Analysis of Pressure Traces from an Ethanol Fuelled Compression Ignition Engine

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It has been shown that alcohol fuel may be used as a substitute for diesel fuel, provided an ignition promoter is used (1, 2, 3, 4). In the present research, the ignition promoter dimethyl ether (DME), was aspirated with the intake air. The mixture of air and ignition promoter was then compressed before the main fuel was injected into the combustion chamber. Examination of combustion chamber pressure traces revealed an earlier departure from the motoring curve than in the case of diesel fuelling. This phenomenon is discussed in the present work where pressure traces obtained with diesel and ethanol/DME are compared.

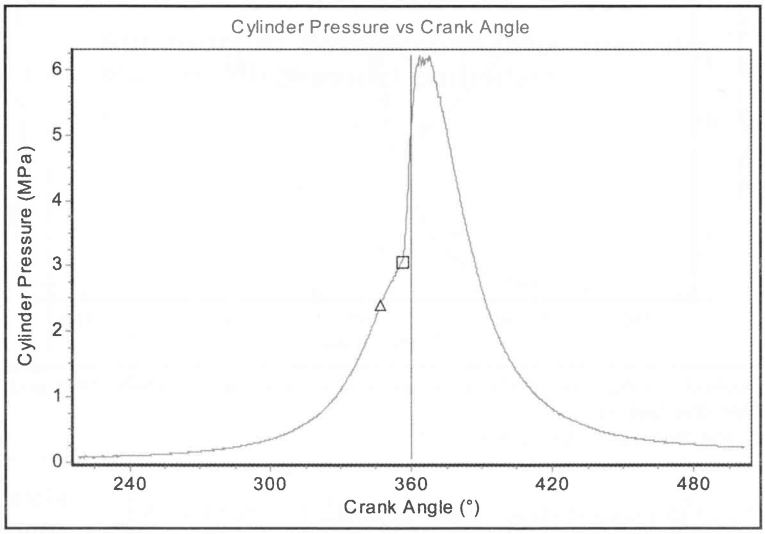


Figure 1: Combustion chamber pressure versus crank angle for diesel fuelling
△: Injection point □: Ignition point

Experimental Setup and Procedure

The research was performed on a two-cylinder, direct-injection, water-cooled, four-stroke compression ignition engine, coupled to an eddy current dynamometer. Dimethyl ether was supplied to the engine through the air intake manifold, and was fed to each cylinder separately.

Data recorded included combustion chamber pressure, fuel line pressure, crank angle, top dead centre, engine speed, fuel and airflow rates, various temperatures and atmospheric pressure.

Tests were initially performed on diesel to serve as a reference. All tests were performed at the midrange constant speed of 1500 rev/min, while the load was gradually increased. The tests were repeated with ethanol/DME fuelling.

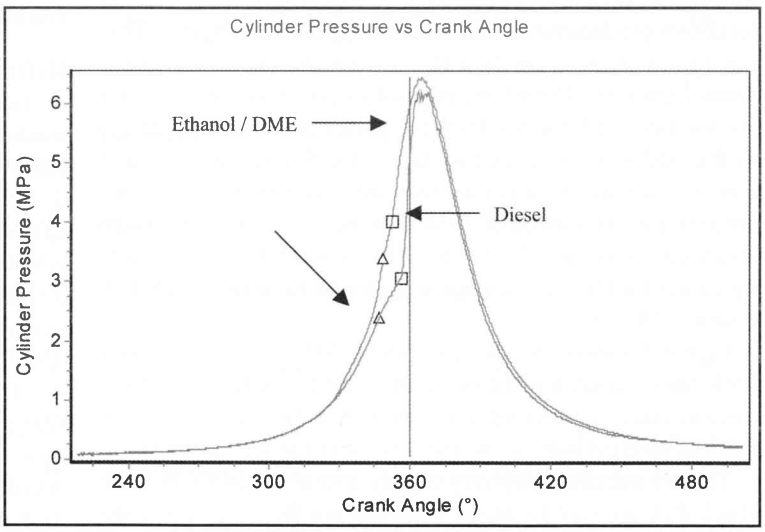


Figure 2: Combustion chamber pressure versus crank angle for ethanol/DME and diesel fuelling
△: Injection point □: Ignition point

Results and Discussion

The performance achieved with ethanol and DME fuelling, in terms of brake power and fuel conversion efficiency was discussed in (3). It was found that the power produced was similar with both fuelling methods, however, the efficiency was some 4% better in the case of diesel fuelling. The ignition delay of both fuelling methods was also discussed (3). Ethanol/DME displayed a much shorter ignition delay than that of diesel.

It was pointed out that since DME is aspirated with the intake air, it starts combusting during the compression stroke, before ethanol injection. Therefore energy release occurs before TDC.

Figure 1 shows the combustion chamber pressure trace using diesel as a fuel, at a load of 42,9 Nm. The injection and ignition points were 346,7^0 CA and 355,7^0 CA respectively, representing an ignition delay of 9^0 CA. The ignition point was determined by the inflection on the pressure curve. These are indicated on the diagram, shown by a triangle and a square respectively. After ignition, the pressure rises very steeply (from 355,7^0 CA) to reach a maximum of 6262,3 kPa. Figure 2 shows the combustion chamber pressure diagram for ethanol/DME fuelling at a load of 44 Nm, with the diesel trace of figure 1 superimposed on it. Injection and ignition of ethanol occur at 348,3^0 CA and 351,7^0 CA respectively, resulting in a shorter ignition delay of 3,4^0 CA. Certain aspects of this diagram are worth noting. The trace is smoother than that of diesel fuelling. There is no marked change in slope between injection and ignition. Careful analysis of the pressure trace shows the presence of a very slight 'hump', indicated by the arrow, starting at some 330^0 CA, and lasting for about 10^0 CA. This is the early departure from the motoring curve, mentioned above, and is the result of part of the DME releasing energy at this stage. The remaining DME releases

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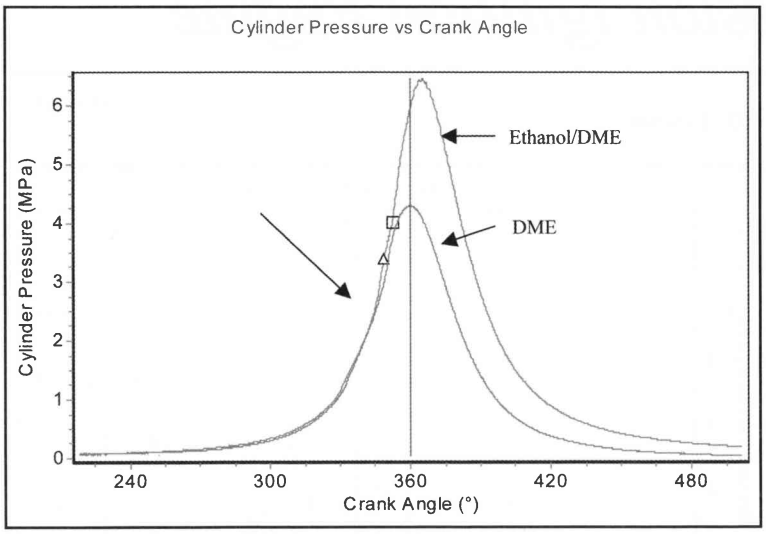


Figure 3: Combustion chamber pressure versus crank angle for ethanol/DME and DME only fuelling
△: Injection point □: Ignition point

energy in a second stage. In this particular test the first release occurred at 328,8° CA, while the second release began at 351,2° CA, with a duration of some 12° CA. The starting crank angle position of both the second stage of energy release and its duration were determined from the energy release diagram. This was followed by a gentle inflection on the curve indicating ethanol ignition. Therefore, ethanol injection occurs in a hot environment with the result that it ignites after a shorter delay. As the load was increased the start of the first stage was noted to occur early as a result of the increasing combustion chamber temperature. At a speed of 1550 rpm the start of the first stage advanced from some 330° CA to 324° CA, while the corresponding values for the second stage were found to be from 345° CA to some 339° CA.

Figure 3 shows the above ethanol/DME trace as well as a DME trace superimposed on it. In order to capture the DME pressure trace, the ethanol injection was cut for one cycle to the instrumented cylinder while the other was fuelled normally.

The two traces overlap very closely up to about 345° CA, after which they are seen to depart from one another. The deviation between the traces prior to ethanol injection may be due to ethanol injection being entirely stopped a cycle or two before the capture of a DME only cycle. This graph shows the contribution of the DME to the pressure rise in the combustion chamber (lower curve) and that of ethanol to the further increase in pressure to a maximum of some 6522 kPa. This is comparable to that achieved with diesel fuelling at similar conditions, where a maximum of 6262,2 kPa was achieved.

Figure 4 shows a DME, an ethanol/DME and a diesel pressure trace plotted over one another. This figure distinctly shows the difference between the start of combustion of ethanol and DME and that of diesel fuel relative to each other. This phenomenon, of the pressure traces separating during the compression stroke, was found to occur in all tests analysed. The early combustion of DME discussed in (3) has also been reported in (4, 5, 6).

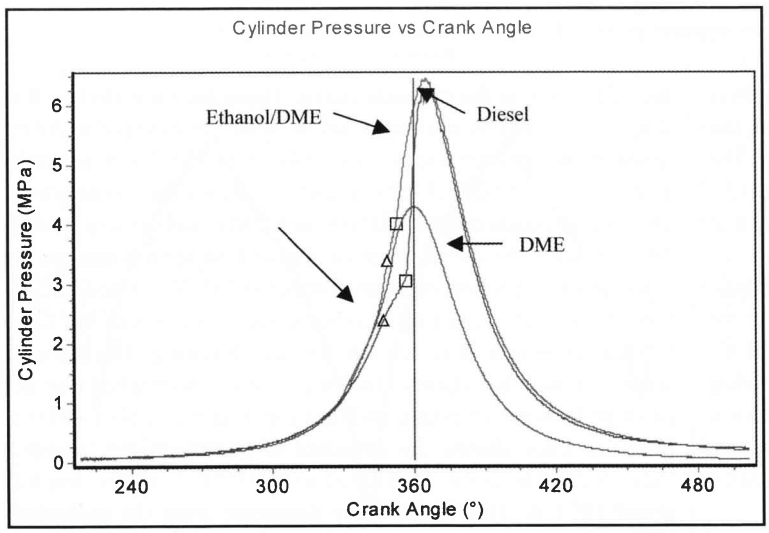


Figure 4: Combustion chamber pressure versus crank angle for ethanol/DME, diesel and DME only fuelling.
△: Injection point □: Ignition point

Conclusions

From the above analysis, it was found that when DME was aspirated with the intake air, it released energy in two stages. The first occurred at some 330° CA followed by a second stage occurring at about 351° CA. The first stage of DME energy release serves as a precursor for the combustion of ethanol.

References

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