Investigation of performance and emission characteristics of four stroke single cylinder diesel engine with DEE as oxygenated fuel additive

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Abstract : ***The aim of this experiment was to enhance the performance of a four stroke single cylinder diesel engine by using oxygenated fuel additive with different concentration in diesel which is a base fuel. The oxygenated fuel additive consists of oxygen concentration which allows better combustion and controls the emission from diesel engine. It also enhances the performance of the engine because it mainly depends on combustion process. The fuel additive used in the experiment is diethyl ether. DEE was mixed in diesel in different proportion as 2%, 6%, 10%, 13%, 15% . Experiment was performed on single cylinder four stroke diesel engine. The result showed a significant improvement in fuel consumption, CO, HC emissions and smoke density as well.***

IndexTerms – Oxygenated fuel, Diethyl ether, emission, fuel consumption.

I. INTRODUCTION

As compared to petrol engine, diesel engines are more familiar worldwide for power generation because of its high thermal efficiency, high torque capacity, low HC & CO emission etc. So diesel engines cannot replace by any other prime mover in near future. Various technologies are invented to face the issue of confined resources of petroleum fuel & emission reduction like Exhaust gas recirculation technology, Common rail direct injection system, Homogeneous charge compression ignition & Premixed charge compression ignition combustion technology, duel fuel injection etc. Using these various engine & combustion technologies strict pollution norms can be meet. Biodiesel, ethanol, methanol, vegetable oils, LPG, CNG etc. are the various renewable alternative fuels are being used to meet the stringent emission norms & improve engine performance. These alternative fuels having some disadvantages like high viscosity, low Cetane number, storage problem, low energy density, safety requirement & miscibility limit with diesel[9]. Although CI engines have a higher thermal efficiency when compared with SI engine, advanced research in the combustion of diesel fuel in CI engine shows that the Brake thermal efficiency, Brake power can further be increased by allowing the fuel to combine with more oxygen atoms to form complete combustion, this also reduces the smoke, CO and HC emissions. The oxygen composition in the combustion chamber can be increased by adding oxygenates in the diesel fuel. Oxygenates like ethanol, 1-propanol, 1-butanol, 1-pentanol, 2-methoxyethanol, 2-ethoxyethanol, 2- butoxyethanol dibutyl ether and methanol are widely used. Ethanol is used in SI engines to improve the combustion, it has a higher octane value, but for CI engine ethanol has poor cetane value, so it is not possible to use in CI engines. When Ethanol is dehydrated diethyl ether is obtained which has a cetane number of 125 which is very good as a fuel[10]. DEE is liquid at ambient temperature which make it attractive fuel for handling. Various properties of Diesel, Biodiesel and Diethyl ether are given in Table 1.

Table 1 Properties of Diesel, Biodiesel and DEE[8]

Properties	Diesel	Biodiesel	DEE
Density (Kg/m3)	823	850	713
Oxygen content %	0	11	21.6
Calorific value (MJ/Kg)	43000	40600	37000
Auto ignition temperature °C	315		160
Viscosity @40°C (cst)	3.9	9.2	0.26
Flash point °C	56	140	-40
Boiling point °C	188		34

The experiment carried out by J. Wang, J. Xiao and S. Shuai[1] explores the possibility to significantly reduce the particulate matter (PM) emissions by new fuel design. Several oxygenated blends were obtained by mixing the biodiesel, ethanol, and dimethyl carbonate (DMC), and diesel fuels. The tests were conducted on two heavy-duty diesel engines, both with a high-pressure injection system and a turbocharger. The total PM and its dry soot (DS) and soluble organic fraction (SOF) constituents were analyzed corresponding to their specific fuel physiochemical properties. A blended fuel that contains biodiesel, DMC, and high cetane number diesel fuels was chosen eventually to enable the diesel engines to meet the Euro IV emission regulation. Based on the test results, the basic design principles were derived for the oxygenated blends that not only need the high oxygen content, but also the high Cetane number and the low sulfur and low aromatic contents. The fuels used in this study include a baseline diesel fuel, three types of biodiesels, and their blends with ethanol, DMC, DMM, and straight-run (or directly distilled) diesel fuel. Ethanol, DMC, and DMM are used as oxygenates to raise the oxygen content, while the straight-run diesel fuel is used to improve the auto-ignition capability of the blended fuel. When fueling oxygenated blends, the direct soot constituent in PM emissions decreases significantly as the fuel oxygen content increases. However, when the oxygen content reaches 15% or higher, reduction rate becomes slow.
S.K. Mahla[6] et al. Studied The Performance Characteristics Of Acetylene Gas In Dual Fuel Engine With Diethyl Ether Blends. Experiments were conducted to study the performance characteristics of DI diesel engine in dual fuel mode by aspirating Acetylene gas in the inlet

manifold, with diesel- diethyl ether blends (DEE) as an ignition source. Fixed quantity of Acetylene gas was aspirated and Blend of diethyl ether with diesel (DEE10, DEE20 and DEE30) was taken and then readings were taken at various loads. From the detailed study it has been concluded that the blending ratio of DEE20 gives better performance. Dual fuel operation along with addition of diethyl ether resulted in higher thermal efficiency when compared to neat diesel operation. Acetylene aspiration reduces smoke and exhaust temperature.

Thamaraikannan M. et al.[7] Carried an experimental analysis of Combustion and Emissions characteristics of CI Engine Powered with Diethyl Ether blended Diesel asFuel. Experiments were carried out with 5% DEE and 10 % DEE blend. When the DEE composition was further increased beyond 10% the engine became unstable and heavier smoke were observed. This may be due to the phase separation of the blend, which results in cavitation in the injector nozzle and it leads to poor injection of fuel in to the combustion chamber. Blending DEE with diesel and its usage in conventional diesel engine increases the brake thermal efficiency and reduces the BSFC. The NOx emissions are reduced and there is an increase in the CO and HC emission this can be avoided if optimum DEE and Diesel fuel blending ratio is used without making the fuel mixture to be too lean. The high latent heat of evaporation of DEE counter acts the Cetane benefit which increases the HC emission.

Combustion and emission characteristics of a direct-injection diesel engine fueled with diesel-diglyme blends were investigated by Yi Ren, Ke Zeng and Bing liu.[2] The results show that the ignition delay and the amount of heat release in the premixed combustion phase decrease with the increase of the oxygen mass fraction in the blends. The diffusive combustion duration and the total combustion duration decrease, while the amount of heat release in the diffusive combustion phase increases with the increase of the oxygen mass fraction in the blends. The maximum mean gas temperature in the cylinder increases and the duration of the high gas temperature decreases with the increase of the oxygen mass fraction in the blends. The center of the heat-release curve moves close to the top dead center and the effective thermal efficiency increases with the increase of the oxygen mass fraction in the blends. Moreover, the smoke concentration decreases with the increase of the oxygen mass fraction in the blends. Under the high engine load, smoke decreases by 3.7% for a 1 wt % increase of the oxygen mass fraction in the blends. The NO*x* concentration shows a slight decrease or remains unchanged with the increase of the oxygen mass fraction in the blends.

The experiment was carried out by Zuohua Huang, Ke Zeng, Bing Liu and Xibin Wang[3] on single cylinder diesel engine. Oxygenated blends were prepared by adding methanol and solvent to diesel fuel, and engine performance and emissions of the oxygenated blends under various fuel delivery advance angles were conducted in a compression ignition engine. The results showed that the engine thermal efficiency increased and the diesel equivalent brake specific fuel consumption decreased as the fuel delivery advance angle for the oxygenated blends increased, and the behavior had a tendency to be more obvious at high engine speed. The NO*x* concentration in the oxygenated blends increased as the fuel delivery advance angle increased. For a specific fuel delivery advance angle, the NO*x* concentration increased as the oxygenate mass fraction in the fuel blends increased, whereas a large addition of oxygenates in the diesel fuel reduced the NO*x* concentration. The addition of oxygenate in the diesel fuel had a strong influence on the NO*x* concentration at high engine load, whereas it had little influence at low engine load. The CO content decreased as the fuel delivery advance angle at high engine load became retarded, whereas at middle and low loads, the CO concentration varied little with variation of the fuel delivery advance angle but presented a low value for the diesel/oxygenate blends. The fuel delivery advance angle had little influence on the exhaust hydrocarbon (HC) content for the diesel/oxygenates blends. The amount of smoke can be decreased remarkably by the addition of oxygenate in diesel fuel at the setting of various fuel delivery advance angles. The amount of smoke decreased as the fuel delivery advance angles for both diesel fuel and diesel/oxygenate blends increased; this phenomenon would be due to the increase in the fraction of fuel burned in the premixed burning phase and the decrease in the fraction of fuel burned in diffusive combustion phase, as well as the improvement of the diffusive combustion in the presence of oxygenated blends. The study also showed that a flat NO*x*/smoke tradeoff curve existed when the oxygenated blends were used.

The experiment was carried out by Juhun Song, Vince Zello and Andre Boehman[4] on single cylinder turbo diesel engine. The experiment was carried out to check the effect of oxygen enrichment of air and oxygen enrichment of fuel on the emission characteristics of engine. Test was performed at 75% load and 1900 rpm because the effect of oxygen enrichment is considerable at full load than no load condition. For oxygen enrichment of fuel a mixture of glycol ether and diglyme with a cetane number 100 was used. The other fuel additive used was 1, 3-dioxolane.They concluded that oxygen enrichment of intake air reduces diesel PM significantly more than fuel oxygenation, fuel oxygenation can provide PM reduction with only a modest affect on NOx emissions. With their linear structure, the glycol ethers that comprise CETANER were shown to be far more effective for soot reduction than equivalent oxygen addition via Dioxolane with its ring structure.

The investigation was carried out by T. Nibin, A. Sathiyagnanam and S. Shivprakasam[5] to improve the performance of a diesel engine by adding oxygenated fuel additive of known percentages. The effect of fuel additive was to control the emission from diesel engine and to improve its performance. The fuel additive dimethyl carbonate was mixed with diesel fuel in concentrations of 5%, 10% and 15% and used. The experimental study was carried out in a multi-cylinder diesel engine. The result showed an appreciable reduction of emissions such as particulate matter, oxides of nitrogen, smoke density and marginal increase in the performance when compared with normal diesel engine. The experiment was carried out on a Matador, four cylinders, four strokes, diesel engine which was loaded by a hydraulic dynamometer. They concluded that Smoke level and PM decreases with 5% DMC addition with the neat diesel fuel. The NOx level decreases with 5% DMC addition with the neat diesel fuel. The soot level decreases with addition of additives to the neat diesel fuel. There is a marginal increase in brake thermal efficiency with 5% DMC addition with the neat diesel fuel. The 5% DMC addition to the neat diesel fuel gives the best results. This result is optimum for the performance and emission characteristics of the diesel engine.

II. EXPERIMENTAL SET-UP

A single-cylinder, 4-Stroke, water-cooled diesel engine of 5 hp rated power is considered for the purpose of experimentation. The engine is coupled to a rope brake dynamometer through a load cell. It is integrated with a data acquisition system to store the data for the off-line analysis. Cooling water is circulated separately to the engine and the dynamometer at the required flow rates. Necessary provisions are made to regulate and measure the flow rates of the air, fuel and the coolant. The experimental work towards engine performance evaluation was done in two steps. The steps are as follows.

1. Base data generation
2. Performance evaluation for various flows of additional oxygen and for various concentration of DMC additive in diesel.

1. Base data generation:

For the engine, fuel injection pressure was maintained constant 150 Kg/cm^2 and injection advance angle was kept 20°C before TDC. Load on the engine was varied from no load to 20%, 40%, 60%, 80%, 100% and 110% of full load. Following readings were taken for each load applied on engine.

(i) Speed of the engine
(ii) Time in seconds for 100 cc fuel consumption
(iii) DBT, WBT of ambient air and height difference between two limbs of manometer
(iv) Cooling water inlet and outlet temperature and mass flow rate
(v) Exhaust gas temperature
(vi) Exhaust emission and smoke density.

Fuel consumption, exhaust gas temperature and exhaust emission was measured for Complete load range from no load to over load condition.

2. Performance evaluation at different DEE concentration:

The fuel additive DEE was added in 2%, 6%, 10%, 13% and 15% in diesel (vol/vol). The experiment was carried out at different load conditions and various parameters such as fuel consumption, cooling water inlet and outlet temperature, exhaust gas temperature and exhaust emissions were measured.

Fig 1. Experimental Set-up

III. RESULT & DISCUSSION

3.1 Specific fuel consumption:

The brake specific fuel consumption decreases marginally with increase in load up to 60% of full load and then curve becomes flat and it again increases at overload condition. The brake specific fuel consumption decreases with increase in concentration of DEE due to more oxygen availability. At 10% of DEE concentration minimum specific fuel consumption is achieved. The reduction in BSFC varies around 6% to 8% for various loads at 10% of DEE concentration. Further increase in concentration of brake specific fuel consumption increases because calorific value of mixture of diesel and DEE decreases considerably due to lower calorific value of DEE and due to which more fuel is required to produce same power. At part load condition the variation in specific fuel consumption for various concentrations of DEE is very less. Considerable reduction is achieved at full load condition.

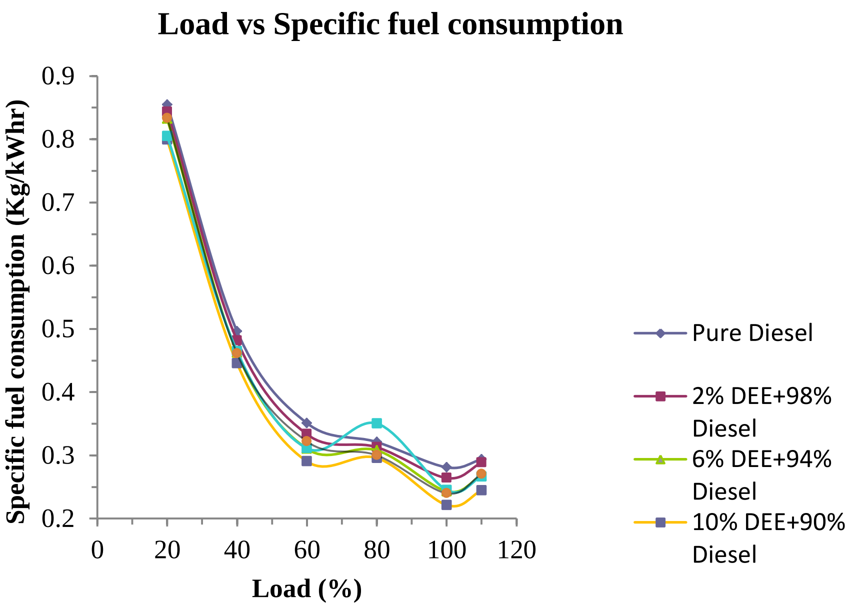

Fig 2. Effect of oxygen enrichment of fuel on specific fuel consumption

3.2 Brake thermal efficiency:

From the graph it is clear that the brake thermal efficiency increases with increase in load when load varies from no load to full load condition and it decreases suddenly at overload condition. The brake thermal efficiency increases with increase in concentration of DEE due to achievement of complete combustion. With increase in load the brake thermal efficiency increases up to full load then again it decreases at overload condition. The graph shows that maximum increment in brake thermal efficiency is achieved for full load condition compared to part load. The maximum improvement in brake thermal efficiency is at full load condition when DEE concentration is varied from 6% to 10%. The peak rise in brake thermal efficiency is achieved at 10% DEE concentration. The brake thermal efficiency for 6% DEE and 15% DEE is quite similar at all loading conditions.

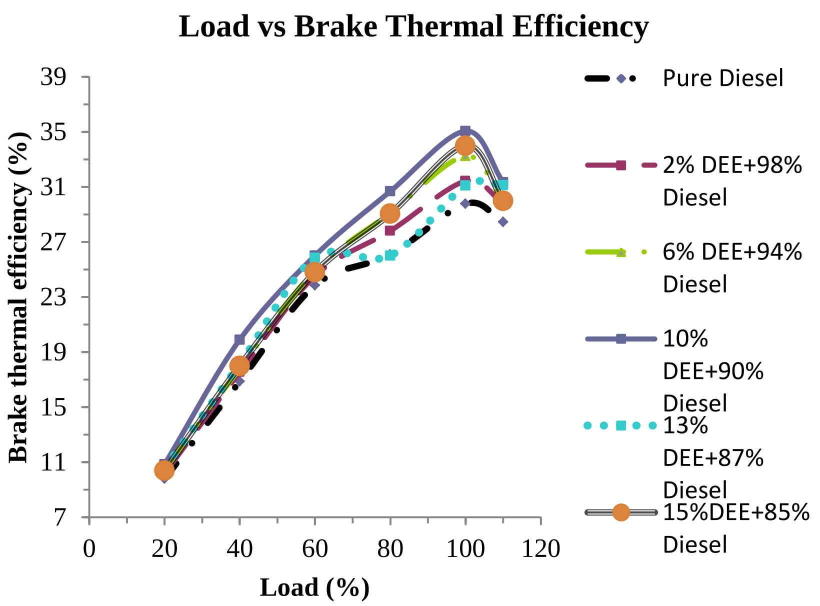

Fig 3. Effect of oxygen enrichment of fuel on brake thermal efficiency

At full load condition brake thermal efficiency is increased in the range from 2% to 9% for various concentration of DEE. The maximum brake thermal efficiency is achieved for 10% DEE. The variation in brake thermal efficiency for various concentrations of DMC is less at part load compared to that of at full load.

3.3 CO Emission:

The generation of CO emission is generally due to incomplete combustion due to less availability of oxygen. From the graph it is clearly seen that the CO emission increases slightly when load varies from no load to 50% of full load. With further increase in load the CO emission increases considerably. The variation in CO emission is negligible with change in concentration of DEE up to 40% loading condition. After 50% of full load, there is significant variation in CO emission for different concentration of DEE. With increase in DEE concentration, emission decreases due to more availability of oxygen which gives complete combustion of fuel. The considerable reduction in CO emission is achieved at full load condition when the DEE concentration is varied from 13% to 15%. At full load condition CO emission is reduced around 18% to 40% for various concentration of DEE.

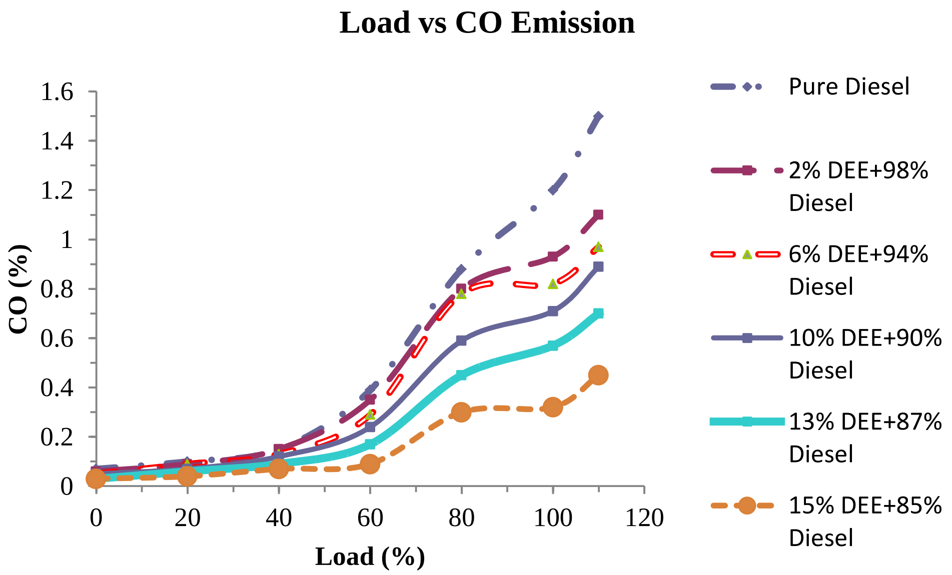

Fig 4. Effect of oxygen enrichment of fuel on CO emission

3.4 HC Emission:

From the graph it is clear that the HC emission increases linearly with increase in load at different load conditions. With increase in concentration of DEE, HC emission decreases due to more oxygen content in mixture of diesel and DEE which reduces the amount of unburnt hydrocarbon fuel. The reduction in HC emission is negligible up to 6% DEE concentration at all the loading condition but with further increase in concentration of DEE in diesel gives more advantage of reduction in HC emission. The minimum HC emission is achieved for 15% of DEE concentration and it varies around 12% to 18% for various loading condition.

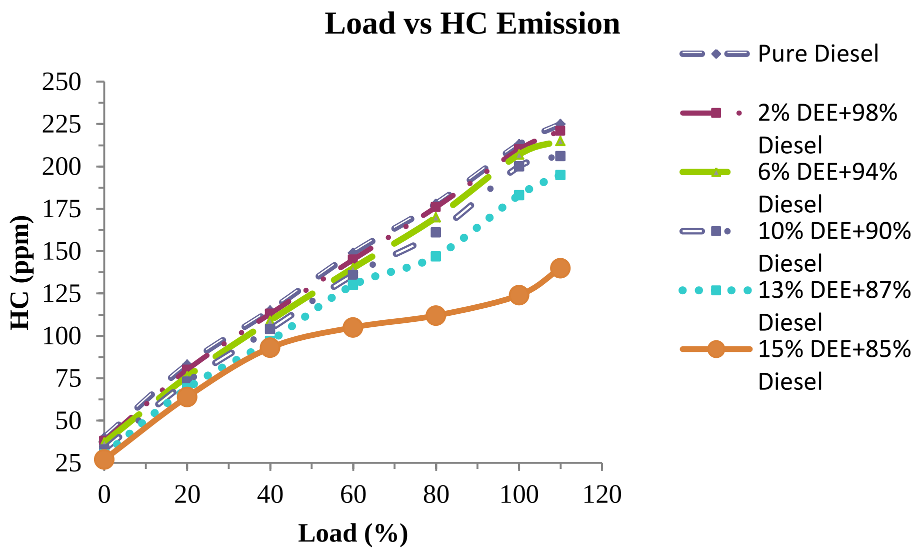

Fig 5. Effect of oxygen enrichment of fuel on CO emission

3.5 Smoke density:

From the graph it is clear that the smoke emission increases with increase in load at all load conditions and for all concentrations of DEE. Smoke emission decreases with increase in concentration of DEE in diesel. With increase in DEE concentration, oxygen content in mixture of diesel and DEE increases which provides improved diffusive combustion and more available oxygen provides oxidation of soot which in turn reduces the intensity of smoke. The reduction in smoke density at 2% and 6% DEE concentration is less as compared to 13% and 15% DEE concentration for entire working load range. At 60% of full load condition there is a considerable reduction in smoke emission when DEE concentration is varied from 6% to 10%. The same advantage is achieved at full load condition when DEE concentration is changed from 10% to 13%.

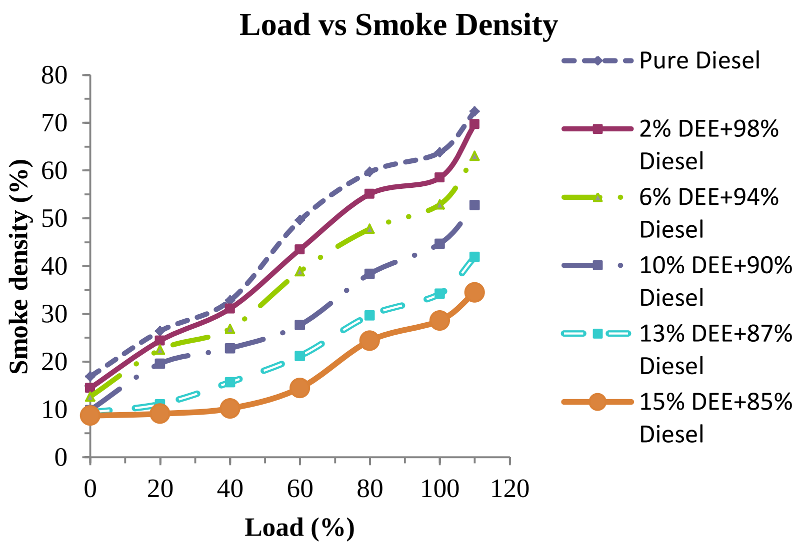

Fig 6. Effect of oxygen enrichment of fuel on Smoke density

IV. CONCLUSION:

Experiment was performed on four stroke single cylinder diesel engine by using different concentration of DEE (Diethyl ether) in diesel (base fuel). Various performance parameters are investigated during experiment like brake thermal efficiency, CO, HC emission, Smoke density etc. From the experiment, following conclusions can be derived.

1. Brake thermal efficiency is maximum for 10% DEE concentration in diesel, further rise in DEE concentration reduces energy content of the blend due to low Calorific value of DEE.
2. The CO, HC emission and smoke density is minimum for 15% DEE concentration in diesel.
3. The marginal decrement in brake specific fuel consumption is observed for 10% DEE concentration in diesel.

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