Technical Note: A brief comparison of the performance of a compression ignition engine fuelled on methanol/dimethyl ether and diesel

D. Cipolat[1] and **N. Bhana**[2]

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The work reported here investigates some performance characteristics of a compression ignition engine fuelled on methanol as the main fuel and dimethyl ether as ignition promotor. Constant speed tests were performed on diesel fuel and then repeated with methanol and dimethyl ether. In addition two exhaust species, namely CO and $N0_x$ are compared for both fuelling methods. Results of tests performed at 1 550 rev/min show that, for any given equivalence ratio, both the brake power and brake specific fuel conversion efficiency are higher in the case of diesel fuelling. A significant reduction in $N0_x$ was achieved with methanol and dimethyl ether fuelling, while the CO emissions were lower only at higher values of equivalence ratio.

Introduction

The use of dimethyl ether as an ignition promotor for methanol as a fuel in compression ignition engines has been shown in several instances.[1,4,5] An initial analysis of the emissions of aspirated dimethyl ether has shown significant reductions in the concentration of NO.[1] However, a comparison of the performance of the engine under the two fuelling systems was not made.

The aims of the present work are to compare some performance indicators of a compression ignition engine fuelled with methanol/dimethyl ether with those of diesel fuelling and to see their effects on some emission species. The tests were performed at constant speed with increasing load.

Test facility

The work was performed on a standard two-cylinder, direct-injection, water-cooled, four stroke, compression ignition engine. The bore and stroke were 87.4 mm and 110.0 mm, respectively. Load was applied by means of a water-cooled eddy current dynamometer.

The liquid fuel was supplied to the engine by means of the existing pump and injector system. The DME was aspirated together with the intake air, at the inlet manifold. One cylinder of the engine was instrumented to measure combustion chamber pressure, fuel line pressure, injector needle lift, degree crank angle, and top dead centre.

[1]School of Mechanical Engineering, University of the Witwatersrand, Private Bag 3, Wits, 2050 South Africa

[2]School of Mechanical Engineering, University of the Witwatersrand, Private Bag 3, Wits, 2050 South Africa

Steady-state data recorded were engine speed and torque, fuel and air flowrates, cooling water, and exhaust temperatures. Exhaust emissions were monitored by means of an electrochemical sensing device.

Test procedure

Reference tests were performed on diesel fuelling at a constant speed of 1 550 rev/min. The load was gradually increased from no load to the point where the smoke level was in excess of 75 HSU. The tests were repeated with methanol/DME fuelling. The contribution of DME, as a percentage of total combustibles, was decreased with increasing load, as shown in Table 1.

Table 1 Percentage DME to total fuelling

Test No.	Equivalence ratio	% DME to total fuelling
1	0.279	67.0
2	0.369	52.8
3	0.417	49.8
4	0.500	46.9
5	0.584	38.8
6	0.650	35.2
7	0.837	32.8

Results

The results will be limited to a discussion of brake power, specific fuel conversion efficiency, maximum combustion chamber pressure, and ignition delay for both fuelling methods. The emission species under consideration are CO and NO_x. These results are plotted against equivalence ratio. This is defined as the ratio of the actual fuel/air ratio to the stoichiometric ratio.

Figure 1 shows brake power *vs* equivalence ratio for both fuelling methods. The maximum power developed with diesel fuelling is about 9.8 kW at an equivalence ratio of 0.76 while, with methanol/DME, these are 8.3 kW and 0.84, respectively. Thus to obtain the same power output with methanol/DME as with diesel fuelling more fuel is required, since the calorific value of both methanol and DME are less than that of diesel. Furthermore, the curve for diesel fuelling appears to show that if more fuel was supplied, the brake power could increase a little further, before dropping off. However, the smoke emitted at the last test was in the region of 80 HSU, therefore any further increase in fuelling would only aggravate the smoke emitted. This would be detrimental to the environment.

The brake power curve for methanol/DME fuelling shows that a maximum has been reached, and a further increase in load and fuel would not produce more power. An attempt was made to increase both, but it was found that the engine speed could no longer remain constant.

Figure 2 shows the brake specific fuel conversion efficiency *vs* equivalence ratio for both fuelling methods. A maximum of 34.7% was achieved at an equivalence ratio of 0.59 with diesel fuelling, while with methanol/DME fuelling a maximum of 28.4% was reached at a ϕ value of 0.65. In both instances the curves show a decreasing trend after reaching their maximum values. Thus any further increase in the amount of fuel would result in a further decrease in brake specific fuel conversion efficiency and consequently engine performance.

The maximum combustion chamber pressure achieved in each test for both fuelling systems is shown in Figure 3. In both instances the pressure rises with increasing equivalence ratio until a maximum is reached. The curve then shows a slight decrease in the case of diesel fuelling, while a more significant drop is observed with methanol/DME. Thus any further increase in fuel and load would only bring about a decrease in performance, as mentioned above. This is also confirmed in the graph of brake specific conversion efficiency, where a decrease is noted at the highest value of equivalence ratio.

Figure 4 shows the ignition delay for both fuelling systems, against equivalence ratio. The ignition delay for diesel fuelling follows the generally accepted almost linear trend of decreasing with increasing load.[2] The delay is noted to decrease by some 5° crank angle over the test range. As the load is increased the combustion chamber temperature also increases. The fuel thus ignites more easily resulting in a reduced ignition delay.

In the case of methanol/DME fuelling the trend is also a decreasing one. The delay is found to be less than that of diesel fuelling throughout the equivalence ratio range. A possible reason for this is that when the methanol is injected into the combustion chamber, the DME has already ignited, thus facilitating the ignition of the methanol. In addition, as the load is increased, the combustion chamber pressure increases, as shown in Figure 3, and as a result the combustion chamber wall temperature increases as well. Therefore the ignition delay decreases further. At a value of ϕ of 0.65, the ignition delay is observed to be a mere 0.3° crank angle, indicating that methanol is ignited as it is injected in the combustion chamber.

The concentrations of CO emissions for both fuelling methods *vs* equivalence ratio are shown in Figure 5.

At low values of ϕ, the CO concentration for diesel fuelling starts low, at about 800 ppm for an equivalence ratio of 0.24. This concentration decreases with increasing load, until a minimum of some 480 ppm is achieved at a ϕ value of 0.48. As the load is further increased, the concentration of CO also increases considerably to reach a maximum of about 4 800 ppm at the maximum value of equivalence ratio.

A different situation arises in the case of methanol/DME fuelling. The concentration of CO starts considerably higher than that with diesel fuelling, about eight times more for about the same value of ϕ. However, as the load is increased CO emissions show a virtually decreasing trend. A minimum value of 1 640 ppm was achieved at maximum equivalence ratio, which represents a reduction by a factor of approximately 3. With regard to CO emissions, methanol/DME fuelling does reduce these emissions, particularly when the engine is operating at higher loads. The values of ϕ, at which the CO concentrations are around their minimum, occur in the region where the brake specific fuel conversion efficiency and brake power are at their maximum, and the ignition delay is close to, or at, a minimum.

Emissions of NO_x *vs* equivalence ratio for both fuelling methods are shown in Figure 6.

The trend exhibited for diesel fuelling conforms to that in the literature.[3] The NO_x concentration reaches a maximum of about 2 100 ppm at a ϕ value of 0.59. At this value of equivalence ratio, the brake specific fuel conversion efficiency is at its maximum, while the corresponding brake power is close to the maximum.

In contrast, the NO_x concentrations with methanol/DME fuelling are considerably lower throughout the equivalence ratio range. The maximum concentration was just under 1 200 ppm at a ϕ value of 0.58, which corresponds to a reduction of almost 50%, in terms of maximum values reached with both fuelling systems. The value of equivalence ratio, at which the maximum occurs, corresponds to that at which maximum combustion chamber pressure also occurred. In addition the maximum combustion chamber pressure with methanol/DME was lower than that achieved with diesel fuelling, as shown in Figure 3, therefore the temperature would also be lower. Since the formation of NO_x is favoured by high temperature, a higher concentration can be expected in the case of diesel fuelling.

Conclusions

The aims in this work were to study some performance characteristics of a compression ignition engine fuelled on methanol/DME, and to look at their effects on some exhaust emissions . Tests were conducted at constant speed while the load was increased.

In terms of performance, the engine was found to produce more power with a higher brake specific fuel conversion efficiency with diesel fuel than with methanol/DME. Ignition delay with methanol/DME fuelling was found to decrease sharply with increasing equivalence ratio.

The analysis of the emissions was limited to CO and NO_x. The concentration of CO was found to be higher with methanol fuelling for values of ϕ less than approximately 0.65. For values larger than this, the concentrations were found to be below those of diesel fuelling. The NO_x emissions showed a benefit in the case of methanol fuelling, as in general the levels were below those with diesel fuelling. Reductions of almost 50% were achieved.

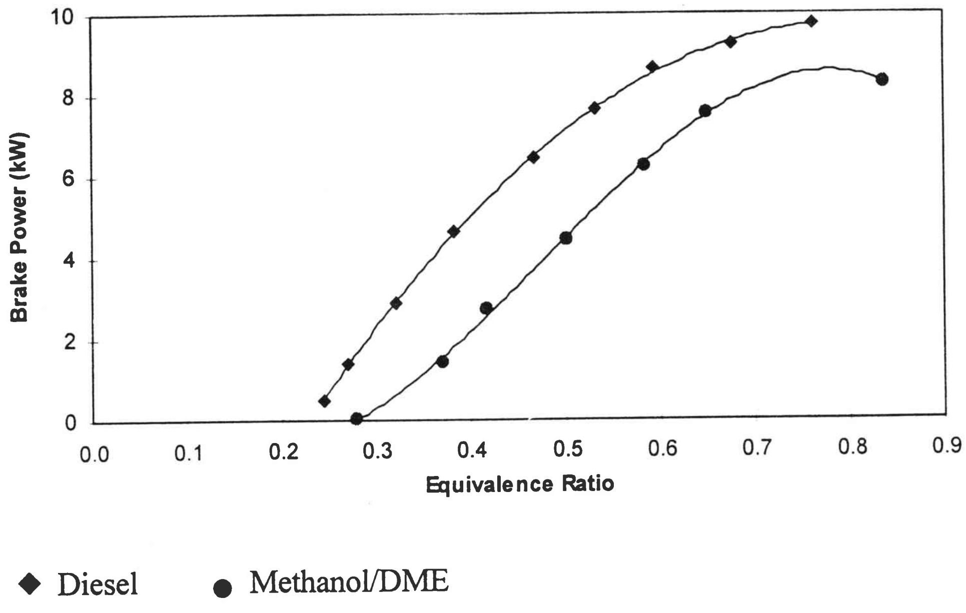

Figure 1 Brake power *vs* equivalence ratio

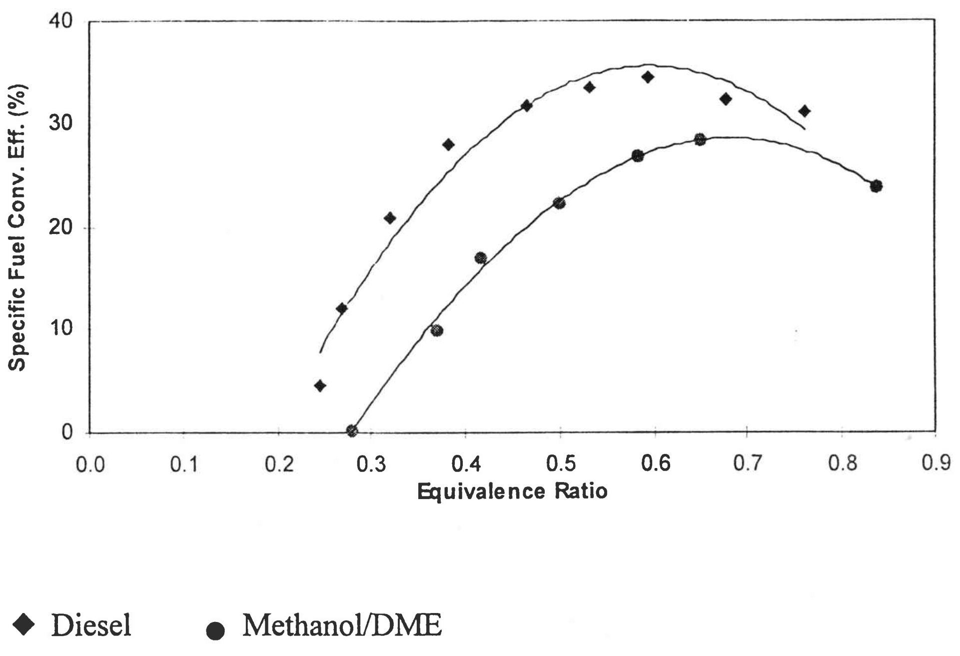

Figure 2 Brake specific fuel conversion efficiency *vs* equivalence ratio

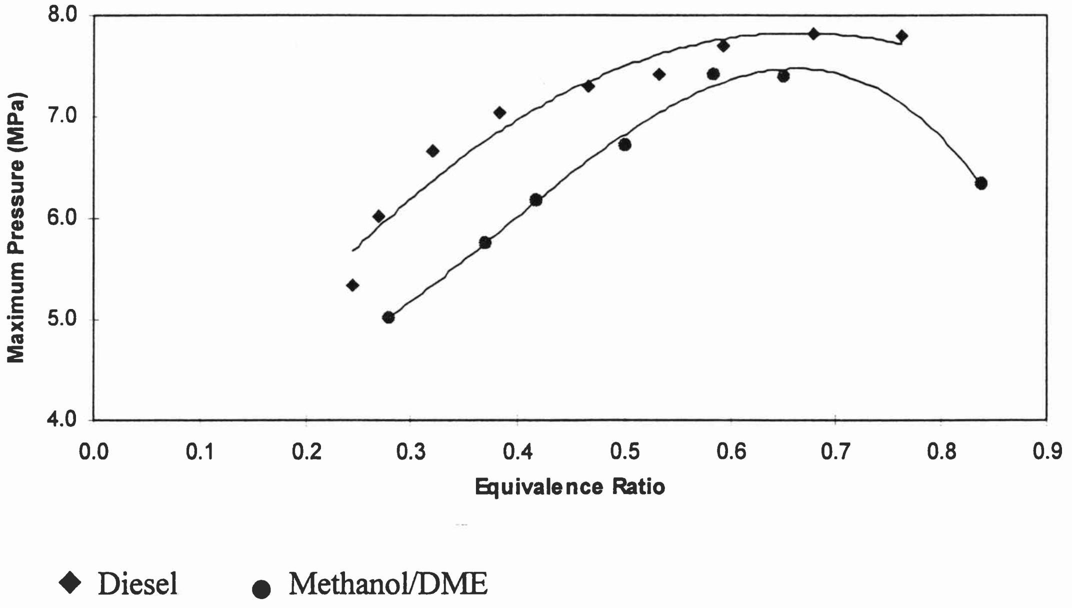

Figure 3 Maximum combustion chamber pressure *vs* equivalence ratio

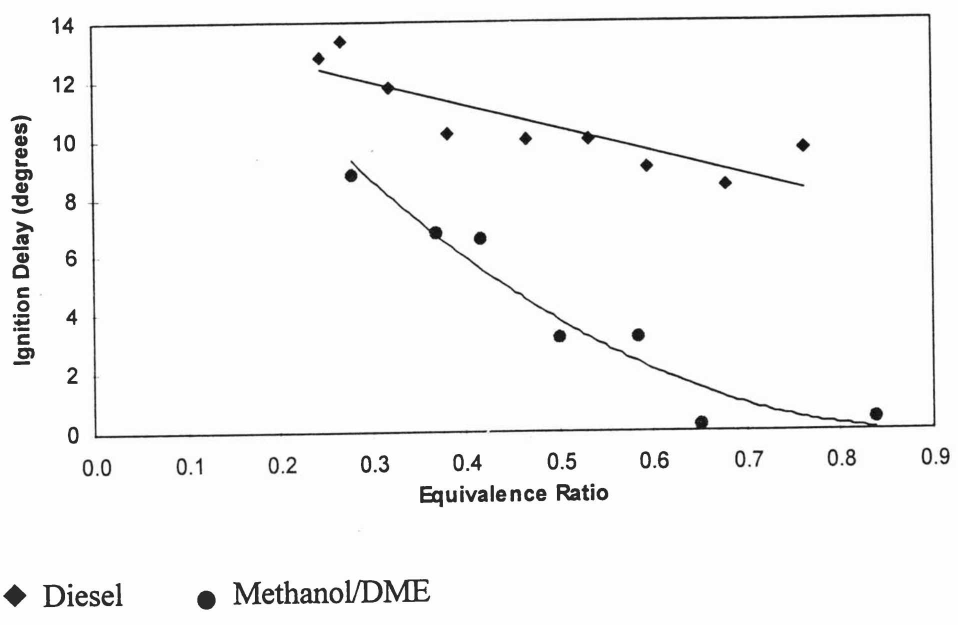

Figure 4 Ignition delay *vs* equivalence ratio

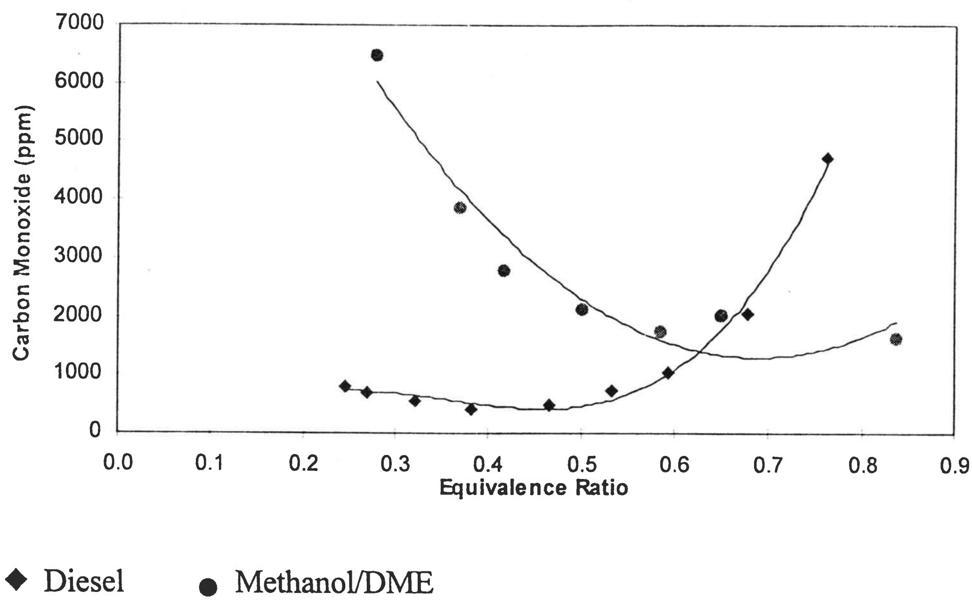

Figure 5 Concentration CO *vs* equivalence ratio

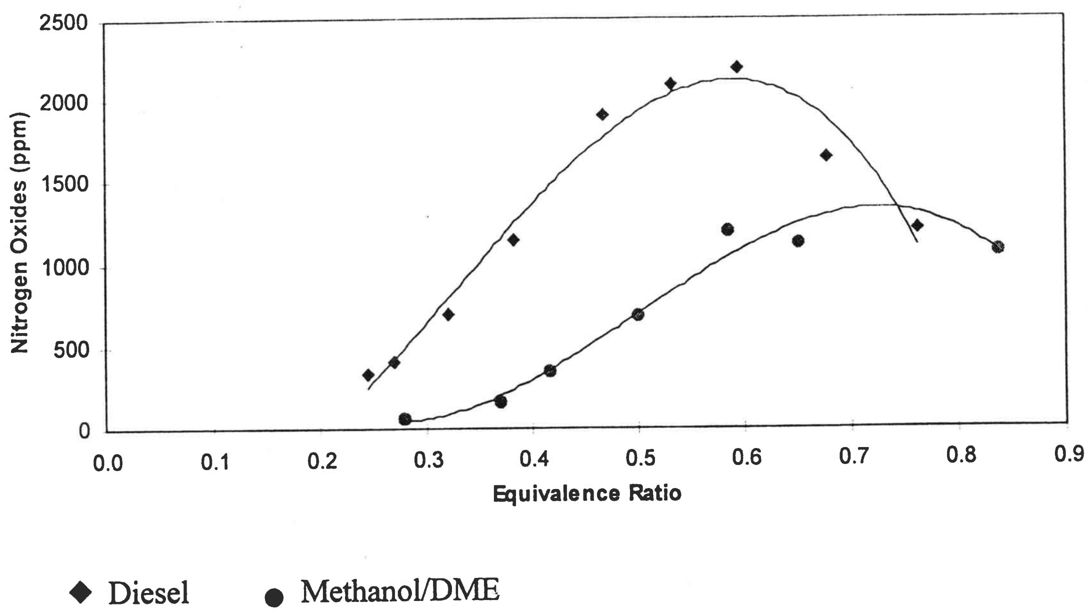

Figure 6 Concentration NO_x *vs* equivalence ratio

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