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A Study on Smoke Reduction in Diesel Engines Through Organic Fuel Additives

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In addition to industrial applications, diesel engines find wide use in power vehicles due to the economy over gasoline engines. Some earlier studies on diesel engine emission control employing metallic additives are briefly reviewed. Considering the formation of undesirable toxic combustion products by the deposits left by the metallic additives, the authors have in the present study examined, rated and reported the smoke reduction characteristics of eight non-metallic organic compounds (one non-oxygenated and seven oxygenated). The effects of additive concentration and the engine load per cent are outlined. The test results are promising. However, further studies are required to evolve ideal additives and to better understand the smoke reduction mechanisms.

Key Words: Diesel Engines, Organic fuel additives.

INTRODUCTION

Diesel engines originally intended for industrial purposes today find ever increasing use in power vehicles due to their economy in operation over gasoline engines. The diesel engines have substantial emissions of which particulate matter in the smoke and oxides of nitrogen are vital. Most particulate material result from incomplete combustion of the fuel hydrocarbons[1]. particularly paraffins, olefins and aromatics; some is contributed by the lubricating oil.

Typically 15–30 mass per cent[2] of the exhaust particulate is extractable in organic solvent (soluble organic fraction, SOF). The biological activity of SOF assessed by Ames test on diesel smoke has shown[3] that the particulate extract contains mutagens.

Until 1970's there was little use of additives in automotive diesel fuel. Now additives are used to improve the flow properties, anti knocking properties and Cetane number. Additives for emission control have gained importance all over the world to combat air pollution. Different types of additives for emission control have been proposed and tested. Badin found[4] that 0.1 to 0.6% (by weight) of barium and zinc, 2-ethyl hexanoates mixed in diesel fuel have substantially

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reduced smoke, the weight ratio of barium to zinc being 10 to 1. Ferrocence[5] (0.1% by volume) hydroquinone ethers[6], nitrated paraffin-naphthene fractions[7] are other additives reported. About 20–50% reduction in smoke could be obtained with these additives. As it has been found[8] that metallic additives leave deposits in engine crank case and can form undesirable toxic combustion products, their uses have been abandoned. In the present work the following eight non-metallic organic compounds have been tested as fuel additives for reducing smoke in the diesel engine exhaust.

1. Cyclohexane
2. 1,4-Dioxane
3. Cyclohexanol
4. Cyclohexanone
5. Morpholine
6. Non-ionic detergent N-100
7. 2-Methoxyethanol
8. Polyethyleneglycol-400

EXPERIMENTAL

All experiments were performed on a single cylinder, naturally aspirated, vertical, water cooled, 4 stroke KIRLOSKAR AV-1 diesel engine coupled with a swing field type DC shunt wound generator-dynamometer. The specifications of Kirloskar AV-1 engine are given in Table-1. The smoke densities in Hartridge Smoke Units of the exhaust were measured using a Netal portable smoke meter kept at the exhaust outlet 3 meters away from the engine. The diesel engine was run at 1500 rpm for about 30 min to attain steady state. Additional two smoke density measurements were made with an interval of 10 min and the concordant values are reported.

TABLE-1
SPECIFICATIONS OF KIRLOSKAR AV-I ENGINE

Bore	80 mm
Stroke	110 mm
Rated output	3.68 kW (5HP) at 1500 rpm
Injection Nozzle	3 Hole nozzle
Injection pressure	225 bar
Type of combustion	Hemi-spherical open combustion
Chamber	Chamber

Bulk quantity of diesel purchased at a time from a single source was used for the entire study. First for the neat diesel run the engine was run at a constant speed of 1500 rpm, at a constant injection pressure of 225 bar and at a constant cooling water flow of 6 lit/min. Using the DC generator 10% of load was applied to the diesel engine and then smoke density, fuel consumption and exhaust gas temperature were measured. In a similar manner, these values were obtained for 24, 35, 48, 62 and 77% of full load (these discrete values of load percentage correspond to the possible variations in electrical resistance). For the run on neat diesel, the measured smoke densities in HSU are 14, 20. 25, 31, 36 and 43 under the above loads respectively.

The additive compounds except non-ionic detergent N-100 were SD/s LR grade chemicals. Non-Ionic detergent N-100 is a condensation product of Nonylphenol and ethylene oxide with approximately 10 ethylene oxide molecules.

These chemicals were used as fuel additives for smoke reduction in diesel engines. The volume percentages of the additives in diesel used were 0.5, 0.75, 1.0, 1.25 and 1.5 for each additive and measurements were made for each blend. A new diesel filter was used for each additive blend to maintain identical conditions.

The percentage reduction in smoke density is calculated as

$$\frac{\text{Smoke density for neat diesel run} - \text{smoke density for additive blend run}}{\text{smoke density for neat diesel run}} \times 100$$

RESULTS AND DISCUSSION

Tests were conducted on KIRLOSKAR AV-1 diesel engine to evaluate the performance of eight organic compounds as anti-smoke additives for diesel. These additives were tested at five different concentration levels (0.5 0.75, 1.00, 1.25 and 1.5% by volume in diesel) each at six different loads (10, 24, 35, 48, 62 and 77%) on the diesel engine.

The variation of smoke density with load for neat diesel run is graphically shown in Fig. 1. The corresponding variations for each additive blend run at different concentrations are depicted in Figs. 2 to 9.

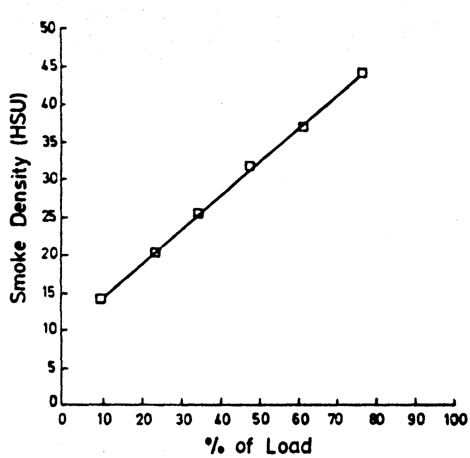


Fig. 1. Variation of smoke density with load for neat diesel

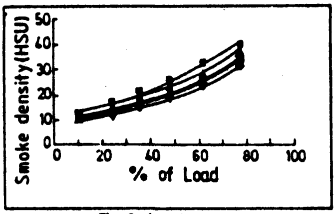


Fig.2 for Adt-1

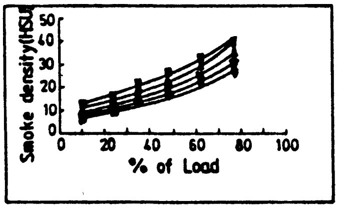


Fig.3 for Adt-2

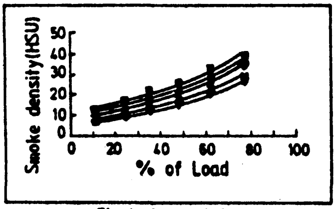


Fig.4 for Adt-3

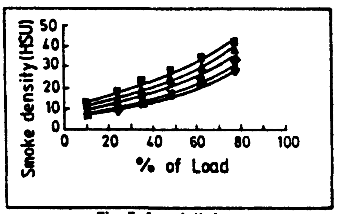


Fig.5 for Adt-4

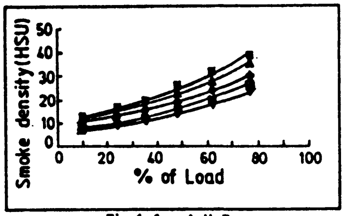


Fig.6 for Adt-5

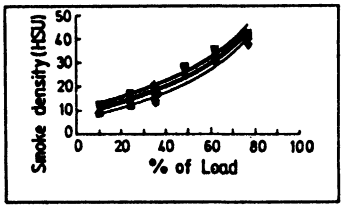


Fig.7 for Adt-6

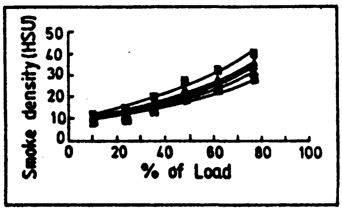


Fig.8 for Adt-7

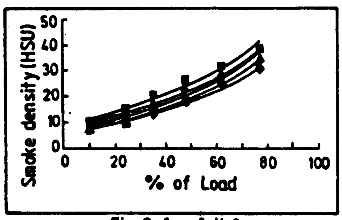


Fig.9 for Adt-8

■ 0.50% ▲ 0.75% ◆ 1% 1.25% ◆ 1.5%

VARIATION OF SMOKE DENSITY WITH LOAD AT DIFFERENT CONCENTRATIONS

For each load, the variations in the percentage reduction in smoke density for all the additives at different concentrations are summerised in Figs. 10 to 15.

Common observations:

There is no appreciable change in specific fuel consumption/brake thermal efficiency due to the blending of chosen additives in diesel.

The smoke density if found to decrease with increasing concentration (in the range tested) of additives. This trend is observed for all the additives and at all loads.

The percentage reduction in smoke density is found to vary appreciably with the type of additive, its concentration in diesel and load on the engine.

All the additives have smoke-reducing properties.

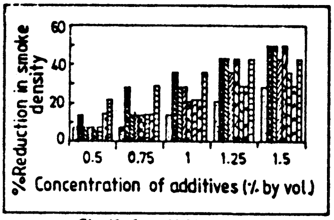


Fig.10 for 10% load

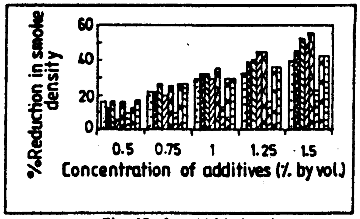


Fig.13 for 48% load

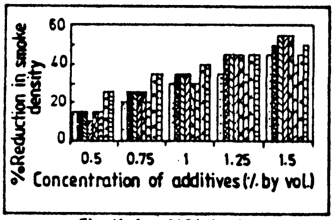


Fig.11 for 24% load

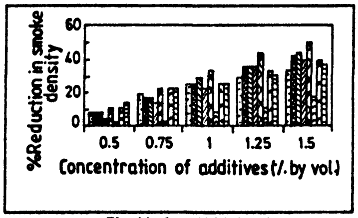


Fig.14 for 62% load

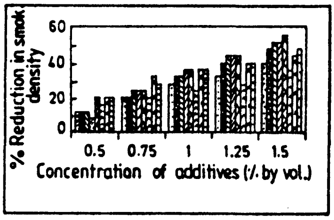


Fig.12 for 35% load

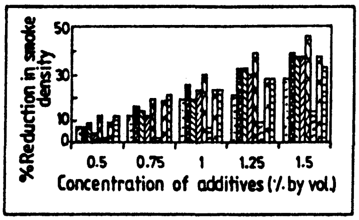
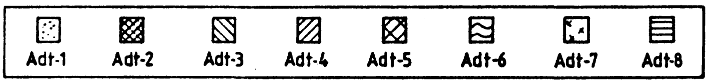


Fig.15 for 77% load



EFFECT OF CONCENTRATION OF ADDITIVES ON SMOKE DENSITY REDUCTION (AT DIFFERENT LOADS)

Very low concentration of the additives (0.5 to 1.5% by volume) and their low calorific values may be the reason for the absence of appreciable change in thermal efficiencies.

From the graphs it is found that the additives used perform well only under certain range of concentrations and loads. The results obtained for the performance of the eight additives tested are reported in the Table-2.

Conclusions

The general performance trend indicates that the oxygenated additives do better than the non-oxygenated cyclohexane. In the case of cyclohexane (density 0.768 g/cc), it decreases the density of diesel blend from that of neat diesel (0.834 g/cc). The anti-smoke property of cyclohexane may be attributed to its ability of lowering the density of diesel blend and hence the fuel droplet size. The efficient burning of small size fuel droplets tend to reduce the smoke. The exact mechanism of smoke reduction by other additives could not be assessed. However, the better performance of oxygenated additives may be attributed to the hydroxy radicals[9] that are formed from the oxygenated additives, which can attack the soot precursors and reduce smoke.

A good anti-smoke additive should produce maximum percentage reduction im smoke density over a wide range of loads at low concentration. On this basis the performance of eight additives tested were evaluated and the rating observed follows the order:

Morpholine > Cyclohexanol > Cyclohexanone > Polyethylene glycol-400
> 1,4-Dioxane > 2-Methoxyethanol > Cyclohexane
> Non-ionic detergent N-100

TABLE-2
PERFORMANCE OF ADDITIVES

Additive	Concentration of the additive (%)	Percentage reduction in smoke density	Optimum load range (%)
Adt-1	1.00	30	Near 24
	1.50	40	20–40
Adt-2	1.25	40	10–35
	1.50	50	10–35
Adt-3	1.25	40	10–48
	1.50	50	10–48
Adt-4	1.25	40	24–48
	1.50	50	24–48
Adt-5	1.25	40	All loads
	1.50	50	10–62
Adt-6	1.25	35	Near 24
	1.50	40	Near 24
Adt-7	1.25	40	24–35
	1.50	45	24–35
	1.00	40	Near 24
Adt-8	1.25	40	10–40
	1.50	50	24–35

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