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# Experimental Studies on Di Diesel Engine Using Pre Heated Cotton Seed Oil Ethyl Ether as Alternative Fuel

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## Abstract

In this investigation, the Cotton Seed Oil Di-Ethyl Ether (CSODEE) was prepared by transesterification using cotton seed oil, Di-Ethyl Ether and potassium hydroxide (KOH) as a catalyst. At different preheated temperatures, the performance and exhaust emissions of a diesel engine fuelled with preheated CSODEE were obtained and compared with neat diesel. Experiments were conducted at different load conditions in a single cylinder four stroke DI diesel engine. CSODEE was preheated to temperatures namely 30, 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 CSODEE leads favorable 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 CSODEE. On the whole the results shows that CSODEE preheated up to 80°C can be used as an alternate fuel for diesel fuel without any significant modification in expense of increased NOx emissions.

**Keywords :** Cotton seed oil ethyl ether, Diesel engine performance, Exhaust emissions, Pre-heated biodiesel

## 1. INTRODUCTION

The idea of using vegetable oil began in the year 1893 itself when diesel engines came into existence. In the year 1911, Rudolf Diesel operated his first engine using straight vegetable oil (peanut oil). The physical and combustion properties of vegetable oils are closer to that of diesel and in this context; vegetable oils can stand as an immediate candidate to substitute for fossil fuels. The greatest advantages of vegetable oils are that they are obtained from seeds of various plants. In view of this, researchers have started showing renewed interest towards vegetable oils because of its advantages as a potential alternate fuel. Vegetable oils are renewable and eco-friendly in nature and at the same time, it can be easily produced in rural areas. Sustainable development of a country depends on the extent that it is managing and generating its own resources. This also helps in conservation of depletion of non-renewable petro-products. However due to inherent high viscosity and low volatility, vegetable oils would pose problems such as fuel flow and poor atomization and constrain their direct use in engine without any modifications vegetable oils are either edible or non-edible. Some of the edible oils are sunflower oil, palm oil, rice bran oil, and cottonseed oil. The non-edible oils are mahua oil, jatropha oil, rubber seed oil, etc. As rice bran and cottonseed oil (CSO) are not very much in use for cooking purpose, these can be used as substitute for diesel in CI engines. Cottonseed oil has several properties closer to that of diesel but certain properties such as high viscosity and low volatility pose problem when used as an alternate fuel for C.I engines.

The potential of using vegetable oil for diesel engines was studied by Recep Altin et al. [1], Yoshomoto .y et al. [2] and Kensuke Nishi et al.[3]. The engine performance was very much similar to that for diesel with little power loss and slight increase in the emission level. Karaosmanoglu.F et al[4] studied long-term utilization of vegetable oil and no significant increase or loss in power was noticed. Nwafor O.M.I et al. [5] carried out combustion studies on both diesel fuel and vegetable oil fuel with standard and advanced injection timings. Advanced injection timing compensates the effects of the longer delay period and slower burning rate that is exhibited by vegetable oils. The problems related to low volatility and high viscosities are offset by subjecting the oil into the process of transesterification, and the high viscosity can be reduced. Methyl and ethyl esters of vegetable oil (called as bio-diesel) have the physical and chemical properties closer to that of diesel. The performance and emission characteristics of the diesel engine using methyl ester are comparable with that of diesel as per Dilip Kumar Bora et al. [6]. Babu A.k et al. [7] also has reported problems related to high viscosity. Blending vegetable oil with diesel decreases the viscosity and improves the volatility. This improved properties results in better mixture formation and spray penetration. A number of investigators tried the vegetable oils in varying proportions with diesel. Results obtained from experiments shows that vegetable oil and diesel blends showed improvement in engine performance [8, 9]. Pre heating the vegetable oil reduces the viscosity and improves combustion characteristics (Pramanik. K [10]). This paper examines the use of preheated cottonseed oil diesel blends on the performance of a single cylinder diesel engine. Preheating the vegetable oil decreases the viscosity and improves the atomization and mixing process, which results in better combustion.

## 2. PRODUCTION OF COTTONSEED OIL DI-ETHYL ETHER

Cotton seed 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 DEE (30% by weight) and the mixture was added to the cotton seed oil. Then the prepared mixture was stirred at 60$^{o}$c for 30 minutes. There after the reactant material was poured into transparent vessel and allowed for cooling at room temperature for 7-8 hours. It was allowed to settle for separation of glycerol as bottom layer. The upper layer of biodiesel was kept into another vessel for washing with equal amount of water. The biodiesel was heated up to 110$^{o}$c for 15 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 lab. 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. The gross calorific value of the cotton seed oil, cotton seed ethyl ether and diesel were determined with the help of Bomb calorimeter.

## 3. EXPERIMENTAL SETUP AND TEST PROCEDURE

The experiments were conducted on a single cylinder four stroke DI diesel engine as shown in Fig 1. The engine specifications are described in Table 1. The test set up consists of 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 CSODEE at five different temperatures of 30$^{o}$C, 40$^{o}$C, 60$^{o}$C, 80$^{o}$C, 100$^{o}$C.

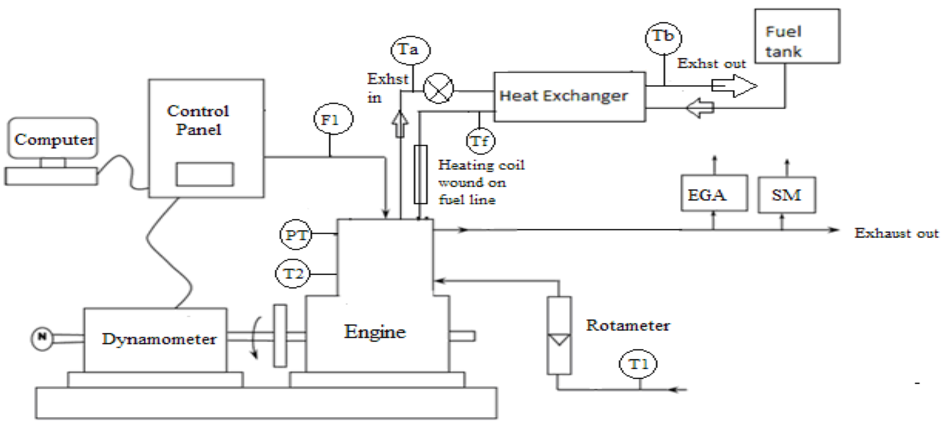


**Fig 1:** Schematic diagram of the experimental test rig

T1- Inlet engine water temperature PT - Pressure transducer N - RPM Decoder
T2 - Outlet engine jacket water temperature Ta, Tb - In and out temperature of exhaust gas in H.E
Tf - Fuel temperature at outlet of H.E EGA - Exhaust Gas Analyzer (5 gas)
F1- Fuel Flow (Differential Pressure unit) SM – Smoke Meter

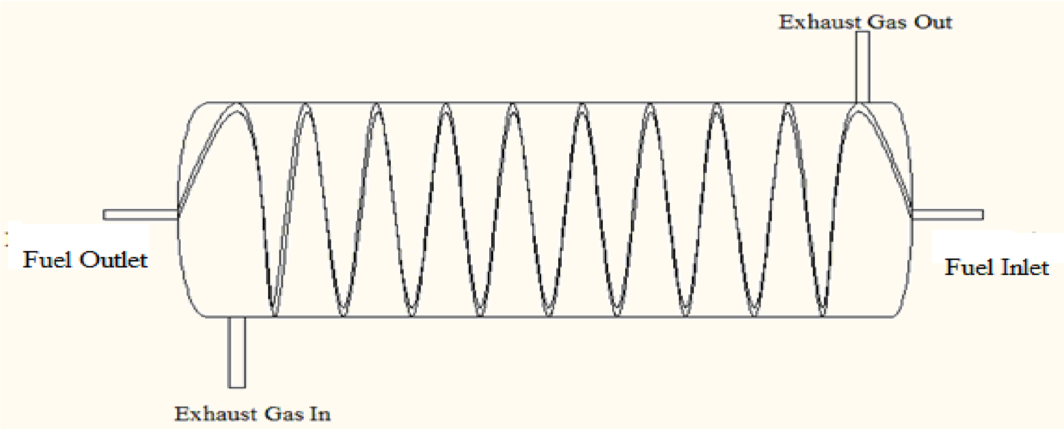


**Fig 2:** Heat Exchanger

**Table.1** Test Engine Specification

| | |
|---|---|
| Engine | Four-stroke, single cylinder, constant speed, water cooled CI Engine |
| Make | Kirloskar |
| Model & BHP | TV1 & 5.2kW@ 1500 RPM |
| Compression Ratio | 17.5:1 |
| Dynamometer Type | Eddy Current, with loading unit |
| Load Measurement | Strain Gauge Load cell |
| Interfacing | ADC card- PCI 1050 |

The engine was connected to an eddy current dynamometer and the engine was running at a constant speed of 1500rpm. 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. The smoke density is measured by smoke meter. The gas analyzers were calibrated with standard gases and zero gas before each test. Same procedures were repeated for CSODEE at different temperatures namely 30,40,60,80, and100$^{o}$C. The physical properties of neat diesel fuel of CSODEE are shown in Table 2,

**Table: 2** The properties of diesel fuel and COSDEE

| Property | Cotton seed oil | Cotton seed oil Di-Ethyl Ether (CSODEE) | Diesel fuel |
|---|---|---|---|
| Density(g/ml) | 0.96 | 0.926 | 0.830 |
| Kinematic viscosity, cS at 38°C | 226.82 | 8.58 | 5.80 |
| Gross calorific value($MJkg^{-1}$) | 36.20 | 40.16 | 46.22 |
| Flash point(°C) | 317 | 157 | 47 |
| Acid value(mgKOH/g) | 1.642 | 1.018 | 0.00 |
| Free fatty acid content (%) | 2.8 | 1.96 | 0.00 |

**Table: 3** The Properties of CSODEE at different Temperatures

| Temperature of CSODEE(°C) | 30 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|
| Specific gravity | 0.872 | 0.898 | 0.876 | 0.867 | 0.885 |
| Kinematic viscosity(cSt) | 7.98 | 7.85 | 5.9 | 4.8 | 1.9 |

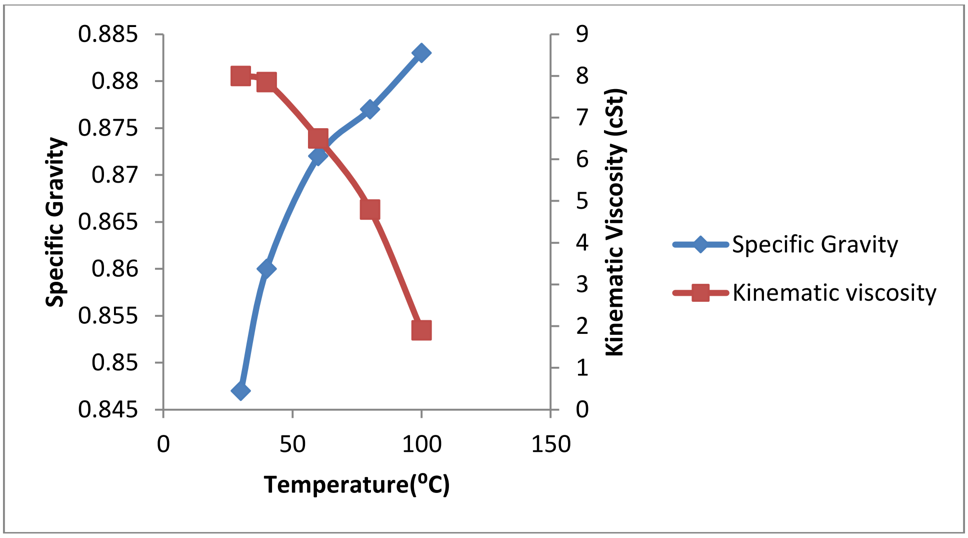


**Fig 2:** Effect of preheating on the Kinematic viscosity and specific gravity of CSODEE

### 3.1 Engine Performance and exhaust emissions

The changes of brake specific fuel consumption (BSFC) with brake power for different CSODEE are presented in Fig 3. The BSFC of all CSODEE is higher than that of diesel for all loads. For all CSODEE 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 556 g/kWhr to 665g/kWhr for diesel and CSODEE 100 respectively at full load. This is due to the effect of higher viscosity and poor mixture formation of CSODEE. But the BSFC is decreased due to increasing the preheating temperature of CSODEE. This is due to the reduced viscosity and improved spray characteristics of CSODEE.

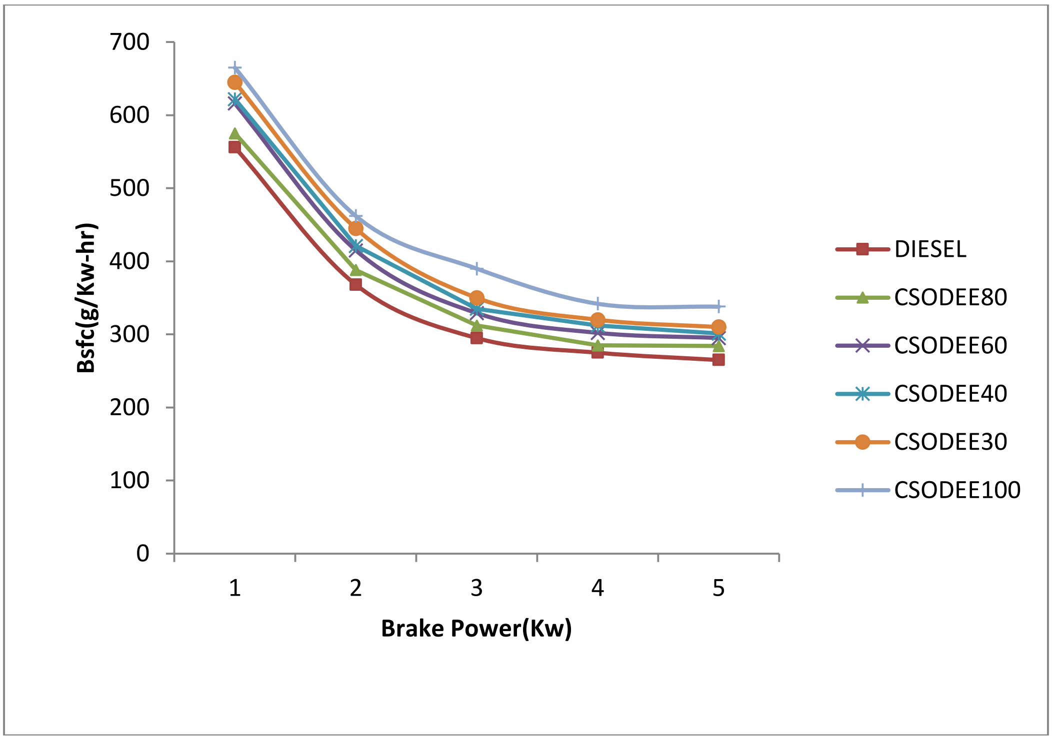


**Fig 3:** Brake specific fuel consumption

The variation in the brake thermal efficiency (BTE) of the engine fuelled with CSODEE preheated to30°C, 40°C, 60°C, 80°C and 100°C which are indicated by CSODEE30, CSODEE40, CSODEE60, CSODEE80, CSODEE100, Respectively, with reference to diesel fuel are shown in Fig 4. The increase in BTE with CSODEE operations can also be attributed to the good combustion characteristics of bio-diesel owing to their decreased viscosity and improving volatility by means of preheating process. It is seen that the BTE of CSODEE increased by the preheated temperature 30°C, 40°C, 60°C, and 80°C , But for 100°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 CSODEE100 is 5% and 13% lower than that of CSODEE 80 and diesel fuel respectively.

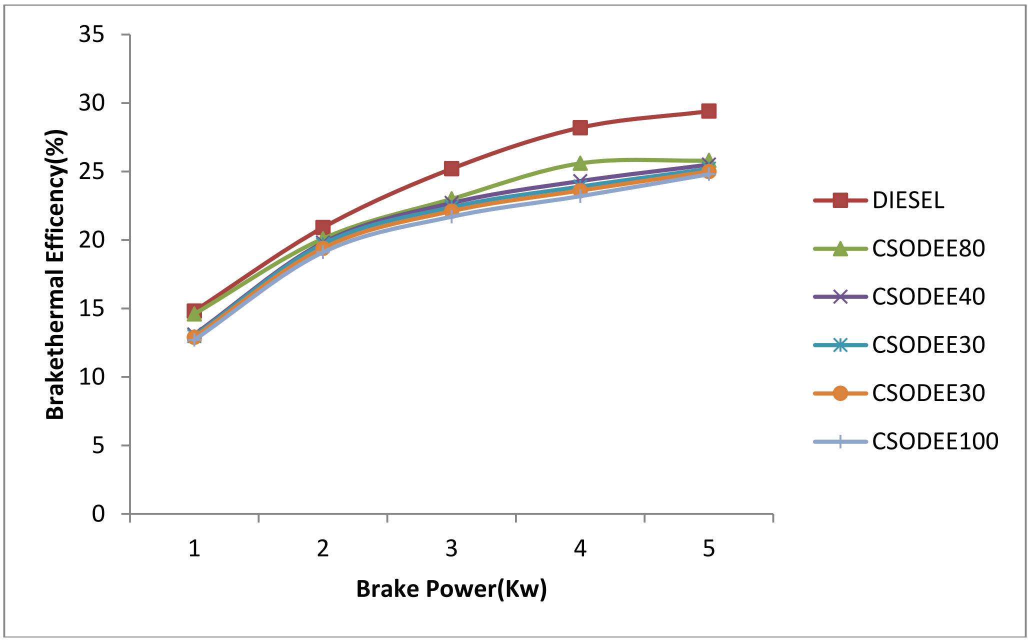


**Fig 4:** Brake thermal efficiency

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 CSODEE 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 CSODEE100, the CO emission is higher than that of CSODEE30, CSODEE40, CSODEE60 and CSODEE80, 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 CSODEE80 were 13% lower than that of diesel operations at full load.

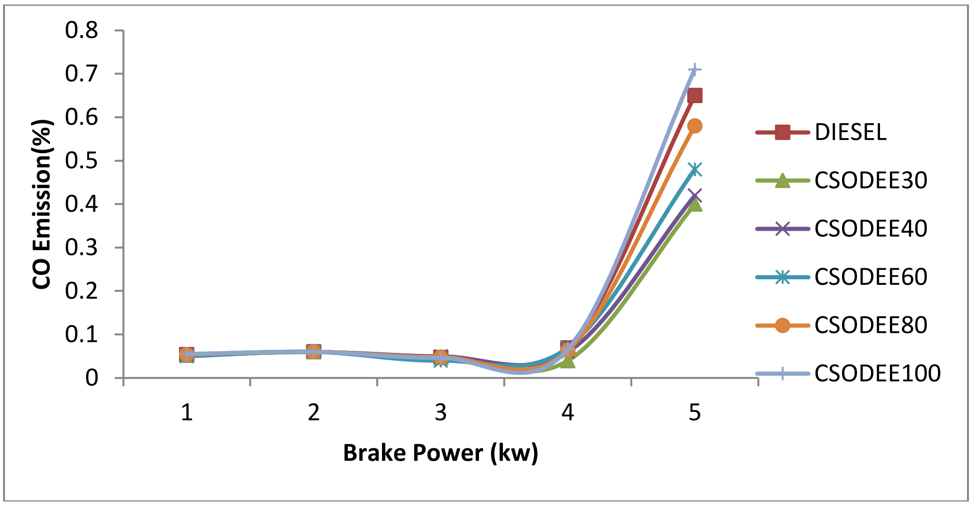


**Fig 5:** CO Emission Vs Brake Power

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, CSODEE give lower HC emissions. The HC emissions of CSODEE80 decrease 5.4 % at the maximum load of the engine in comparison with diesel fuel. The higher oxygen content of CSODEE leads to better combustion, resulting in lower HC, However, the HC emissions of CSODEE100 are higher than of other CSODEE. This is due to incomplete combustion occurring at uneven spray characteristics.

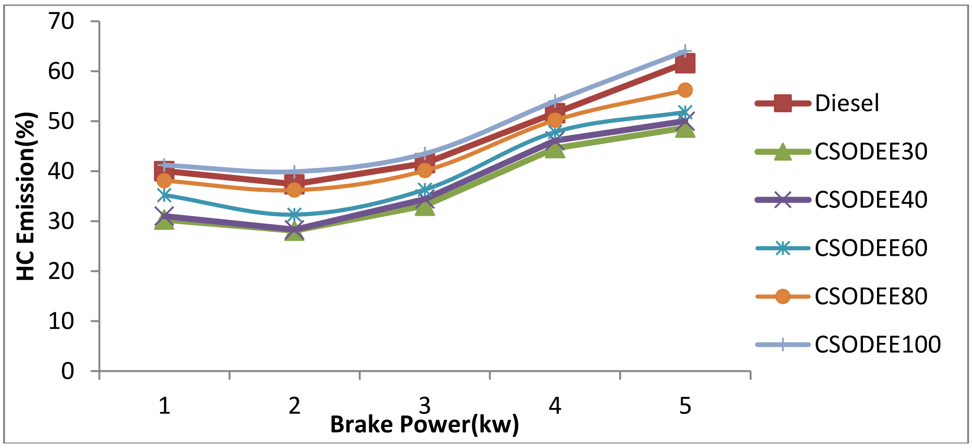


**Fig 6:** HC Emissions Vs Brake power

Fig7 shows the variation of the $NO_X$ emissions of the test engine for CSODEE with reference to diesel fuel. It is seen that the CSODEE operations usually yield higher $NO_X$ emissions at all loads compared to diesel fuel operations. The increase in $NO_X$ emissions with CSODEE may be attributed to various reasons, such as improved fuel spray characteristics, better combustion of biodiesel due to its high oxygen content and high temperatures in the cylinder as a result of preheating. The maximum increase in $NO_X$ emissions were obtained in CSODEE80. The $NO_X$ emissions with CSODEE80 increase as compared to diesel fuel at full load.

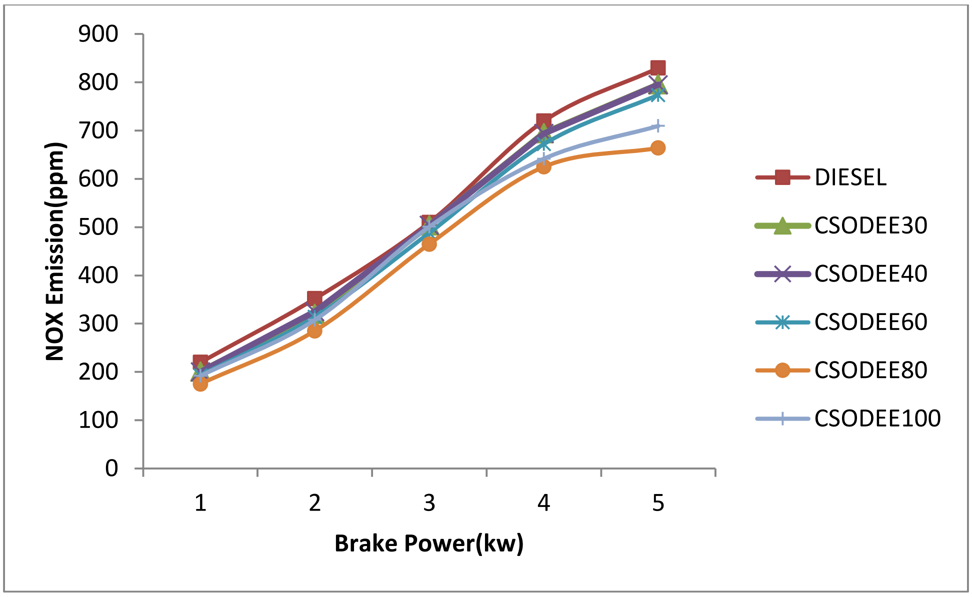


**Fig 7:** $NO_X$ Emission Vs Brake Power

The variation of smoke density for different CSODEE is shown in Fig . The Smoke density of CSODEE is lower than that of the diesel oil. The viscosity of preheated CSODEE is comparatively lower than neat diesel. Due to this, the spray pattern and fuel penetration are improved. But for CSODEE100 the smoke density is slightly higher that of diesel and other CSODEE. 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 89HSU to 73 HSU for diesel and CSODEE80 respectively at full load.

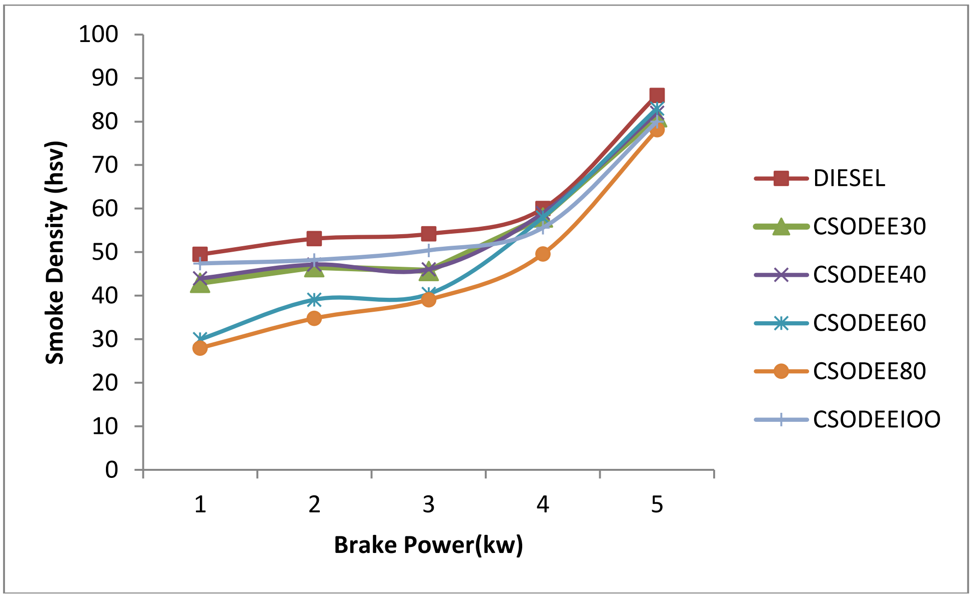


**Fig. 8:** Smoke density Vs Brake power

## CONCLUSIONS

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

- Preheating of CSODEE makes significant decrease in its kinetic 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 CSODEE100 respectively at full load.
- The Brake Thermal Efficiency (BTE) with the CSODEE100 is 5% and 13% lower than that of CSODEE80 and diesel fuel.
- The use of preheated CSODEE produced a considerable decrease in CO emissions. CO emissions obtained with CSODEE80 operations were 34% lower than that of diesel fuel operations.
- Compared with diesel fuel, CSODEE gives lower HC emissions, The HC emissions of CSODEE 80 decreases by 16% at maximum load of engine in Comparision with the diesel fuel.
- $NO_X$ emissions are increased due to higher combustion temperatures caused by preheating and oxygen content of CSODEE. The maximum increase in

$NO_X$ emissions were obtained in case of CSODEE80. The $NO_X$ emissions with CSODEE80 increases approximately 11% as compared to diesel fuel at full load.

- The smoke density decreased from 89 HSU to 73 HSU for diesel and CSODEE80 respectively at full load.
- In general the performance and emission level of preheated ethyl ether of cottonseed oil are improved. But the $NO_X$ emissions are increased due to high combustion temperature and oxygen content in CSODEE.

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