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Research Article

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Effect of combustion chamber in a DICI engine with corn oil methyl ester

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ABSTRACT

In this investigation, attention is focused to find out the effect of combustion chamber shape on the performance and emission characteristics of a stationary diesel engine fuelled with methyl esters of vegetable oil. Toroidal shape combustion chamber was fitted in a 4.4kW naturally aspirated single cylinder Direct Injection Compression Ignition (DI CI) engine and tests were conducted when fuelled with diesel and Corn oil Methyl Ester (COME). COME had shorter ignition delay than diesel because of its better spray characteristics. From performance characteristics it was observed that COME had slightly lesser thermal efficiency compared to diesel. The specific fuel consumption of the COME is slightly higher than that of diesel. HC, CO and Smoke density and soot concentration emissions are lesser for COME than diesel. At part load condition NOx emission was found to be higher for COME than diesel.

Keywords: Diesel engine, Corn Oil Methyl Ester, Performance characteristics, Emission characteristics

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INTRODUCTION

With the stock of fossil fuels diminishing throughout the world and demand for energy based comforts and mobility ever increasing, time is ripe that we strike a balance between energy security and energy usage. Moreover having uplifted to such a sphere of engineering excellence, reverting back to the ages of the bull carts will prove next to impossible thereby compelling us to search for a basket of alternative fuels to derive energy to cater to our needs.

Several sources of energy, especially for driving the automotives are being developed and tested. Judicious utilization of this alternative fuels is the call of the hour for a nation to see itself through the tough days ahead. Engine development is heavily controlled by increasingly stringent emission legislation, leading to rapid developments. The future of gaseous/alternative fuels depends on the maximum of polluting emission allowed, the technology available and the cost of concepts developed. Promising developments are taking place in the area of the conventional prime mover for the diesel engine.

Vegetable oil based fuels are renewable but usually cannot be directly used as fuel for engines as they cause a lot of problems which include deposit formation, carbonization of injector tips, misfire and so on [2,3]. These problems reduce the life of the engines and increase the emissions as the engine wears out. Hence, all these fuels are subject to processes to reduce their viscosities, which include trans esterification, micro emulsion and pyrolysis etc. out of which trans esterification is most widely used [4,5].

In this present study an attempt is made to investigate the effect of toroidal combustion chamber shape on the performance and emission characteristics of the engine when fuelled with COME and diesel. Methyl ester derived from Corn oil was employed as a fuel and the results were compared with that of diesel.

1. MODIFICATIONS ON THE COMBUSTION CHAMBER

The combustion chamber has been modified to a toroidal shape from the sphericalshape on the piston crown for the squish and swirl movement of the air, maintaining the constant compression ratio. The K-factor of the combustion chamber geometry (ratio of the piston bowl volume to the clearance volume) was maintained at 0.74.The ratio of D/d (ratio of piston crown diameter to piston bowl diameter) is altered to achieve toroidal shape from the Spherical shape.

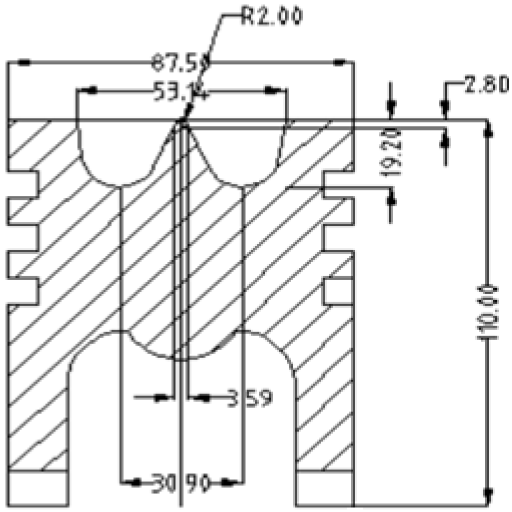

Fig.1.Toroidal Combustion Chamber

Table1: Properties of Diesel and COME

Property	Unit	Diesel	COME
Density	kg/m^3	821	882
Kinematic viscosity	cSt	3.52	7.64
Flash point	ºC	49	178
Cetane Number	-	50	38
Calorific value	kJ/kg	44,300	39,700

Table2: Engine Specifications

Engine Type	Four stroke, constant speed, direct injection, diesel engine
Make and Model	Kirloskar and TAF1
Combustion Chamber	Toroidal
Maximum Power	4.4 kW @ 1500 RPM
Maximum Torque	28 N-m @ 1500 RPM
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Injection Timing	23.4^0bTDC

2. TESTING PROCEDURE

The engine was fitted with toroidal combustion chamber and tests are conducted at different loads starting from no load to rated load condition to maintain constant engine speed. At each load air, fuel flow rate, combustion and composition of exhaust gases are recorded. Under steady state conditions the above parameters were recorded at various loads. The engine is interfaced with AVL Indi meter software for the measurement of combustion parameters such as P-θ diagram, heat release rate, ignition lag. Exhaust gas constituents were measured with exhaust gas analyzer and smoke intensity was measured with AVL smoke meter. The engine was next run with COME and the readings were taken as before. The test results presented for toroidal combustion chamber at different loads for diesel and COME.

RESULTS AND DISCUSSION

3.1. Combustion Characteristics

3.1.1. Ignition Delay

Fig.2 shows the ignition delay for diesel fuel and COME with Brake power. The ignition delay of COME is found to be lower compared to diesel. The reason may be due to the cylinder gas temperature at the time of injection. The toroidal shape of the combustion chamber is greatly increasing the turbulence in the piston bowl to facilitate breakup of the fuel jet and improving evaporation and physical delay. It enhances faster reaction starts and then accelerates it to ignition. The self igniting capability is indicated by means of cetane number of the fuel. It has direct impact on ignition delay and also intentional to the knocking characteristics of DICI engines. Higher the cetane number the ignition delay period is shorter.

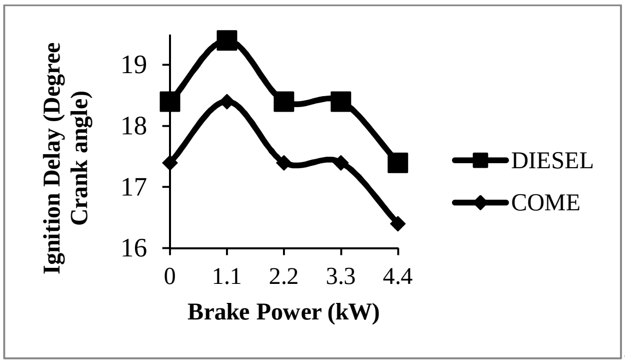

Fig.2 Variation of Ignition delay with Brake power

3.1.2. Pressure Variation with Crank angle

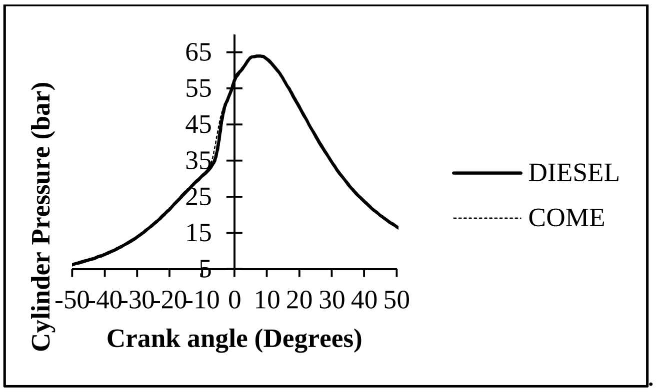

Fig.3Variation of Cylinder pressure with crankangle

Fig.3 shows the rate of pressure rise of diesel and COME with respect to crank angle. Diesel fuel has the maximum rate of pressure rise near TDC and COME reach the maximum rate of pressure rise earlier than diesel. COME possesses high viscosity than diesel and that is the reason lower rate of heat release. The trend shown by diesel release higher heat rate due to fuel accumulates, port swirl and turbulence motion of the air leading to sudden and drastic rise in pressure in the toroidal combustion chamber. The piston shape is help to attain the maximum rate of pressure rise than that of COME.

3.1.3. Heat release rate

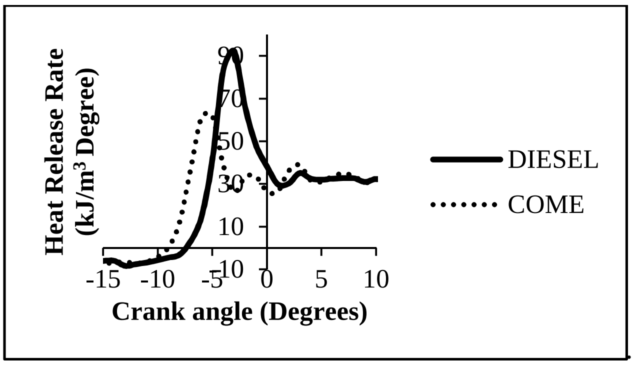

Fig.4Variation of Heat release rate with crankangle

Fig.4 shows the heat release rate of diesel and COME with respect to crank angle. This is mainly due to the toroidal chamber having capable of proper fuel mixing with high pressure air by means of turbulence motion, also premixed burning phase is to increase higher heat release rate. Diesel has higher heat release rate compared to the COME. The pre combustion phase of the air fuel mixture having high intensity, it is help to release higher heat rate. COME have lower heat release rate, so lesser fuel accumulates inside the cylinder and hence the pre combustion phase is lesser for the COME. It is observed that, diesel ignites later, but releases a higher amount of heat. However COME ignite earlier and the advance in ignition. This is mainly increased oxygen content in the fuel, which reduces the ignition delay and heat release rate. It is observed that the maximum heat release rate of 92.25 J/Deg. CA is recorded for diesel at 3° bTDC, while COME records its maximum heat release rate of 61.957 J/Deg.CA at 5° bTDC.

3.2. Performance Characteristics

Engine performance characteristics are the major justification that governs the suitability of a fuel. This study is concerned with the estimation of brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) of the Diesel and COME.

3.2.1. Brake thermal Efficiency

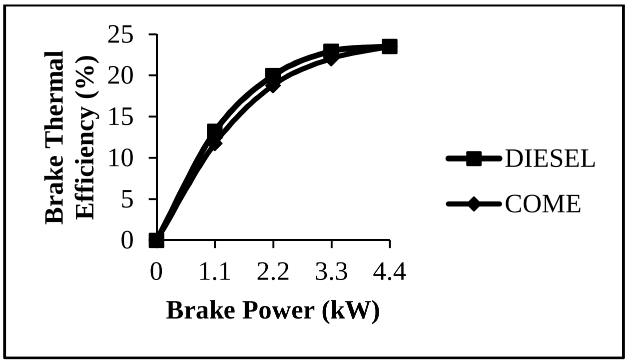

Fig.5Variation of Brake thermal efficiency with Brake power

Fig.5 shows the variation of brake thermal efficiency with respect to brake power for diesel and COME. Diesel shows higher brake thermal efficiency than that of COME. Swirl air motion of the toroidal combustion chamber is used to promote rapid mixing of the injected fuel with air to accelerate combustion. COME having higher viscosity and lower heating value, lower self ignition temperature, can results in low gas flow resistance there by reducing volumetric efficiency. It also increases heat transfer, this may result in loss of brake thermal efficiency.

3.2.2. Specific fuel consumption

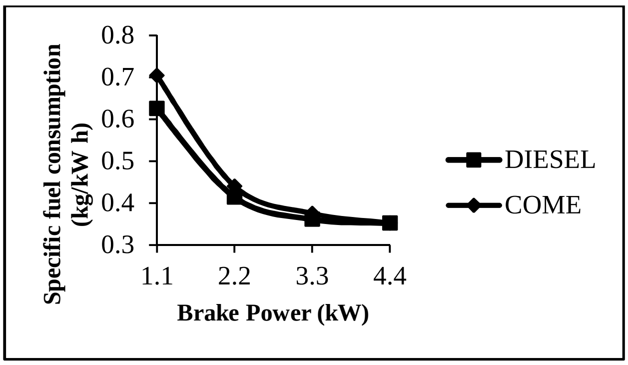

Fig.6Variation of Specific fuel consumption with Brake power

Fig.6 shows the variation of specific fuel consumption with respect to brake power for diesel and COME. The brake specific fuel consumption for COME were slightly higher than that of the diesel at the part load condition except full load. The brake specific fuel consumption of a diesel engine depends on the relationship among volume of fuel injection, specific gravity, viscosity and heating value of the fuel. COME is not having capable to produce the same amount of energy because of its lower specific gravity and lower heating value compared to Diesel.

3.3. Emission Characteristics
3.3.1. Nitrogens of oxide

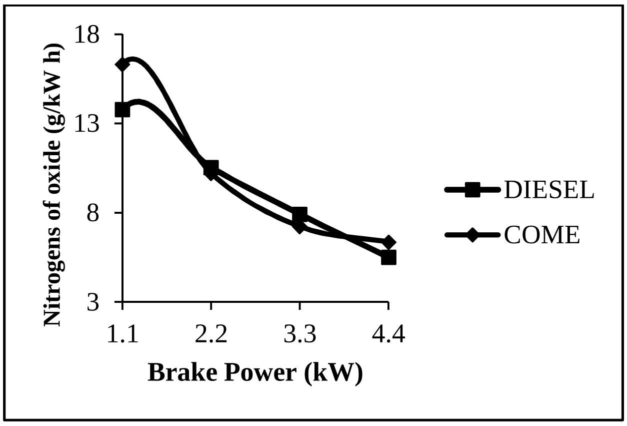

Fig.7Variation of Nitrogens of oxides with Brake power

Fig.7 shows the variation of NOx with respect to brake power for diesel and COME. The NOx emission of the COME is slightly higher than that of the Diesel at 25% of the load and full loads. The NOx variation of the COME and diesel shows similar trends. The higher combustion temperature and oxygen present in the COME, causes higher Nox emission, especially at maximum output power.

3.3.2. Carbon monoxide

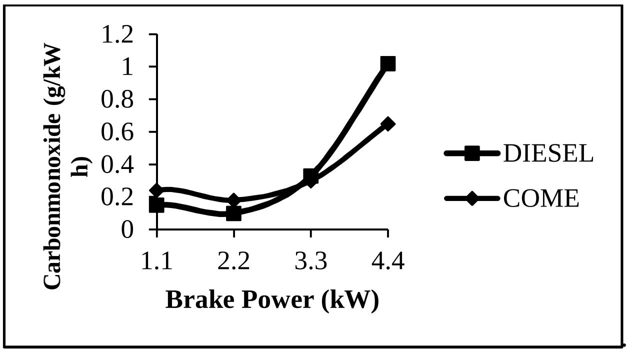

Fig.8Variation of Carbonmonoxide with Brake power

Fig.8 shows the variation of CO with respect to brake power for diesel and COME. Carbon monoxide (CO) in diesel engines is formed during the intermediate combustion stages. Diesel engine operates well on the lean side of the stoichiometric ratio. The CO emission of diesel is higher compared to COME. Because of the oxygen content in the fuel, in addition to the air supplied during induction of toroidal combustion chamber to reduce the CO by combining with CO to form CO_2. At high temperatures, fuel sprays of vegetable oils undergo chemical reactions, which include thermal cracking (producing lighter compounds) and polymerisation at the spray core (producing heavy, low-volatility compounds). The air–fuel mixing process is affected by the difficulty in atomisation of the heavy compounds. The resulting locally rich mixture causes more CO to be produced during combustion, due to the lack of oxygen.

3.3.4. Soot

Fig.9 shows the variation of soot concentration with respect to brake power for diesel and COME. Soot concentrations are an indication of particulate matter present in the exhaust of an engine. Particulates primarily contain carbon particles. The soot concentration follows the same trend as that of HC and CO emissions. From fig.9 it is clear that the soot concentration reduced with increasing COME. The variation in soot concentration at lighter loads was negligible. The soot formation stage usually involves dehydrogenation of unburned hydrocarbon, forming carbon nuclei for the particles. Then the growth stage occurs through coagulation and aggregation of other carbons in the exhaust. During formation and growth, oxidation of the particles occurs and it forms CO and CO_2. One such oxidation species exist in the combustion products of the COME, thus explaining the increase in CO_2 emissions and the decrease in soot concentration. This theory is supported by the fact that soot oxidation is based on the partial pressure of oxygen present in the exhaust. As the partial pressure of oxygen increases, soot oxidation increases, thereby reducing particulates. Since COME is an oxygenated fuel, the oxygen present in the fuel increases the partial pressure of oxygen present in the exhaust, thereby increasing soot oxidation.

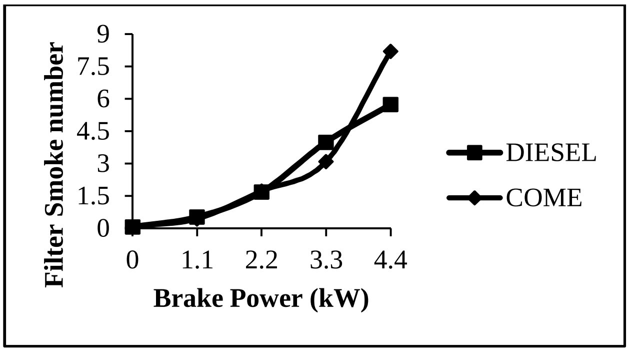

Fig.9Variation of Filter Smoke number with Brake power

CONCLUSION

The main conclusions of this study are as follows:
The ignition delay for COME is found to be lower than that of diesel which may be due to higher oxygen content of COME and better spray characteristics. The ignition delay decreases with increase in load.

The rate of pressure rise pattern is same for both diesel and COME.

The combustion rate was found to be maximum for diesel and minimum for COME.

Heat release was found to be maximum for diesel to its intensive pre combustion phase. The maximum heat release occurs for COME was found to be earlier.

The specific fuel consumption of the COME is slightly higher than diesel due to its specific gravity, viscosity and heating value of the fuel.

The brake thermal efficiency of the COME is slightly lower than the diesel due to the lower heating value of COME and formation of CO_2.

The COME burn more efficiently than diesel and releases lesser CO. This indicates better combustion of the COME. The NOx emissions of the COME were slightly higher than diesel at 25% and full load condition.

The HC emissions decrease which implies efficient combustion of COME compared to diesel because of its higher oxygen content.

Soot concentration was considerably low for the COME compared to diesel because of oxidation of the carbon particles emissions to CO otherwise CO_2.

Smoke density of COME lower compared with diesel at part load.

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