A Review on Reducing Emissions in CI Engines by using Porous Medium

F. Justin Dhiraviam[1] M. Naveen Kumar[2] C. Prakash[3] R. Sabari Karthick[4] M. Surya Prakash[5]
[1]Assistant Professor [2,3,4,5]UG Scholar
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Sri Eshwar College of Engineering,Coimbatore-641202, India

Abstract— The present heterogeneous combustion engine results in incomplete combustion and uneven heat distribution of the engine cylinder. This results in high Nox formation, CO and unburned hydrocarbon emissions (UHC).The emissions can only be improved by catalytic treatments but it results in a high cost. Therefore, we have introduced Porous Medium (PM) to overcome this above problem. The main objective of using porous medium in IC engines is to achieve homogeneous combustion, it leads to lean burn combustion due to increased heat transfer co efficient ,high heat capacity and large surface area of porous medium .So that the temperature inside the cylinder decreases resulting in lower Nox and Co formation.

Key words: Porous Medium, Homogeneous Combustion, Diesel Fuel Spray, Fuel Penetration, Multi-Split Effect, Vaporization

I. Introduction

Durst and Weclasfirstly proposed the concept of the PM engine based on the PM combustion technique. They performed a systematic experimental study on a test engine, which was a modified diesel engine by inserting a silicon monocarbide (SiC) PM into the cylinder head between the intake and exhaust valves. Fuel was injected into the PM volume, and consequently, all combustion events, i.e. fuel vaporization, fuel air mixture formation and homogenization, internal heat recuperation, as well as combustion reactions occurred inside the PM. Their results demonstrated many attractive characteristics of the PM engine in comparison with the conventional one, such as very low emissions, high cycle efficiency and low combustion noise. The measured NOx and CO emissions were found to be significantly reduced to a very low level compared with conventional engine. Meanwhile, there is a noticeable reduction in soot formation.[1]

II. Porous medium

Porous media combustion (PMC), also known as filtration combustion, pertains to the heterogeneous interaction between two different media, usually a solid and a gas. The theory of filtration combustion involves a new type of flame with exothermic chemical transformation during fluid motion in a porous matrix. In the PMC terminology, a porous medium (PM) is defined as a solid medium with interconnected pores (high permeability), available as either a packed bed of discrete solids (mainly ceramic material or metal) or foam. [2]

III. Types of porous medium

Heat conductivity of porous medium (PM) is highly depend on the type of material. Since the concept depends on the high temperature resistant porous material, so we need to identify and survey about such porous materials. Various types of porous materials have been identified are silicon carbide (Sic), aluminum oxide (Al2o3), zirconium oxide (ZrO2). However, they possess outstanding properties like thermal shock, mechanical strength and heat transfer capability. Solid Zirconia present a highest temperature resistance which ranges up to 2300 0C. Heat conductivity of solid Zirconia is hardly temperature dependent and in the range of 2W/ (m K) to 5 W/ (m K). When compare to the properties that we have mentioned above, we came up with zirconium oxide (Zr02) to this project which has high heat conductivity and also have high mechanical properties. [3]

IV. Methodology

PM-Engine may be classified with respect to the heat recuperation are as follows

- Engine with periodic contact between PM and working gas in cylinder (closed chamber).
- Engine with permanent contact between PM and working gas in cylinder (open chamber).On the other hand, possible positioning of the PM combustion chamber in engine can be used to design different engines.

- Cylinder head (PM is stationary).
- Cylinder (PM is stationary).
- Piston (PM moves with piston).

One of the most interesting features of PM-engine is its multi-fuel performance. Independently of the fuel used, this engine is a self-ignition engine characterized by its 3D-thermal ignition in porous medium. Finally, the PM-engine concept may be applied to both two- and four-stroke cycles. [3]

V. Homogeneous combustion

Homogeneous combustion in an IC engine is defined as a process characterized by a 3Dignition of the homogeneous charge with simultaneous-volumetric-combustion, hence, ensuring a homogeneous temperature field. When the temperature of porous material is equal to the ignition temperature that is when it is called as homogeneous combustion. [4]

VI. Principle

The working principle of this process is by injecting fuel into the porous medium volume and then consequently all the events i.e. fuel vaporization, air-fuel mixture formation and homogenization as well as combustion reactions occurred inside the porous medium in a fast and complete manner. The results shows that when compare to the conventional one such as low emissions, high cycle efficiency and low combustion noise has been noticed. The presence of porous medium can absorb the reaction heat in the local high temperature to reduce the peak temperature so that less Nox is reduced when compare to the conventional one and also there is a significant reduction in soot formation. This results in achieving homogeneous combustion process. The fuel injection timing is also a key factor which plays a vital role in auto ignition temperature. Porous medium will act as a heat storage as well as exchange function. During the combustion process, it stores some of the enthalpy in form of heat. During next cycle enthalpy is transferred from porous medium again to heat up the air in the cylinder. [4]

VII. EQUIVALENCE RATIO

Equivalence ratio is the ratio of actual air-fuel to the stoichiometric air-fuel ratio. With increasing in equivalence ratio HC concentrations are reduced, while the Nox and CO increased. This is mainly due to the raised combustion temperature with the more fuel burned. For equivalence ratio 0.07, the gas temperature rises faster and higher before combustion and also in early part of combustion at lower porosity (e=0.7) than at higher porosity, because the porous medium can heat up the gas more easily (with less amount of gas in pores).this results in higher gas temperature at porosity facilitates combustion. This leads to more complete combustion. [5]

VIII. POROUS STRUCTURE

The most important factor that determines whether combustion process can take place inside a porous structure is its critical pore size. If the pore size is smaller than this critical dimension, the flame is always quenched. However, flame can propagate inside the PM with the pore size exceeding the critical dimension. In all cases, flame propagation within all kinds of PM is realized. Therefore, the pore size of all kinds of PM is larger than the quenching distance under the specified flow conditions. The difference in the number of pores and pore diameter causes changes in the volumetric heat transfer coefficient as well as the dispersion effect of the PM. Increasing pore diameter yields a decrease in the volumetric heat transfer coefficient and an increasein the dispersion effect. [6]

IX. NO_X EMISSIONS REDUCTION TECHNIQUES

The heat transfer between solid and gas phase in the porous medium (PM) is directly affected by engine speed, while it also reduce the former heat in the engine combustion and enthalpy is transferred from the solid phase back to the gas phase in the porous medium(PM) at the same time.[7]

The volumetric heat transfer coefficient was determined, and it showed strong dependence on the mean pore diameter. As the pore diameter increased the volumetric heat transfer coefficient decreased. The average heat transfer coefficient was nearly constant over the time period during which data were taken. [8]

X. MIXATION PROCESS

The multi-jet splitting effect is the reason for wide spatial spreading of the impinging diesel spray. They also reported significantly reduction in spray axial penetration and velocity after interacting with PM. Their results showed that multi-jets are produced after interaction with ceramic PM and the fuel reflection from PM surface because of closed pores is significant. [9]

XI. INFLUENCE IN CHAMBER PRESSURE

Chamber pressure plays significant role on the diesel spray cone angle. It can be easily seen that the higher injection pressure and higher chamber pressure led to bigger spray cone angle. [9]

XII. INFLUENCE IN CONE ANGLE

When the time of fuel distribution inside the porous medium (PM) structure, the fuel propagation is different when at the time of atmospheric pressure 5 and cone angle 600 after injection starts. When changing the cone angle from 600 to 920, length of axial penetration is greatly reduced where as radial jet propagation is greatly increases results in homogeneous formation [10]

XIII. DIFFERENT PHASES OF JET INTERACTION

There are four characteristic phases of liquid-jet interaction with the cold porous medium.
Phase A: liquid outlet from the nozzle and free jet Formation.
Phase B: jet interaction with PM interface.
Phase C: liquid distribution throughout the PM Volume.
Phase D: liquid leaving the PM volume.

In this phase, the jet is distributed (propagates) throughout the PM volume, and this process is characterized by a wide jet spreading (self-homogenization) in the PM Volume. This effect is related to a multijet splitting. The multijet splitting is a result of jet interaction with a large number of pore junctions (walls) present in the PM volume. [11]

Diesel combustion is mainly considered as diffusion combustion however it consist of premixed and diffusion phase, controlled by a fuel–air mixing process. Premixed phase of combustion occurs before the start of diffusion combustion. It plays a significant role in combustion process. Premixed combustion greatly influenced by the engine speed, load and injection process, mainly the quantity of fuel injected in cylinder during the ignition delay. The diffusion phase is governed by the turbulent mixing of air and fuel. The in-cylinder turbulence resulting from air motion and also fuel jet induced turbulence, which is predominant in modern high pressure injection system is used in modern engine. [12]

XIV. INFLUENCE OF EXCESS AIR RATIO

When the excess air ratios increase from 1.12 to 1.42 that the flame moves away from the grate and simultaneously toward the first row. The premixed gas inlet velocity increases, and the content of the fuel decreases when increasing the excess air ratio at a constant firing rate. [13]

XV. INFLUENCE OF INITIAL TEMPERATURE OF POROUS MEDIUM

The PM temperature is a dominating parameter determining the auto-ignition in the PM zone, combustion cannot occur in the PM zone or in the cylinder zone when the initial PM temperature is lower than 900 K. At 1000 K, the combustion occurs in the PM zone, however, ignition in the cylinder zone still could not be realized. Only with farther increase in temperature auto-ignition in both zones can succeed. The calculation indicates that the higher the initial PM temperature is, the easier the auto-ignition takes place, at the same time more Nox emission will be produced. [14]

In porous medium (PM), the UHC are drastically reduced by very fast and complete vaporization of fuel injected into the porous medium (PM) and also by complete combustion. The following are the two main factors responsible for eliminating UHC formation that is over mixing (over-leaning) and under-mixing (over-riching).the level of these emissions varies strongly with the operating conditions(engine load) and also the fuel accumulates into the crevice volume results in unburned hydrocarbon(UHC).This leads to incomplete and soot formation.[15]Large amount of heat are released from the condenser for the same input.This heat helps in winter seasons inside the conditioned space[16] Torque required to open the valve in the fluid system needs some separate external mechanical equipment for easier the operation of valve[17].Reducing the detonation by decreasing inlet temperature of air to engine through intercooler. Power and torque have been increased with the increase in mass flow rate of flowing air [18].

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