IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

THE IMPACT OF POROUS MEDIA COMBUSTION CHAMBERS ON DIESEL ENGINE PERFORMANCE AND EMISSIONS: A TECHNICAL ANALYSIS

[1]Mr.Bhaveshkumar Variya, [2]Mr. Narendra Dalia, [3]Mr.Dharmang Patel

[1]PG Student, [2]Ass. Professor, [3]Ass. Professor

[123]Department of Mechanical Engineering,

[123]Bhagwan Mahavir College of Engineering and Technology, Surat

Abstract: This paper provides an overview of porous media combustion techniques utilized in engines. A key objective of this review is to acquaint readers with the utilization of porous media in internal combustion engines. Porous Medium (PM) functioning as a heat reactor in diesel engines has emerged as a promising concept toward achieving near-zero emissions. Leveraging the geometric and material properties of PM, it enables homogeneous combustion, thereby substantially reducing emissions across various operational scenarios.

I. Introduction

Homogeneous Charge Compression Ignition (HCCI) engines show promise for low emission and high efficiency, but limitations remain:

- Increased hydrocarbon (HC) and carbon monoxide (CO) emissions due to lack of external ignition control.
- Restricted operating range due to challenges in controlling combustion across various engine loads and speeds.

Future internal combustion (IC) engines necessitate near-zero emissions (both gaseous and particulate) with minimized fuel consumption across all operating conditions. Porous medium (PM) engines emerge as a groundbreaking solution, employing regenerative or super-adiabatic combustion within a porous medium to address HCCI limitations. Recent research suggests PM engines hold potential for:

- Achieving homogeneous mixtures through the porous medium, promoting complete fuel-air mixing.
- Lowering NOx and soot emissions due to the combustion process within the porous medium.

The growing interest in PM engines stems from their potential to surpass HCCI engine limitations, paving the way for cleaner and more efficient future IC engines.

II. MATERIALS USED FOR POROUS COMBUSTION CHAMBER

Characteristics and Prerequisites of Porous Ceramic Materials for Uniform Combustion in Engine Utilizations

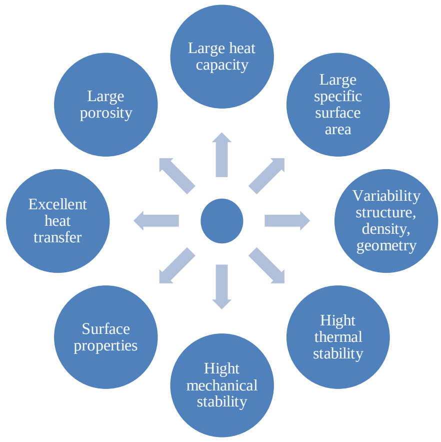

Figure 1. Main features of porous ceramic structures to support individual engine processes

III. Essential Properties of Ceramics for Engine Applications

For successful implementation in engines, ceramic materials must meet several key requirements:

1. **Compactness:** Due to limited space within the engine combustion chamber, the ceramic structure needs to be compact.
2. **Power Turndown:** The engine needs to operate efficiently across a wide range of power outputs. The ceramic material should be compatible with this variable heat source.
3. **Multi-Fuel Capability:** Modern engines should be able to run on various fuels like gasoline, natural gas, hydrogen, and even biofuels. The ceramic structure must allow efficient combustion of diverse gaseous and liquid fuels while maintaining performance.
4. **Low Emissions:** The porous ceramic structure should promote homogeneous combustion, resulting in extremely low emissions across the entire engine's power range and for various fuel types.

IV. 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

V. PRINCIPLE AND THEORETICAL MODEL OF THE PM ENGINE.

This paper defines the PM engine as an internal combustion engine featuring a highly porous medium chamber. This chamber is mounted on the cylinder head (as shown in Fig. 1) and thermally isolated from its walls. A valve allows for periodic communication between the PM chamber and the cylinder volume.

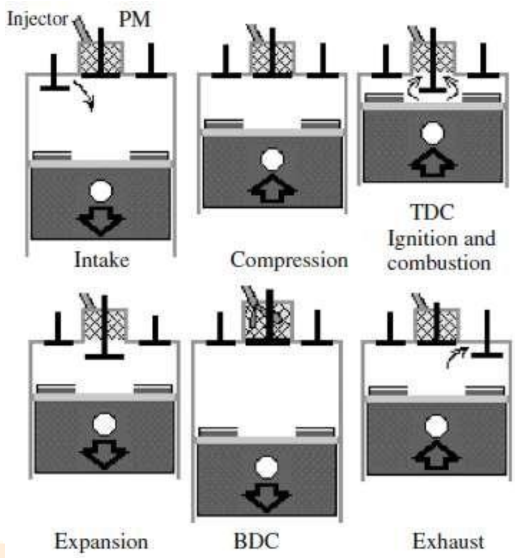

Figure 3. Principle of the PM engine proposed by Durst.'

Figure 3 illustrates the complete operational sequence of the PM engine, as enhanced by Durst [11]. Meanwhile, Fig. 2 provides a depiction of the PM engine head featuring a SiC reactor. Just before the top dead center (TDC), the intake valve initiates opening, allowing fresh air to enter the cylinder. Simultaneously, the valve of the PM-chamber remains shut, ensuring that the PM volume containing fuel vapor remains isolated from the incoming air throughout the intake and compression strokes. that the PM volume containing fuel vapor remains isolated from the incoming air throughout the intake and compression strokes. Upon completion of the compression stroke, the PM-chamber valve opens, enabling the compressed air to flow from the cylinder into the preheated PM volume, fostering a highly turbulent flow environment. Consequently, rapid mixing between vaporized fuel and compressed air transpires within the PM chamber. This mixture absorbs adequate heat from the hot PM and subsequently undergoes auto-ignition across the entire PM volume. The resultant flame swiftly traverses the porous matrix, facilitating thorough combustion within the PM chamber. Throughout the combustion phase, the heat liberated is absorbed by both the working gas and the PM volume. The PM-chamber valve remains ajar until the conclusion of the expansion stroke, at which point fuel injection into the PM volume commences upon valve closure. Vaporization within the PM volume persists throughout the exhaust, intake, and compression strokes. The segregation between the cylinder and the PM chamber is upheld during the exhaust phase, akin to conventional DI engines.

The PM-chamber valve operates in a binary fashion, alternating between open and closed states once per cycle, thereby periodically interfacing with the working fluid. Heat absorption by the PM during combustion is subsequently released at the culmination of the subsequent compression process. The formation of a homogeneous mixture and the occurrence of 3D thermal self-ignition within the PM volume establish favorable conditions for homogeneous combustion, nearly independent of engine load. Additionally, the recuperation of heat within the PM can be leveraged for auxiliary heating purposes

VI. 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.

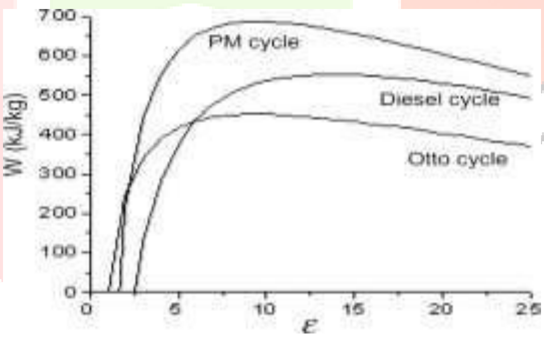

Figure 4 Comparison of the net- work output for Otto, Diesel and PM heat regeneration cycle

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.

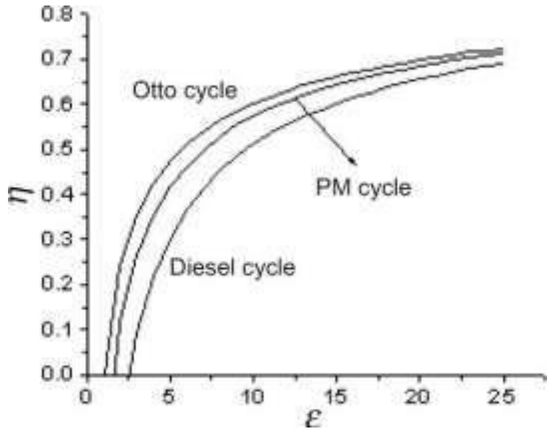

Figure 5 Comparison of efficiency for Otto, Diesel and PM heat regeneration cycle. [6]

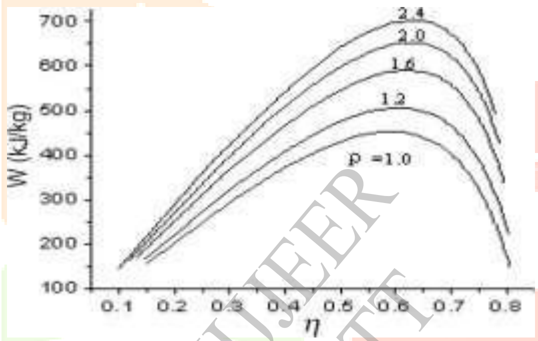

Figure 6 Influence of q on the net- work output versus efficiency characteristic. [6]

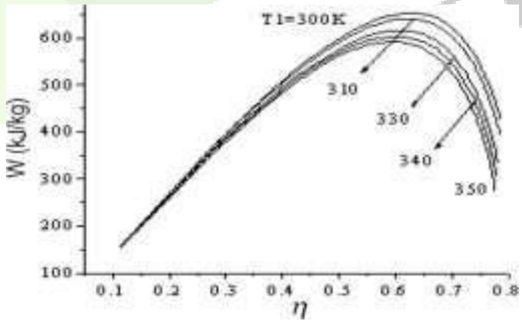

Figure 7 Influence of it T1 on the net- work output versus efficiency characteristic. [6]

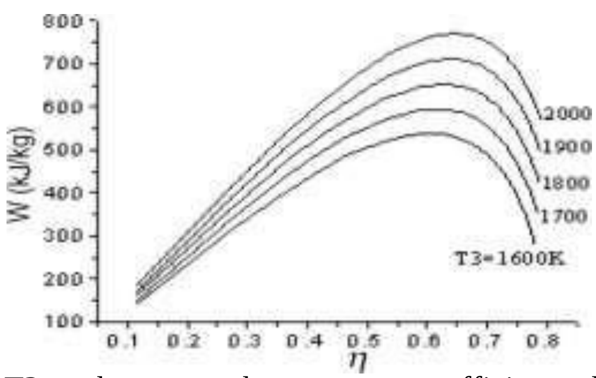

Figure 8 Influence of T3 on the net- work output versus efficiency characteristic. [6]

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.

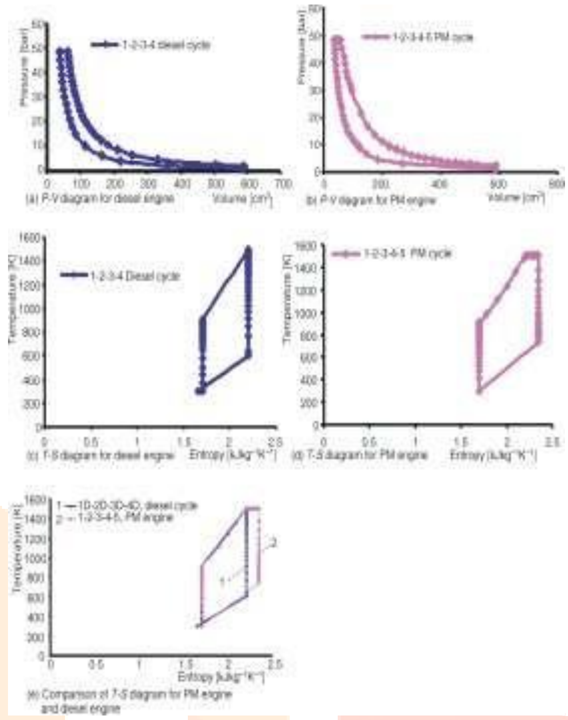

Figure 8(a)-(e). Comparison of engine cycles characteristics (color image see on our website)

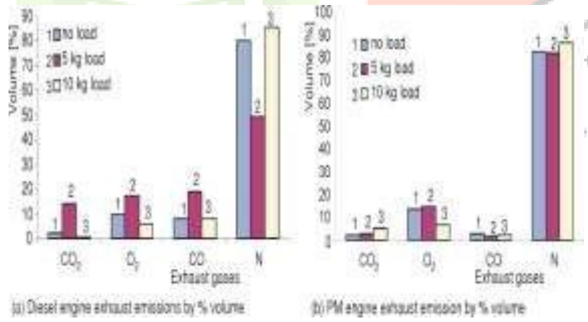

Figure 9(a) and (b). Comparison of exhaust emissions

VII. 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 CO2 but at 5kg load the volume of CO2 is reduced from 12 % to 2 % volume and at 10kg load volume of CO2 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.

VIII. Acknowledgment

The authors would like to thank teaching staff of mechanical department for providing their valuable guidance and overwhelming support to carrying out this work.

References

[1] Prof.Dr.-Ing. Miroslaw Weclas, Potential of porous medium combustion technology as applied to internal combustion engines, Sonderdruck Schriftenreihe der Georg-Simon-Ohm-Fachhochschule Nürnberg Nr. 32 ISSN 1616-0762, 2001

[2] Jan Macek, MilosPolasek, Simulation Of Porous Medium Combustion In Engines, Czech Technical University in Prague, Josef Božek Research Center 2002.

[3] Macek Jan1, Polasek Milos 1 Porous Medium Combustion In Engines May Contribute To Lower Nox Emissions, Czech Technical University in Prague, Josef Božek Research Center F02V147.

[4] Le Duc Chien, Chae Jae Ou, Kwak Yong Hwan, Improving surface characteristics of Porous medium reactor in diesel engine by Plasma technology F2006SC27, (2006).

[5] Zhiguo Zhao, Cuihua Wang, Maozhao Xie, Numerical study on the realization of compression ignition in a type of porous medium engine fueled with Isooctane Fuel 88 2291–2296, (2009).

[6] Hongsheng Liu, Maozhao Xie, Dan Wu, Thermodynamic analysis of the heat regenerative cycle in porous medium engine, Energy Conversion and Management 50 297–303, (2009)

[7] Arash Mohammadi, Ali Jazayeri, Masoud Ziabasharhagh, Numerical Simulation Of Direct Injection Engine With Using Porous Medium, AcademyPublish.org - Journal of Computer and Information Technology Vol.2, No.1,ISSN: 2161-7112,(2009).

[8] M. Abdul Mujeebu, M.Z. Abdullah, M.Z. Abu Bakar, A.A. Mohamad, M.K. Abdullah, Applications of porous media combustion technology – A review), Applied Energy 86 1365–1375(2009).

[9] W. Acchara, F.B.M. Souza, E.G. Ramalho,W.L. Torquato, Mechanical characterization of cellular ceramics(2009), Materials Science and Engineering A 513–514- 340–343, (2009).

[10] M. Weclas and J. Cypris, combustion of diesel spray: low- and high- temperature oxidation processes for free diesel injection and in porous reactors, DIPSI Workshop 2011 on Droplet Impact Phenomena & Spray Investigation, Bergamo, Italy May 27, 2011.

[11] Balvinder Budania, Virender Bishnoi, A New Concept of I.C. Engine with Homogeneous Combustion in a Porous Medium, International Journal of Latest Trends in Engineering and Technology (IJLTET) ISSN: 2278-621X(2012).

[13] Hongsheng Liu, Maozhao Xie, Dan Wu, "Simulation of a porous medium (PM) engine using a two-zone combustion model", Applied Thermal Engineering 29 (2009) 3189–3197.

[14] Dhale, A. A., *et al*. "Analysis Of Internal Combustion Engine With A New Concept Of Porous Medium Combustion For The Future Clean Engine" THERMAL SCIENCE: Year 2010, Vol. 14, No. 4, pp. 943-956