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A Review of Porous-Media Combustion Technology Applied to IC Engine

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Abstract— Global energy demand continuously increasing in transportation sector due to development of many advances in technology causes fast depleting fossil fuel consumption while the demand for automobile industry require high efficiency and low fuel consumption. In this view many researchers goal turns towards new method for efficient combustion of fuels. Porous media combustion is one of the viable methods to reduce emissions in the engine cylinder. In porous media combustion thermal efficiency of engine increases with high radiant output, low emissions with high flame speed, and higher power density. This technique has been used for both gaseous and liquid fuels in steady or unsteady state combustion. The review of this paper is still not well known technology to researchers doing with internal combustion engine processes.

Keywords—Combustion, Thermal efficiency, Flame speed, Porous media, Pollution

I. Introduction

A porous material means a material with connected voids that flow can easily penetrate through its structure. This technique is presently being selected by majority developer's advancing modern combustion engines. The porous media combustion (PMC) is different from conventional combustion, with free flame, thin reaction zone and high temperature gradient. Compare with porous system to without porous media system having better reduction NO_χ, CO, UHC and soot formation. On the other hand, in PM combustion three modes of heat transfer conduction, convection and radiation are significant.

The efficiency and power density of gas compression expansions are strongly dependent on heat transfer during the process. Since porous media inserts can significantly increase heat transfer surface area, their addition to a liquid piston compressor/expander has been hypothesized to reduce the time to complete the compression or expansion process and hence the power density for a given thermodynamic efficiency; or to increase the thermodynamic efficiency at a fixed power density[1]. The conventional diesel engine is a heterogeneous combustion engine which causes soot and NO_χ emissions [2]. To overcome this problems swirl and squish air supply to the engine inlet condition squish pressure fuel injection and different nozzle hole configurations, and sizes have been considered [3].The researcher not satisfied with that process and their goal turns searching for another methods they are dilute premixed or partially homogeneous charge compression ignition (HCCI) combustion (Fig.1) .In this process air fuel mixture must be homogenized before the start of combustion process so that lead to soot and NO_χ formation eliminated[4-6]. However, the drawbacks with dilute premixed combustion are the less time available for homogenization of the charge before the initiation of the combustion process and large amount of Co and HC emissions due to high EGR [7]. There have been numerous patents from 1917 onwards on the application of porous media geometrical and material properties for improving individual engine processes, especially in the intake system and inside the combustion chamber [8]. The novel concept of utilization porous media (PM) in direct injection CI engines to achieve a homogenous combustion of a well premixed charge was recently proposed by Weclas. In this concept, porous media combustion chamber mounted in engine head. During the intake stroke it is weak influence of the PM heat capacitor on the in-cylinder air thermodynamic conditions. Heat exchange process increases with continuing compression, and at the TDC of compression the fuel is inject into the PM volume causes very fast fuel vaporization and mixing with air. A new concept for future trend of homogeneous combustion has been proposed by Durst and Weclas [9]. In order to get feasibility for the PM engine is characterized by positioning of the PM-reactor in the engine [10].

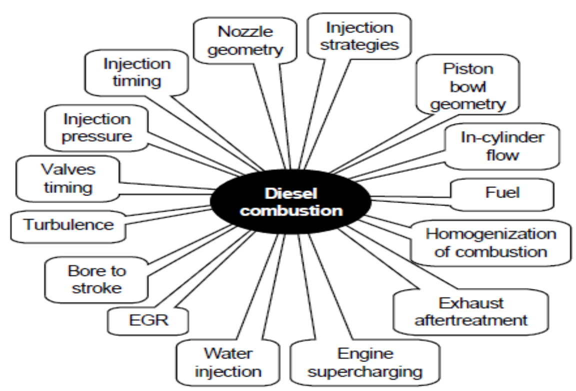

Figure 1. Available Technology for DI diesel Engine.

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II. Material and Methodology

Aluminium Oxide (Al_2O_3), silicon carbide (Sic), zirconium dioxide (ZrO_2) and Fe-Cr-Al and Ni-base alloys are suitable materials for applications (Fig.1). Al_2O_3 and ZrO_2 are recognized as high temperature resistance materials. Fe-Cr-Al and Ni-base alloys were found some applications but they are less heat resistant (fig.2).

Figure.2

Basic requirements for future clean internal combustion engines near zero exhaust emissions level and better fuel consumption. The primary purpose of the media is to enhance the spread as well as the evaporation process of the high pressure fuel spray to achieve charge homogenization [11]. Internal combustion engines have to operate in a wide range of speed and loads. For this purpose future engine should satisfy homogeneous for high power density (full-load) and homogeneous-lean charge for low specific fuel consumption (part load). Realization of homogeneous combustion, for all mixture compositions for lowest emissions [12].

The application parameters of PMC technology to I.C engines are heat capacity, specific surface area, heat transport properties, transparency for fluid flow, spray and flame propagation, pore sizes, pore density, pore stricter, thermal resistance of the material, mechanical resistance and mechanical properties under heating and cooling conditions, PM material surface properties etc. (Fig 3.)

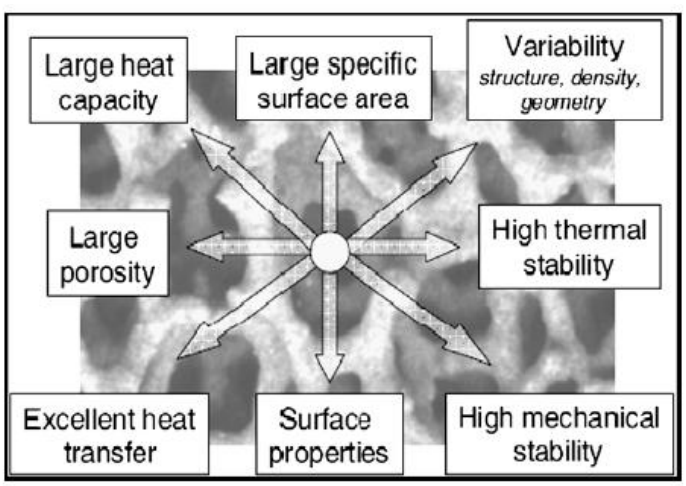

Figure.3. Main features of porous structure to be utilized to support engine process.

(From the work of Weclas)[15]

Principle of PM-Engine Technology

The PM engine means it is an internal combustion engine with a highly porous medium chamber mounted on the cylinder head which satisfied with internal heat recuperation, fuel injection, fuel vaporization, mixing with air, homogenization of charge, 3D-thrmal self-ignition[. According to heat recuperation PM engine classified as PM with closed chamber and PM with open chamber. In closed chamber process PM and working gas in cylinder with periodic contact and open chamber permanent contact. On the other hand the possible positioning of PM combustion with different engines are cylinder head (PM is stationary), cylinder (PM is stationary) and Piston (PM movies with piston). One of the most interesting features of PM- engine is its multi fuel performance. Independently of the fuel is used, this engine is a self-ignition engine characterized by its 3D-thermal ignition in porous medium. The PM-engine concept may be used for both two and four stroke engines.

The PMC technique firstly proposed by Durst Weclas [9]. 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 [9]. The thermal regeneration concept for diesel engines was examined by Park and Kaviany [13] for the roles of the porous insert motion and the fuel injection strategies on the fuel evaporation and combustion, using a two zone model and a single-step reaction mechanism. They claimed that the regenerative engine using an in-cylinder reciprocating porous regenerator can result in a more uniform fuel-vapor distribution and a dominant premixed combustion regime due to the increase in the adiabatic flame temperature. According their studies, the thermal efficiency also increased for a promotion of 10% for thermal efficiency.

To further understand the fundamental mechanism of the PM engine, Computational Fluid Dynamics (CFD) is a useful tool. The aim of this work is to study a new engine with the PM located at piston head using an axisymmetric model with detailed chemistry and two-temperature treatment based on a modified version of the engine CFD software KIVA3V [14] . Effects of relevant geometrical and operating parameters on the engine performance are analyzed and discussed.

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III. Results and Discussion

ASHOK A. DHALE have conducted experiment on single cylinder, four stroke, water cooled, DI diesel engine with bore 80mm, stroke 110mm, 5 HP and compression ratio 16:1 and evaluated efficiency, fuel consumption, plotting P-V, T-S diagrams and recording soot formation initially without PM,[15] as shown in fig.(4-5).

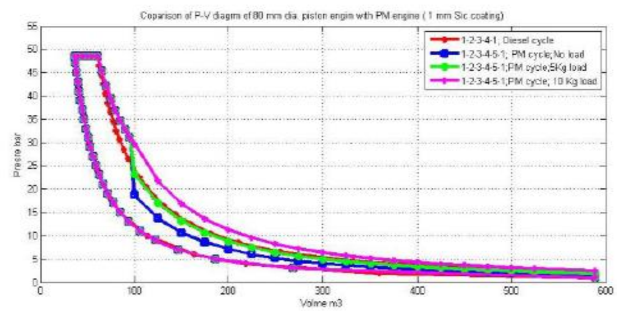

Figure 4. Comparative P-V diagrams for 80mm dai. Piston engine

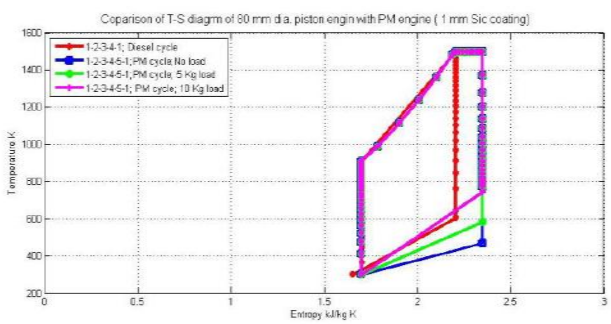

Figure 5. Comparative T-S diagrams for 80mm dai. Piston engine

C.Kannan and P.Tamilporai have taken experimental reading on 4.4 kW, constant speed, single cylinder, four stroke, naturally aspirated, air cooled direct injection diesel engine and measured HC, CO, NOx and Soot shown in fig.6,7,8,9.[16].

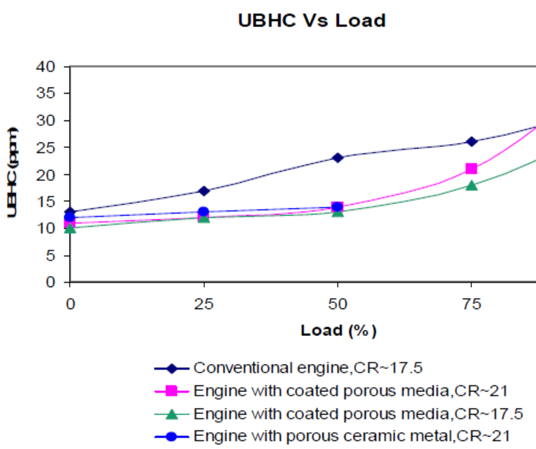

Figure 6. Comparison of hydrocarbon emission

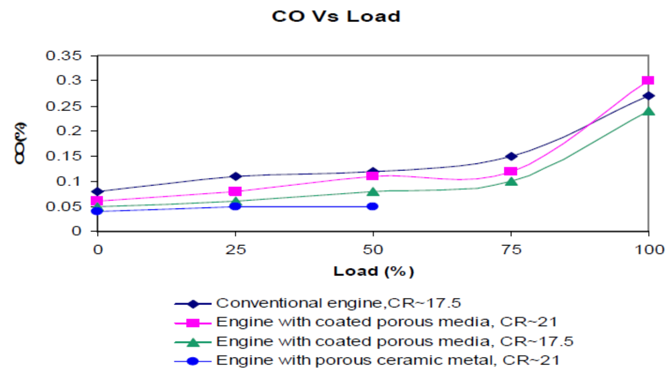

Figure 7. Comparison of carbon monoxide emission

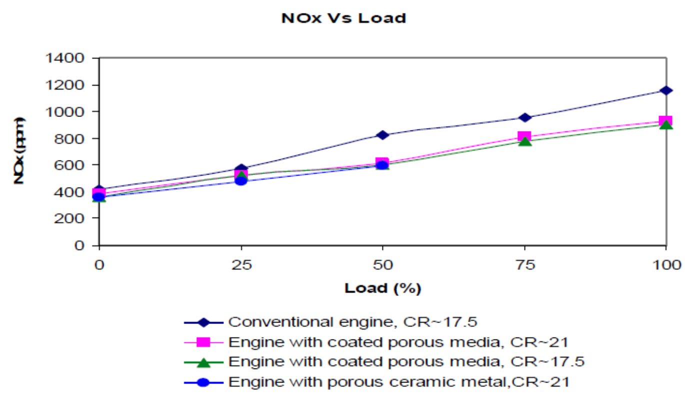

Figure 8. Comparison of nitrogen oxide emission

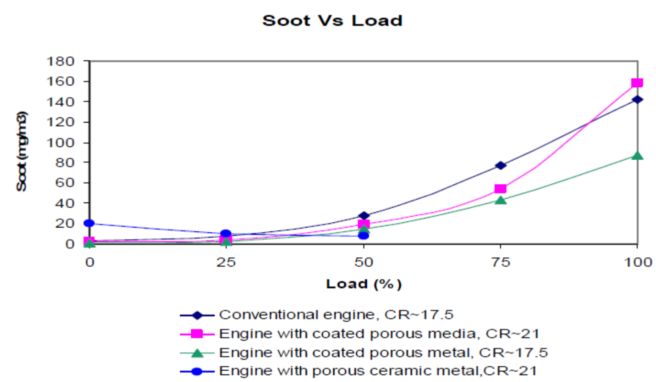

Figure 9. Comparison of soot emission

IV. Conclusion

In this literature review the PM engine offers the novel concept of homogenous combustion with a uniform temperature in the combustion chamber. The efficiency of the diesel engine can be increased 10% compare with conventional diesel engine. Also from the study of p-v and T-S diagram the net-work output is also increased by using porous combustion chamber. The major emission characteristics of PM engine can have lower level of NOx, HC, CO and soot compare with conventional engines. It is unique research work being conducted and an excellent approach towards the overall development of the engine efficiency which is the need of the current scenario in the field of Automobile.

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