization**

There are several parameters present in the combustion chamber of compression ignition engines that affect its emission and efficiency. These parameters include combustion chamber geometry, injection timing, valve timing, turbulence, compression ratio, fuel spray geometry and rate, injection pressure, peak cylinder temperature and pressure, and intake air pressure and temperature (Mohanamurugan & Sendilvelan, 2010). The strategies employed in controlling emissions have proved to be complex because positive influence on one of the polutants causes a negative influence on another pollutant. For example, reduction of NOx using charge air cooling increase PM. Therefore, these complexities require the manufacturers to integrate all the variable present for proper optimization of the systems to meet the proposed standards.

**Timing Retard**

The effect of ejecting timing on performance and emissions plays a key role in creation of vital strategies for controlling emissions. Retard timing is most likely applied at cruising speeds where compression ignition engines take most of their operating time (Jianyong et al, 2014). NOx emissions are reduced as a result of shortened premixed burning phase and lowered pressure. Timing retard raises CO, HC and fuel consumption, but because the end of injection delays in the combustion stroke, the time required to extract energy from combustion of fuel is reduced and cylinder pressure and temperature reduces for incomplete oxidation of PM (Mohanamurugan & Sendilvelan, 2010). One method that can be employed to offset this trend is using high injection pressure.

**Combustion Chamber Geometry**

Many manufacturers are modifying combustion chamber in order to achieve emission reduction (Jianyong et al, 2014). However, according to EPA, various additional changes can be employed to improve emission control. The parameter under investigation includes (1) the location of injection and the shape of the chamber (2) compression ratio and (3) reduced crevice volume. There are efforts to redesign the general shape of the combustion chamber and create suitable location of fuel injection for nonroad and highway engines. The main focus in these initiative is to optimize the relative motion of air and the ejected fuel in order to limit the formation of PM and NOx. Careful consideration must be given to piston crown design for proper matching with injection spray pattern and sufficient pressure for optimal emission behavior. Air motion optimization can be achieved through optimizing the radius of combustion bowl, reentrant piston design, the angle of reentrant lip, and the ratio of bowl depth to bowl diameter (Mohanamurugan & Sendilvelan, 2010). Alternatively, high pressure injection system can be employed to reduce the need for turbulent in-cylinder charge air motion. However, the main challenge with the high pressure system is durability.

Reducing the crevice volume is also expected to reduce HC and PM emission (Mahgoub, Sulaiman & Karim, 2012). This can be achieved by moving the position of top piston ring near the apex of the piston. However, the challenge associated with this method is the high cost expected as a result of modification required to achieve appropriate cooling of the engine.

Another engine design parameter that influences that rate of emission is the compression ratio. High compression ratio is expected to reduce cold start PM and significantly improve on fuel economy (Mohanamurugan & Sendilvelan, 2010). However, the main challenge associated with this method is the chances of increasing NOx. Increased compression ratio can be achieved through increasing piston pin-to-crown length or redesigning the piston crown.

**Swirl**

Inducing swirl or increasing intake air turbulence in the combustion chamber improves emission reduction significantly. This reduces PM by ensuring proper mixing of fuel and air in the combustion chamber (Mahgoub, Sulaiman & Karim, 2012). Manufactures are inducing additional turbulence through reentrant piston design in which the top part of the piston is cut out to enable easy flow of air motion and fuel injection in the piston’s small cavity.

References

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