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Performance and evaluation of DI diesel engine by using preheated cottonseed oil methyl ester

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Abstract

In this investigation, the Cotton Seed Oil Methyl Ester (CSOME) was prepared by transesterification using cotton seed oil, methyl alcohol and potassium hydroxide (KOH) as a catalyst. At different preheated temperatures, the performance and exhaust emissions of a diesel engine fuelled with preheated CSOME were obtained and compared with neat diesel. Experiments were conducted at different load conditions in a single cylinder four stroke DI diesel engine. CSOME was preheated to temperatures namely 40, 60, 80, 100°C before it was fuelled to the engine. From the test the brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), smoke density, CO, HC, NOx emissions were evaluated. The results proved that the preheated CSOME leads favourable on BTE and CO, HC emissions when it is heated up to 80°C. At the same time the NOx emission was increased. But at preheated temperature of 100°C, a considerable decrease in the BTE and BSFC were observed due to the vapour locking in the fuel line caused by vapour formation due to higher temperature of CSOME. On the whole the results shows that CSOME preheated up to 80°C can be used as an alternate fuel for diesel fuel without any significant modification in expense of increased NO_x emissions.

Keywords: Cotton seed oil methyl ester:Diesel engine performance:Exhaust emissions :Prehaeted biodiesel

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1. Introduction

Rising petroleum prices, increasing threat to the environment from exhaust emissions and global warming have generated intense international interest in developing alternative non-petroleum fuels for engines. The use of vegetable oil in internal combustion engines is not a recent innovation. Rudolf diesel (1858-1913), creator of the diesel cycle engines, used peanut vegetable oil to demonstrate his invention in Paris in 1900. Nowadays, it is known that oil is a finite resource and that its price tends to increase exponentially, as its reserves are fast depleting [1]. It has been reported that in diesel engines, crude plant oils can be used as fuel, straight as well as blended with the diesel [2]. However, during extended operation of the engine, problems of injector coking, dilution of engine oil, deposits in various parts of engine, etc. have been reported. The major drawback with the vegetable oils as fuel is its high viscosity [3]. Higher viscosity of oils is having an adverse effect on the combustion in the existing diesel engines. In recent years, systematic efforts were undertaken by many researchers to determine the suitability of vegetable oil and its derivatives as fuel or additives to the diesel [4-7]. Esterification is one of the methods to reduce viscosity of plant oils .It produces plant oil biodiesel commonly known as biodiesels. Several researchers [8] have used biodiesel as an alternate fuel in the existing CI engines without any modification.

The emissions characteristics of diesel engines fuelled with neat biodiesel or its blends with diesel fuel have been investigated by many researchers. They found that there are reductions in carbon monoxide, hydrocarbon and smoke emissions [9-11], while there is increase in NO_X emissions [12-15]. The viscosity of fuels have important effects on fuel droplet formation, atomization, vaporization and fuel-air mixing process, thus influencing the exhaust emissions and performance parameters of the engine. There have been some investigations on using preheated raw vegetable oils such as palm and jatropa oil in diesel engines [16 ,17]. However, it is known that vegetable oils have considerably higher viscosity compared with diesel fuel .The most common source of commercial biodiesel in Europe is rapseed oil, while USA usually produces biodiesel from soybean oil [18]. Eventhough a specified amount of biodiesel is produced from jatropa oil in India, cottonseed oil offers a great potential as the source of biodiesel .

The main objective of this experimental study is to determine the effects of the viscosity of cottonseed oil methyl ester, which is decreased by means of preheating process, on the performance parameters and exhaust emissions of a diesel engine. For this aim, cottonseed oil methyl ester was produced by transesterification method using cottonseed oil and methyl alcohol, and its properties were determined. Then, this biodiesel was preheated up to four different temperatures and tested in the diesel engine at all load conditions. Finally, the results for CSOME were compared with those for diesel fuel.

2. Production of cottonseed oil methyl ester

Cotton oil was converted into biodiesel through the alkaline transesterification reaction for which potassium hydroxide was used as catalyst with methanol. Two percent of the potassium hydroxide catalyst was dissolved in methanol (30% by weight) and the mixture was added to the cotton seed oil. Then the prepared mixture was stirred at 60°C for 30 minutes. Thereafter the reactant material was poured into transparent vessel and allowed for cooling at room temperature for 6-8 hours. It was allowed to settle for separation of glycerol as bottom layer. The upper layer of biodiesel was put into another transparent vessel for washing with equal amount of water. The biodiesel was heated up to 110 °C for 10 minutes to remove excess water. Then biodiesel was cooled down to room temperature before use, presenting a 94% yield. Transesterification, which is also called alcoholics, is a process of substitution of the radical of an ester by the radical of one alcohol, like hydrolysis. The biodiesel was produced from cotton seed oil in our laboratory. Density of the fuel was found using density bottle, kinematic Viscosity of the oil was determined with the help of Redwood Viscometer and flash point was obtained from electrically heated Pesky-Martens apparatus as per the standard test procedure of Bureau of Indian Standards (IS: 1448-1970). The gross calorific value of the cotton seed oil, cotton methyl ester and diesel were determined with the help of Bomb Calorimeter (IS: 1359-1959).

3. Experimental setup and test procedure

The experiments were carried out on a single cylinder, four stroke, DI diesel engine as shown in Fig 1. The engine specifications are described in Table 1. The test setup contains various measuring instruments to measure various parameters like engine torque, air flow rate, fuel consumption, exhaust emissions, temperatures of air and fuel. Experiments were conducted with neat diesel fuel and preheated CSOME at four different temperatures of 40°C, 60°C, 80°C and 100°C.

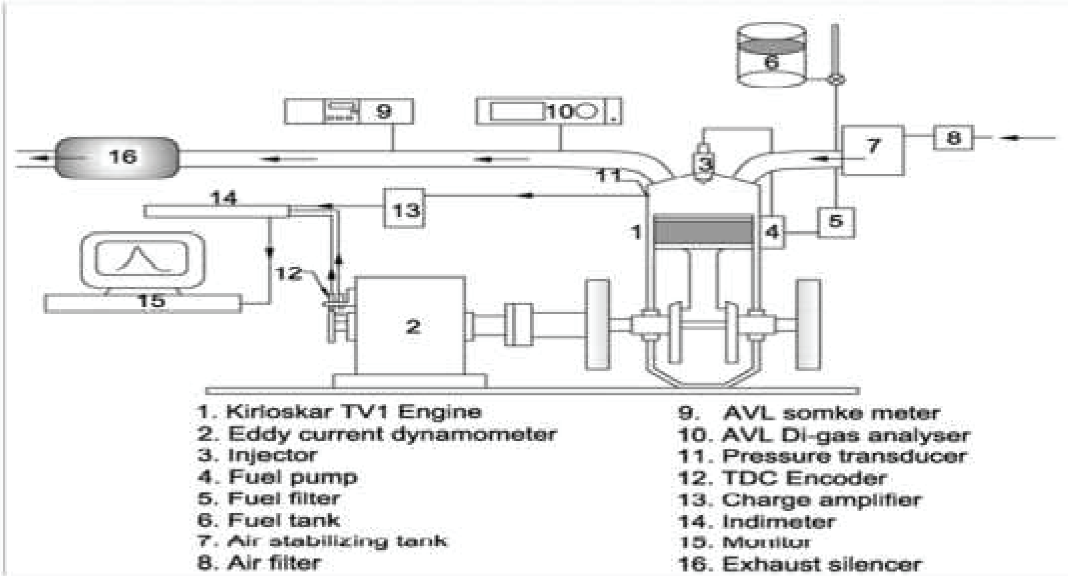


Fig.1: Schematic diagram of experimental setup

Table 1 Specifications of test engine

Make	Kirloskar TV-1
Type	Single cylinder, water cooled
Max.power	5.2 kW at 1500 rpm
Max torque	170 Nm at 1500 rpm
Displacement	660 CC
Bore x Stroke	87x 110
Compression ratio	17.5:1
Fuel injection timing	21deg BTDC
Loading device	Eddy current dynamometer

The engine was connected to an eddy-current dynamometer and the engine was running at a constant speed of 1500 rpm. Experiments were conducted at the engine speed of 1500 rpm and at different engine loads. Initially the experiments were carried out for the diesel fuel for different loads. The fuel consumption, brake power, brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature were measured. The NO_X , CO and HC emission were measured with non-dispersive infra-red analyzers (NDIR) (Make: HORIBA Gas Analyzer). The smoke density is measured by AVL smoke meter. The gas analyzers were calibrated with standard gases and zero gas before each test. Same procedures were repeated for CSOME at different temperatures namely 40, 60, 80 and 100^0C.

4. Results and discussion

4.1. *Fuel properties*

The physical properties of neat diesel fuel and CSOME are shown in Table 2. Many properties of CSOME are same as the diesel fuel. The values of density and kinematic viscosity of CSOME are higher when compared to diesel fuel. But heating value is lowered by 15%. The above mentioned properties affect the exhaust emissions and engine performance parameters The above mentioned properties affect the exhaust emissions and engine performance parameters. The CSOME flash point is higher and it induces for safe storage and transportation. At temperatures 40, 60, 80 and 100 °C the specific gravity and kinematic viscosity of the CSOME were calculated and are shown in Table 3. The specific gravity and kinematic viscosity of the CSOME gradually decreases with increase in the preheating temperature. From the Fig 2, it can be noted that the kinematic viscosity is 7.75cSt at 40^oC and decreases to 1.8 cSt at 100^oC. The specific gravity decreases from 0.867 at 40^oC to 0.842 at 100^oC.

Table 2

The properties of diesel fuel and CSOME

Property	Cotton seed oil	Cotton seed oil methyl ester (CSOME)	Diesel fuel
Density (g/ml)	0.96	0.913	0.830
Kinematic viscosity, cS at 38^oC	226.82	8.50	5.80
Gross calorific value ($MJkg^{-1}$)	36.20	39.16	46.22
Flash point (^oC)	317	149	47
Acid value (mgKOH/g)	1.642	1.008	0.00
Free fatty acid content (%)	2.8	1.86	0.00

Table.3

The properties of CSOME at different temperatures

Temperature of CSOME (^0C)	40	60	80	100
Specific gravity	0.867	0.854	0.847	0.842
\Kinematic viscosity (cSt)	7.75	5.8	4.1	1.8

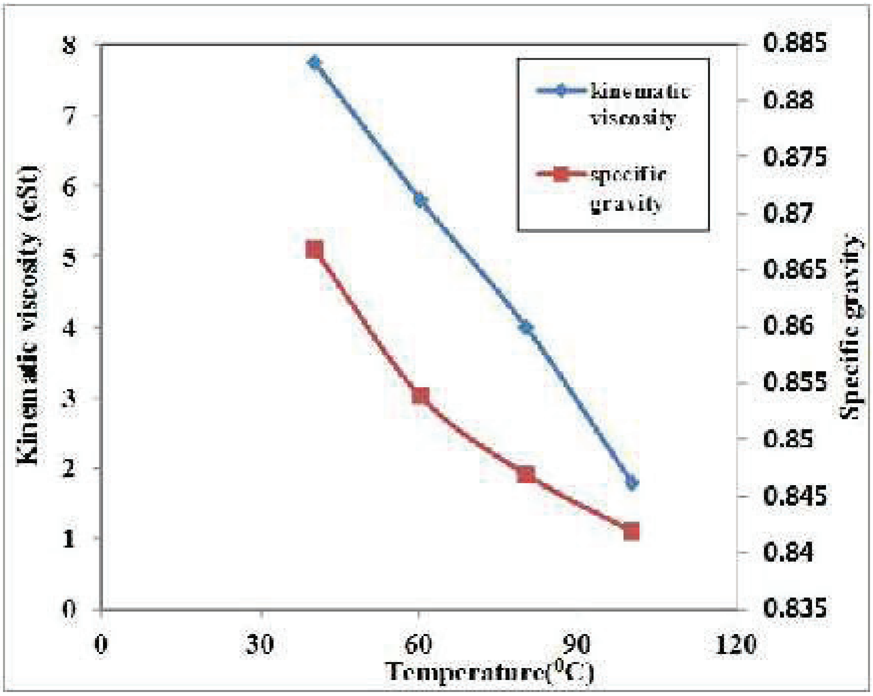


Fig.2 Effect of preheating on the Kinematic viscosity and specific gravity of CSOME

4.2. Engine performance and exhaust emissions

The changes of brake specific fuel consumption (BSFC) with brake power for different CSOME are presented in Fig.3. The BSFC of all CSOME is higher than that of diesel for all loads. For all CSOME tested, BSFC is found to decrease with increase in the load. This is due to more blended fuel which is used to produce same power as compared to diesel. The BSFC increased from 269g/kWhr to 345 g/kWhr for diesel and CSOME100 respectively at full load. This is due to the effect of higher viscosity and poor mixture formation of CSOME. But the BSFC is decreased due to increasing the preheating temperature of CSOME. This is due to the reduced viscosity and improved spray characteristics of CSOME.

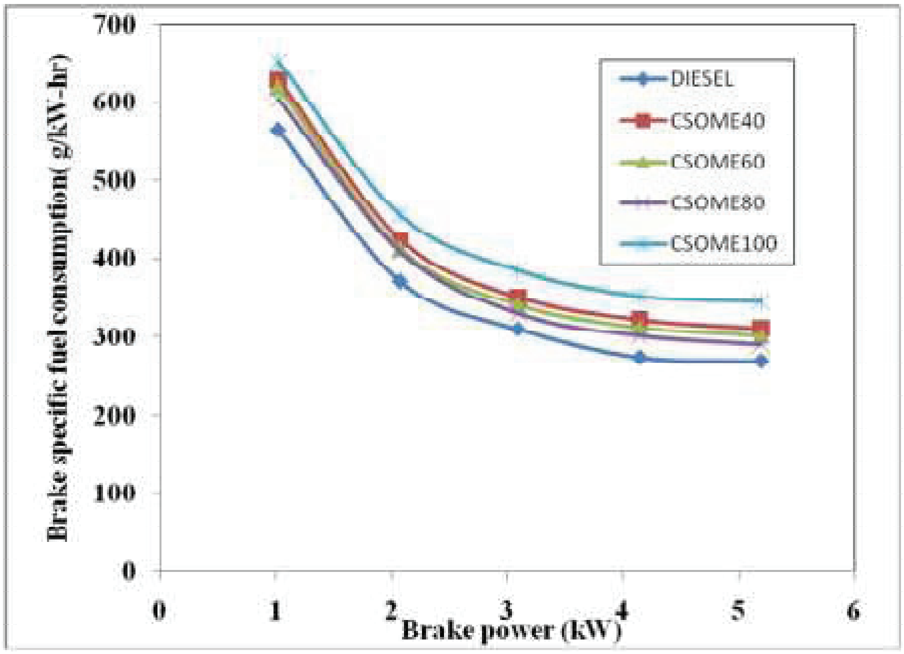


Fig.3 Brake specific fuel consumption

The variations in the brake thermal efficiency (BTE) of the engine fuelled with CSOME preheated to 40, 60, 80 and 100 °C, which are indicated by CSOME40,CSOME60,CSOME80 and CSOME100, respectively, with reference to diesel fuel are shown in Fig.4 . The increase in BTE with CSOME operations can also be attributed to the good combustion characteristics of bio-diesel owing to their decreased viscosity and improved volatility by means of preheating process. It is seen that the BTE of CSOME increased by the preheated temperature 40, 60 and 80^{o} C. But for 100^{o}C the BTE decreases due to vapour locking in the fuel line and hence more fuel consumption is obtained for the same power compared to other mode of operation. The BTE with the CSOME100 is 5% and 13% lower than that of CSOME80 and diesel fuel respectively.

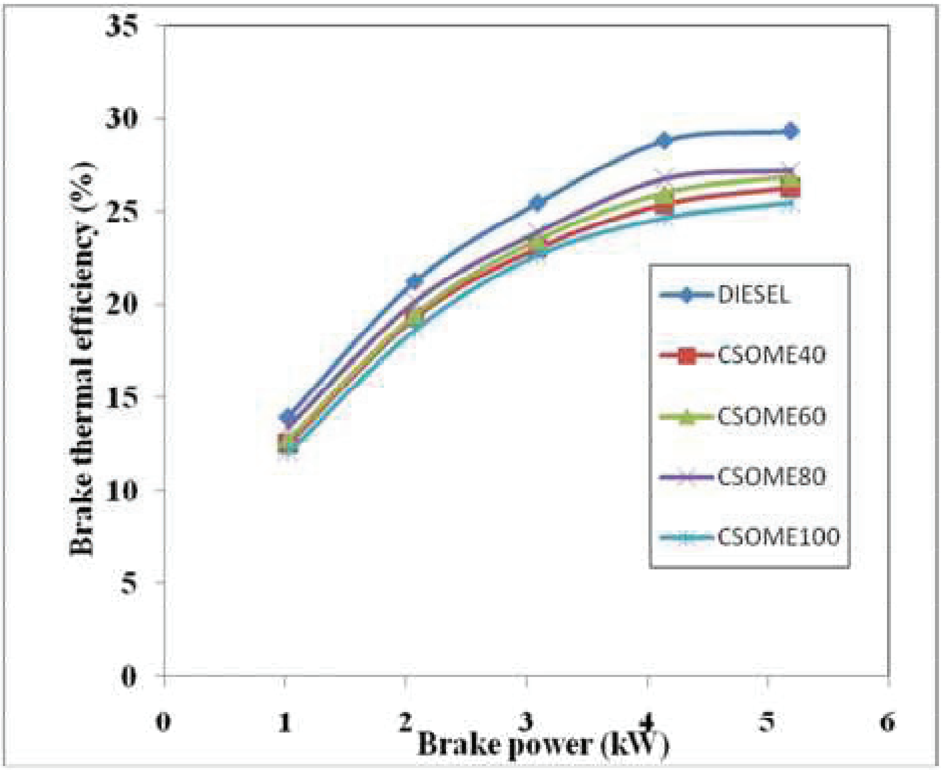


Fig. 4 Brake thermal efficiency

The CO emissions are shown in Fig. 5. As seen in the figure, the emissions increase with increase of engine load, due to rich fuel air mixture. Compared with the diesel fuel, the CO emissions of CSOME are lower, because of the higher oxygen content of biodiesel, which could improve the combustion process. Additionally, the heating process decreases the viscosity of biodiesel and improves the oxidation of biodiesel in the cylinder. Therefore, the CO emissions arising from incomplete combustion is decreased by applying preheating of the fuel. For CSOME100, the CO emission is higher than that of CSOME40, CSOME60 and CSOME80. This is due to uneven fuel spray in the combustion chamber, because of vapour locking in the pump and pipe line. CO emissions obtained with CSOME80 operations were 34% lower than that of diesel fuel operations at full load.

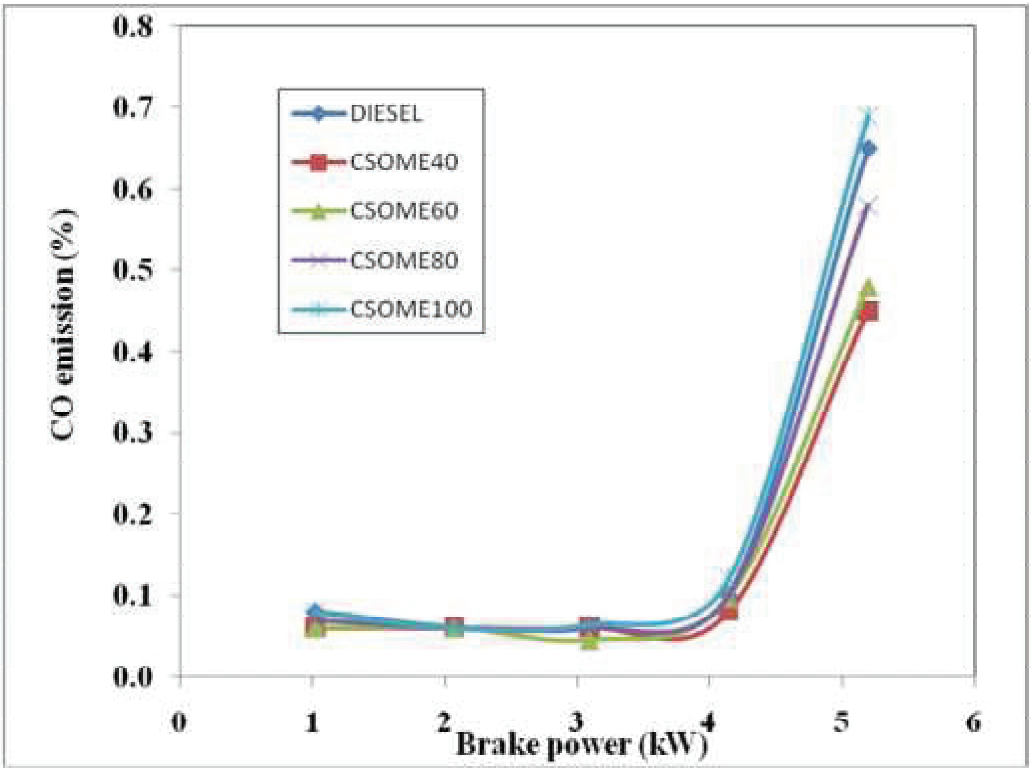


Fig. 5 CO emission

Fig. 6 shows the variation of HC emissions. Similar to the CO emissions, with an increase in the engine load, the HC emissions also decrease. Compared with diesel fuel, CSOME give lower HC emissions. The HC emissions of CSOME80 decrease 16% at the maximum load of the engine in comparison with diesel fuel. The higher oxygen content of CSOME leads to better combustion, resulting in lower HC. However, the HC emissions of CSOME100 are higher than that of other CSOME. This is due to incomplete combustion occurring at an uneven spray characteristics.

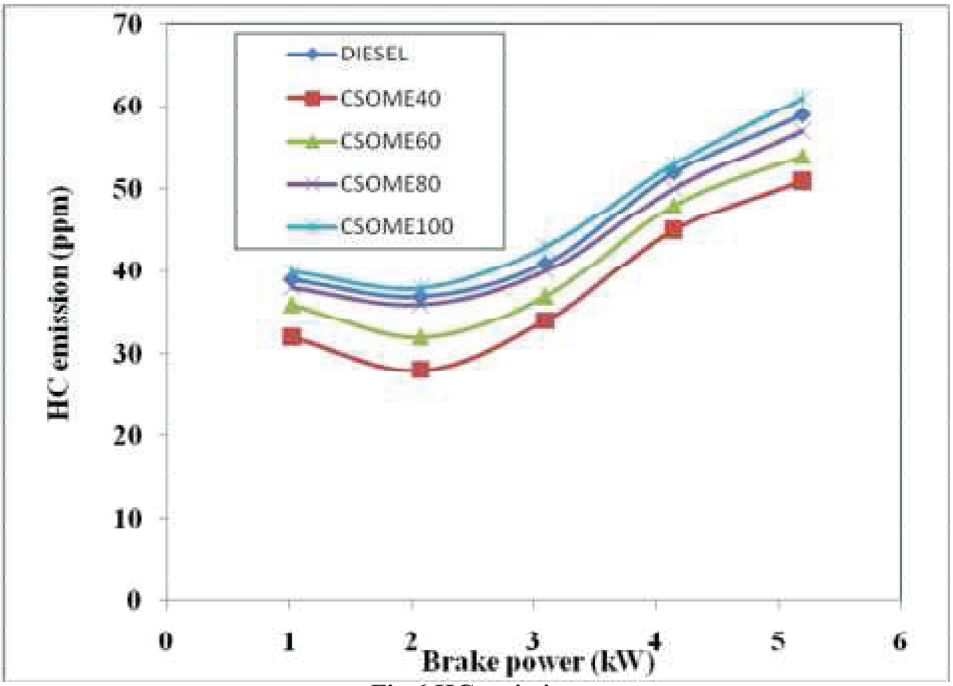


Fig.6 HC emission

Fig.7 shows the variation of the NOx emissions of the test engine for CSOME with reference to diesel fuel. It is seen that the CSOME operations usually yield higher NO_x emissions at all loads compared to diesel fuel operations. The increase in NO_x emissions with CSOME may be attributed to various reasons, such as improved fuel spray characteristics, better combustion of biodiesel due to its high oxygen content and higher temperatures in the cylinder as a result of preheating . The maximum increase in NO_x emissions were obtained in CSOME80. The NO_x emissions with CSOME80 increase approximately 11% as compared to diesel fuel at full load.

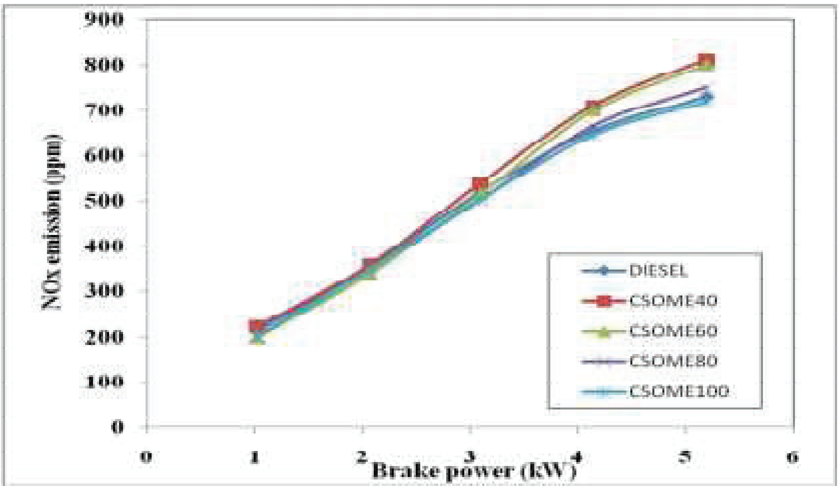
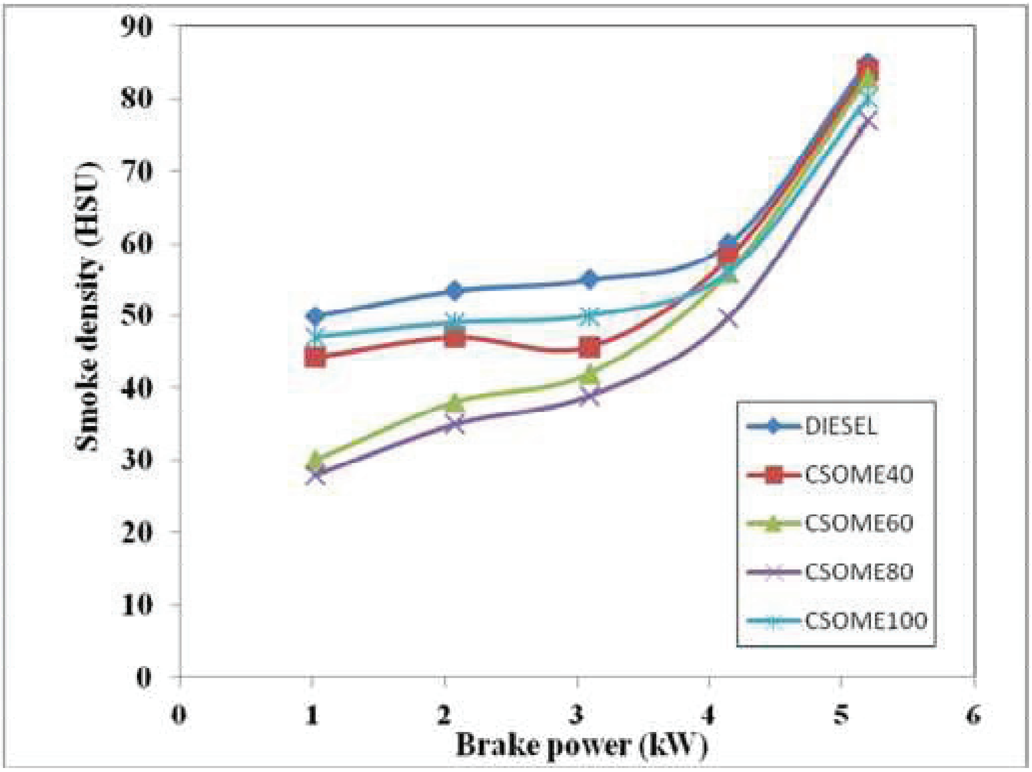


Fig.7 NOx emission

The variation of smoke density for different CSOME is shown in Fig. 8. The Smoke density of CSOME is lower than that of the diesel oil. The viscosity of preheated CSOME is comparatively lower than neat diesel. Due to this, the spray pattern and fuel penetration are improved. But for CSOME100 the smoke density is slightly higher that of diesel and other CSOME. This is due to uneven fuel spray pattern in the combustion chamber, because of vapour locking in the pump and pipe line. The smoke density is decreased from 80 HSU to 76 HSU for diesel and CSOME80 respectively at full load.



5.

Fig. 8 Smoke density

5. Conclusions

Cottonseed oil methyl ester (CSOME) was produced by means of transesterification process using cottonseed oil, which can be described as a renewable energy source. The viscosity of COSME was reduced by preheating it before supplied to the test engine. After the fuel properties of COSME has been determined, various performance parameters and exhaust emissions of the engine fuelled with COSME preheated at different temperatures were investigated and compared with those of diesel fuel. The experimental conclusions of this investigation can be summarized as follows:

- Preheating of CSOME makes significant decrease in its kinematic viscosity and a small decrease in specific gravity. It is almost nearer to the values of diesel fuel.
- The Brake Specific Fuel Consumption (BSFC) increased from 269g/kWhr to 345 g/kWhr for diesel and CSOME 100 respectively at full load.
- The Brake Thermal Efficiency (BTE) with the CSOME100 is 5% and 13% lower than that of CSOME80 and diesel fuel.
- The use of preheated CSOME produced a considerable decrease in CO emissions. CO emissions obtained with CSOME80 operations were 34% lower than that of diesel fuel operations.
- Compared with diesel fuel, CSOME gives lower HC emissions. The HC emission of CSOME 80 decreases 16% at the maximum load of the engine in comparison with diesel fuel.
- NO_x emissions were increased due to higher combustion temperatures caused by preheating and oxygen content of CSOME. The maximum increase in NO_x emissions were obtained in the case of CSOME80.The NO_x emissions with CSOME80 increase approximately 11% as compared to diesel fuel at full load.
- The smoke density decreased from 80 HSU to 76 HSU for diesel and CSOME80 respectively at full load.

In general, the performance and emission level of preheated methyl ester of cotton seed oil are improved. But the NOx emissions are increased due to higher combustion temperature and oxygen content in CSOME.

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