Study of Effect of Porous Media Combustion Chamber on Diesel Engine Performance and Emission: Technical Review

Amratbhai B. Patel
P.G. Student, Mechanical Dept.
L.D.College of Engineering,
Ahmedabad, India.

Prof. V. R. Patel
Assi. Professor in Automobile Dept.
Govt. Engineering College,
Rajkot, India.

Ashish M. Ambaliya
P.G. Student, Mechanical Dept.
L.D.College of Engineering,
Ahmedabad, India.

Abstract- **This paper summarizes the knowledge concerning porous media combustion techniques as applied in engines. The one important reasons of this review is to introduce readers about knowledge for porous media application in internal combustion engine. Porous Medium (PM) as a heat reactor in diesel engine has been considered as a promising concept to approach a near-zero emission system. It takes full advantage of PM geometry and material characteristics to perform homogeneous combustion, therefore reduces significantly emission under all operational conditions.**

Keyword—Ceramic Porous Foam, Diesel Engine, Silicon Carbide (Sic), PM Chamber.

1. INTRODUCTION

Homogeneous charge and compression ignition (HCCI) is one of the most attractive combustion modes for automotive engines to achieve both high efficiency and low NOx and particulate emissions. Despite many advantageous features of the HCCI combustion, it still fronts some challenges including higher HC and CO emissions and expanding operating range, as no external means are used to ignite the mixture, it is especially difficult to control the combustion processes inside the engine. Future internal combustion (IC) engine will be characterized by nearly- zero emissions level (for both gaseous and particulate matter components) under possible lowest fuel consumption permitted at all operational conditions. In this respect, the new concept of the so called porous medium (PM) Engine, based on the regenerative or super-adiabatic combustion in a porous medium, offers new ways in dealing with these problems. Recently, the PM engine has received attention from numerous researchers because of its potential for producing homogeneous mixtures and reducing NOx and soot emissions [13].

Development of porous burners has been encouraged by lower emission standards in recent years. As a burner of liquid fuel, porous medium is also an efficient evaporator. Combination of large heat capacity of the porous material, large specific surface area with excellent heat transfer in PM volume makes the fuel droplets vaporization very fast and complete. The collision of the fuel droplets within the complex porous structure contributes to very effective mixture formation and homogenization, which ensures a homogeneous combustion in the PM volume. Liquid vaporizing combustion in porous medium burner has fine flame stability and characteristic of low emission, which has been proved by experimental and numerical research [13].

2. MATERIALS USED FOR POROUS COMBUSTION CHAMBER

Features and requirements of porous ceramic Materials for homogeneous combustion in engine applications

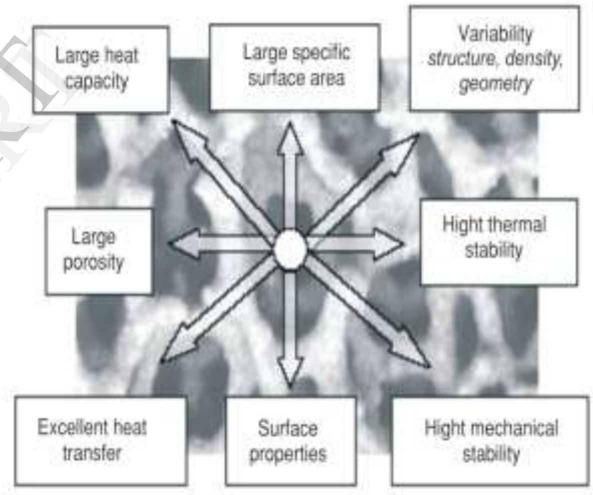

Figure 1. Main features of porous ceramic structures to support individual engine processes (Courtesy: Miroslaw Weclas [14])

Requirements of ceramic materials for engine applications

(1) Compactness: In automotive engines, the space inside the combustion chamber is limited. Therefore, the ceramic structure that is going to be introduced should be compact in size.

(2) Power turndown: The heat source has to allow the complete process to be operated in a wide range of power outputs.

(3) Multi-fuel capacity: For automotive applications, it is essential that the engine must be capable of running with a wide range of fuels such as gasoline, natural gas, hydrogen or even rapeseed oil, industrial gas oil, and rich methyl esters. Hence, it is essential that the porous ceramic structure must admit the burning of different gaseous and liquid fuels with consistent high performance.

(4) Emission output: The emission output of the resultant homogeneous combustion owing to the porous ceramic structure has to be very low over the complete dynamic power range and for a diversity of fuels [14].

Types of porous medium

Silicon Carbide (Sic), Al_2O_3 Mixture, ZrO_2 Foam, Ni Cr Al Foam, High Density Wire Packed.

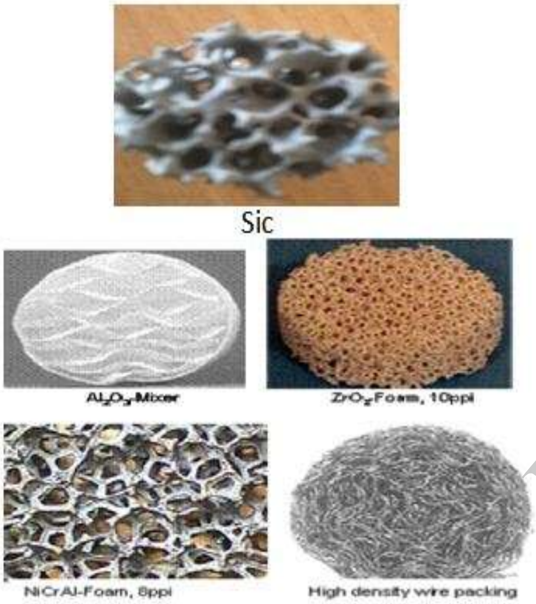

Figure 2 Types of porous medium [1]

Principle and theoretical model of the PM Engine.

The PM engine is here defined as an internal combustion engine with a highly porous medium chamber mounted on the cylinder head (Fig. 1). The PM chamber is thermally isolated from the head walls and equipped with a valve permitting a periodic contact between the PM-chamber and the cylinder volume.

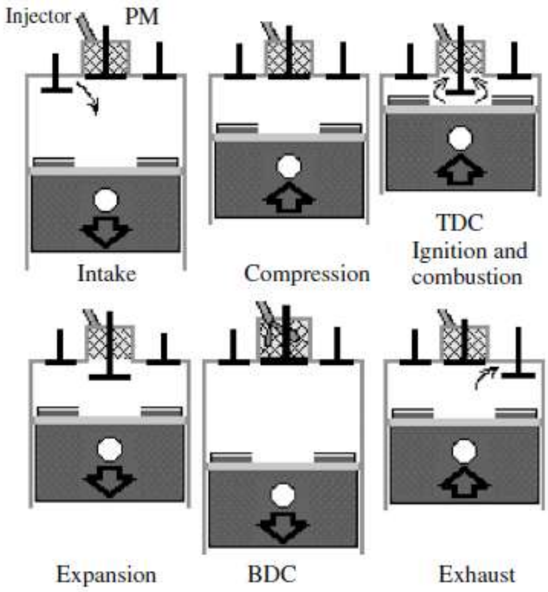

Fig 3. Principle of the PM engine proposed by Durst.

Fig. 3 shows the complete working cycle of the PM engine advanced by Durst [11], and the view of the PM engine head with SiC reactor is shown in Fig. 2. Near the TDC the intake valve opens and flesh air flows into the cylinder, the valve of the PM-chamber keeps closed and the PM volume containing fuel vapor has no contact with the flesh air during intake and compression stokes. At the end of compression the valve of the PM-chamber opens and the compressed air flows from the cylinder into the hot PM-volume, generating a highly turbulent flow condition. As a result, very fast mixing of the vaporized fuel and compressed air occurs in the PM chamber. The mixture receives enough heat from the hot PM and is then auto-ignited in the entire PM-volume. The resulting flame passes through the porous matrix with a high velocity and a complete combustion takes place in the PM- chamber. During the combustion process, the heat being released is absorbed by both working gas and PM-volume. The valve of the PM-chamber remains open until the end of the expansion stroke and fuel is then injected in the PM-volume after closing the valve. The process of vaporization in PM-volume continues throughout exhaust, intake and compression strokes. The large specific PM surface area and excellent heat transfer in the PM-volume as well as the long time available for fuel vaporization make the liquid fuel vaporization very fast and complete. The cylinder and the PM-chamber keep separated during the exhaust processes, which is same with conventional DI engines.

The valve of the PM-chamber switches on and off one time each cycle and the PM-chamber periodically contacts with working fluid. The PM absorbs heat during combustion period and releases it at the end of the next compression process. The formation of homogeneous mixture and 3D-thermal self-ignition in the PM-volume create a realizable condition for homogeneous combustion, which is almost independent of the engine load. Furthermore, the heat recuperation in PM may be used for heating up the compressed air and controlling the combustion temperature level.

Effect of Porous Media Combustion Chamber on Diesel Engine Performance and Emission.

Prof.Dr.-Ing. Miroslaw Weclash[1] described the application of a highly porous open cell structures to internal combustion engines for supporting mixture formation and combustion processes. Porous structures, materials and their properties for engine application. Also described application to a high temperature combustion processes, applications of PM-technology to mixture formation and combustion in IC engines: New combustion system with mixture formation and homogeneous combustion in PM-volume, so-called *"PM-engine concept"*

Zhiguo Zhao et. al.[5] studied on working process and some influential factors for the realization of compression ignition of a PM engine fuelled with Isooctane. In the case of periodic contact between the engine cylinder and the PM, using an improved version of CFD code KIVA-3, under the conditions of compression ratio as 13.6 and equivalence ratio as 0.278, compression ignition can be realized in the PM engine fuelled with liquid fuel. Homogeneous mixture formation and very short combustion period are the two special characteristics of the PM engine. Initial PM temperature is a key factor in determining the onset of the compression ignition in the PM engine. Variation in PM structure significantly affects the heat transfer between the solid and gas phase and dispersion effect of the PM. As far as the PM engine with periodic contact is concerned, PM with more intensity of heat transfer should be adopted. Optimal valve opening timing is necessary for the normal operating of the PM engine.

Hongsheng Liu et.al.[6], developed an ideal thermodynamic model of the PM heat regeneration cycle in PM engine and introduced briefly working processes of PM engine.

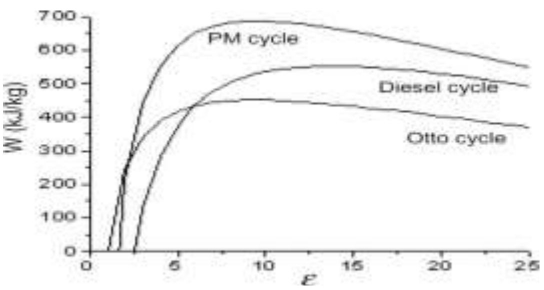

Figure 4 Comparison of the net- work output for Otto, Diesel and PM heat regeneration cycle

The influences of the expansion ratio, initial temperature and limited temperature on the net- work output and efficiency are as shown in figures no. 5,6,7,8 and 9. The PM heat regenerative cycle of the PM engine in comparison to Otto cycle and Diesel cycle shows that PM heat regenerative cycle can improve net- work output greatly with little drop of efficiency.

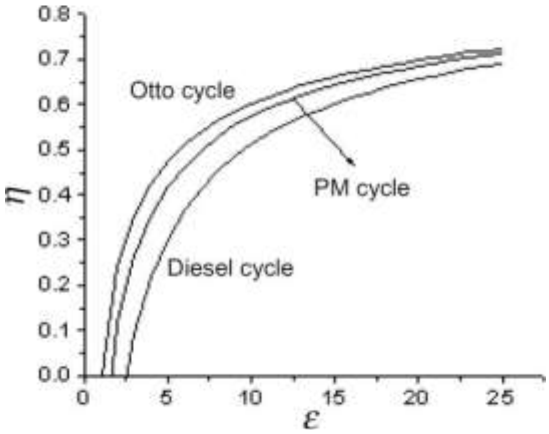

Figure 5 Comparison of efficiency for Otto, Diesel and PM heat regeneration cycle. [6]

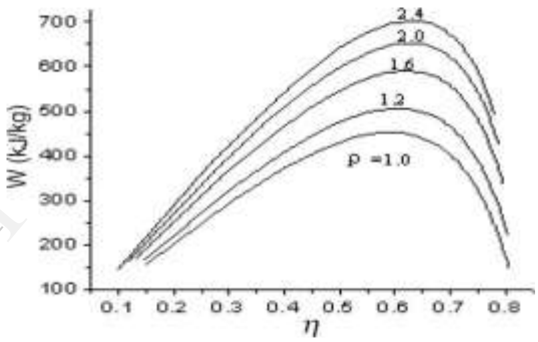

Figure 6 Influence of q on the net- work output versus efficiency characteristic. [6]

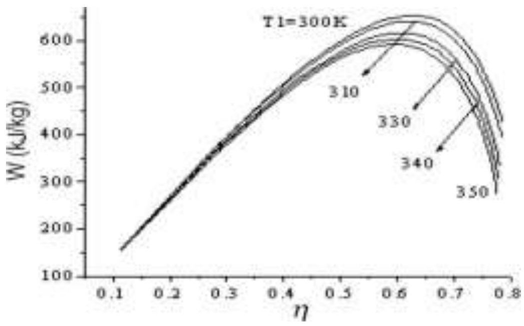

Figure 7 Influence of it T1 on the net- work output versus efficiency characteristic. [6]

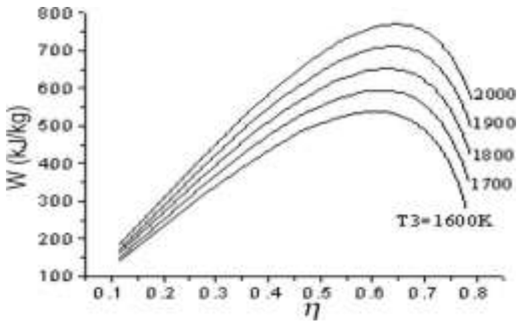

Figure 8 Influence of T3 on the net- work output versus efficiency characteristic. [6]

Dhale, A. A., *et al* [14] have taken experimental reading on single cylinder, four stroke, high speed direct injection diesel engine, water cooled, bore 80 mm, stroke 110 mm, 5 HP and compression ratio 16:1 and performance of the engine is recorded by calculating various parameters like efficiency, fuel consumption, plotting *P-V*, *T-S* diagrams, and recording soot formation initially without PM, as shown in photograph.

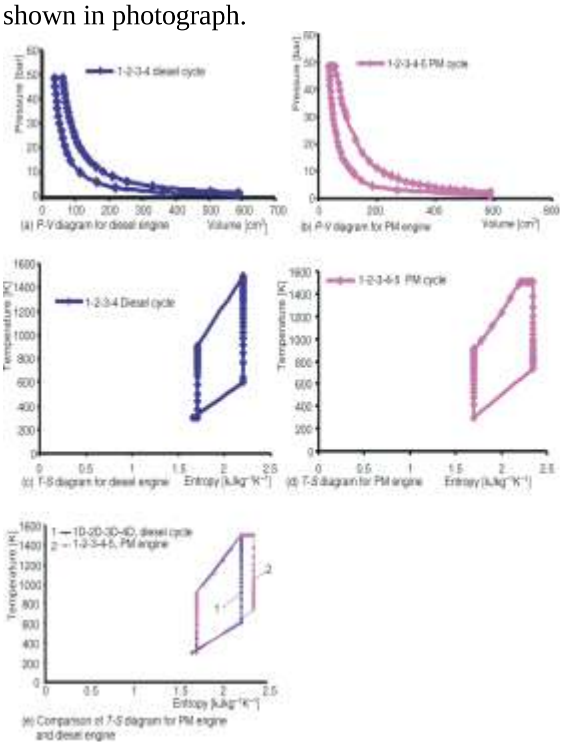

Figure 8(a)-(e). Comparison of engine cycles characteristics (color image see on our website)

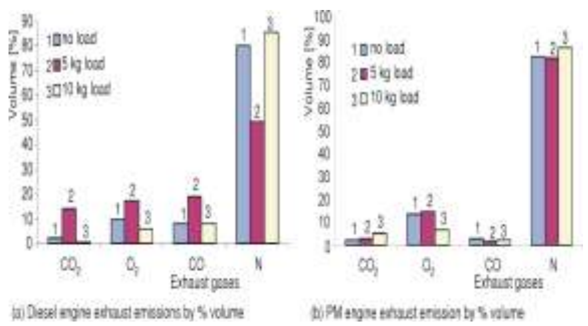

Figure 9(a) and (b). Comparison of exhaust emissions

1. CONCLUSION

From above literature review it is clear that efficiency of diesel engine can be increased from 50% to 60% by using pm combustion chamber. Also from study of p-v and T-S diagram the net- work output is also increased by using porous combustion chamber. At no load condition there is no change in volume of exhaust gas CO and CO_2 but at 5kg load the volume of CO_2 is reduced from 12 % to 2 % volume and at 10kg load volume of CO_2 reduced from 10 % to 3 %. At 5kg load volume of CO is reduced from 20% to 1% and at 10 kg load CO is reduced from 8% to 2% volume.

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