MULTIPLE INTRODUCTIONS OF FUEL AND PERFORMANCE OF A DIRECT INJECTION DIESEL ENGINE

R. Udayakumar[1], and S.Sundaram[2],
[1]Department of Mechanical Engineering, [2]Department of Chemical Engineering,
Regional Engineering College,
Tiruchirappalli,
INDIA – 620 015.

Abstract This work aims at improving the performance of a CI engine by manifold fumigation. The secondary fuel (diesel itself) is injected into the heated inlet air with the help of a separate pump and an injector. The timing of the injection was so arranged as to coincide with the inlet valve opening. The optimum quantity of secondary injection and inlet air temperature were found out. Also the pressure crank angle diagrams were recorded for different operating conditions. It was found that with manifold fumigation there is an increase in brake thermal efficiency and reduction in the delay period with consequent smoothening of the pressure diagram.

Key words: Diesel engine-multiple introduction-manifold fumigation

INTRODUCTION

Modern high-speed compression ignition engine is widely and increasingly used in transportations, in automotives and locomotives due to its high fuel economy and low maintenance cost. The high efficiency of the engine mainly results from the high compression ratio used. But the diesel engine works only on constant pressure combustion cycle which is less efficient than the constant volume combustion cycle for the same compression ratio. Had it been possible to burn the fuel at constant volume in the diesel engine in addition to the high compression ratio, the efficiency would have been much more as it will combine the advantages of diesel engine with that of petrol engine in this aspect.

The constant volume combustion can be approached in a diesel engine if the delay period is reduced and when the rate of combustion is high. Since the slow oxidation plays an important role in the processes leading to ignition delay and since factors favoring knock in SI engines generally improve ignition in CI engines, it would be expected that the ignition of the fuel in CI engine might be accelerated by the presence of the active intermediate products of combustion which will be produced by the fuel introduced with the intake air.

The introduction of the fuel in the form of fine mist or fume into the intake manifold is called manifold fumigation. This will represent a little step away from the diesel engine in the direction of the Otto engine, a step which preserves all the diesel advantages and alleviates two disadvantage (1) incomplete mixing of air and fuel (2) and late combustion caused by long ignition lag.

*Email: uday@rect.ernet.in

The production of exhaust smoke is one of the principal factors which limits the power output of a diesel engine and this is particularly true in the case of those engines used for automotive purpose on the road. Aspirating a secondary fuel in the inlet manifold improves combustion and the incomplete combustion is reduced to an extent that the smoke production is reduced. Thus by aspirating the secondary fuel the smoke limited power output if the engine can be increased. The idea of the present work is to introduce the part of the fuel in the form of fine spray into the intake manifold of a CI engine and study the performance of the engine

LITERATURE REVIEW

Soon – IK, kwon et al. (1989) have studied the effects of fumigated fuel on the initial combustion stage of a diesel spray by measuring the ignition delay period and the rate of heat release, clarifying a self ignition limit of a fumigated fuel. Combustion experiments on both fumigated diesel fuel and methanol in a direct injection diesel engine indicated a rapid combustion with the methanol fumigation, while the diesel fuel fumigation slightly changes the combustion of the main spray of diesel fuel injected directly into the combustion chamber.

Mr. G.A. Karim et al. (1989) have examined the ignition delay period occurring in dual fuel engines operating on a wide range of gaseous fuels and in diesel engines with various inert dilutants added to the intake charge. The observed difference in the delay period between dual fuel and diesel operations are attributed mainly to changes in Oxygen concentration of the charge, the charge effective temperature and the chemical kinetic process.

Mr. Govindarajan et al. (1981) had conducted tests regarding road performance of a diesel vehicle with supplementary carburetion of alcohol. A novel Air-alcohol inductor with an inherent flexibility to tailor the alcohol flow rate has been developed for a multicylinder, variable speed, vehicular diesel engine to enable operation in the alcohol – Diesel bi-fuel mode.

Ole Bjorn et al. (1987) conducted test on a special compression ignition research engine to investigate the effects of gaseous fuels in the ignition delay in dual fuel engines. Diesel oil, n-heptane or Cetane were used as pilot fuels and Hydrogen, CO, Methane were inducted in the inlet manifold.

Alwin Lowi et al. (1984) conducted tests on supplementary fueling of four stroke cycle automotive diesel engines by Propane fumigation.

V.S. Ebendiev et al. (1985) in their work found that comparisons of the results of experimental and theoretical investigations of the performance of an air cooled diesel engine with two stage mixing using a two injector fuel system and the usual single stage mixing have been presented. It is shown that use of a two injector fuel system results in an increase of power output by 20-25% on diesel fuel in both stages and is accompanied by a moderate raise in cycle peak pressure.

EXPERIMENTAL PROCEDURE AND DATA ACQUISITION

The experimental set up is shown in Figure 1. The details of the various units are given below:

The engine chosen for the present work is the single cylinder, 7.5 HP Kirloskar engine the technical details of which are given below:

Type of the engine : Four stroke, water-cooled, cold started, vertical, compression ignition.
Model, No. of cylinders : HV-4, One
Rated output in K.W. : 5.5 K.W.
Rated rpm : 1500
Specific fuel consumption: 251 gms/KW-hr
Type of governing : Class B-1
Rating at site condition : As per IS:10001-1981
Direction of rotation : Clockwise looking towards the flywheel
Bore (mm) : 85.5
Stroke (mm) : 110
Cubic capacity (Liters) : 0.661
Nominal compression ratio: 16.5 :1
Type of fuel pump, make and unit: Plunger type
Type of governor : Centrifugal
Type of silencer : Pepper pot.

Vaporizer Unit

A vaporizer unit was fabricated and attached to the inlet manifold. The secondary fuel was injected into the heated inlet air so that it could vaporize easily and drawn into the cylinder. The vaporizer unit consists of a pipe and an injection chamber and it is attached in between the inlet manifold of the engine and the air tank fitted with an orifice to measure the airflow. A heater tape was wound over the pipe with external insulation so that the heat will not flow outside to the atmosphere. To make effective heating of the air flowing to the engine, a swirler unit which looks like a screw conveyor was fabricated and inserted inside the vaporizer unit. With this arrangement air will not have a straight motion but will have to undergo a swirling motion as it passes through the vaporizer. By this smooth flow of air is ensured at the same time the heating will be more effective. The reduction in volumetric efficiency was not found to be much due to obstruction in the air flow to the engine.

Drive for the Secondary Pump

Earlier works done in the dual fuel operations indicated that the optimum quantity of the secondary fuel injected was not more than 25% of the full load fuel consumption of the engine. Therefore, it was decided to choose a pump which will deliver only less quantity of fuel compared with the conventional pumps used in the automobiles. For this purpose the fuel pump of the Lambardini engine was selected because the Lambardini engine is the smallest (320cc) diesel engine available in the market. The corresponding injector and the camshaft of the engine were assembled and used in this work. The drive for operating the secondary fuel pump was taken from the camshaft of the engine with a chain drive. The timing of the injection was so arranged as to coincide with the opening of the inlet valve.

Experimental Procedure

Diesel was used as the secondary fuel and also as the main fuel. Experiments were conducted for different operational conditions as discussed below:
First the performance test of the existing engine was conducted. Then the secondary fuel was inducted at various quantities into the inlet manifold and the performance test was conducted. Then the inlet air was heated and the performance test was conducted at various inlet air temperatures with out secondary fuel induction. Next the diesel was inducted at the inlet manifold into the heated air, in addition to the main fuel injection and the performance test was conducted. The quantity of the fuel inducted into the inlet manifold was varied and the inlet air temperature was also varied.

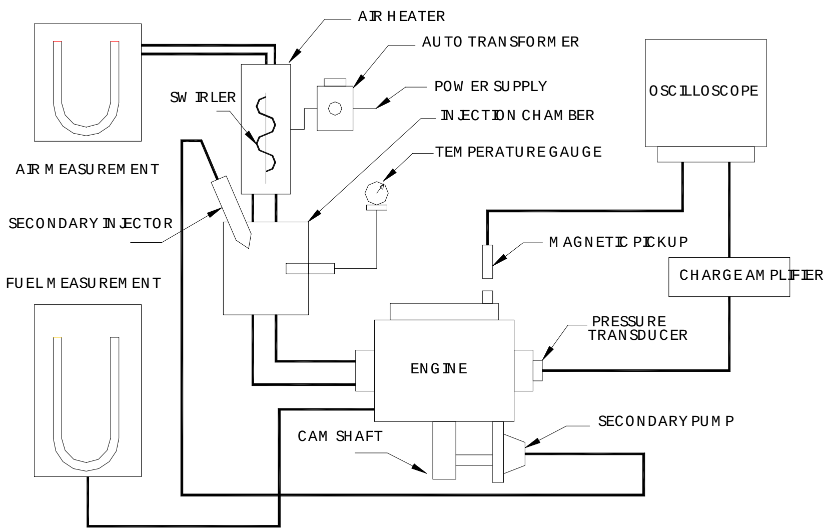

Fig.1 Experimental set up

The various values obtained from the experiments are tabulated and the various graphs are drawn from the data thus obtained.

RESULTS AND DISCUSSIONS

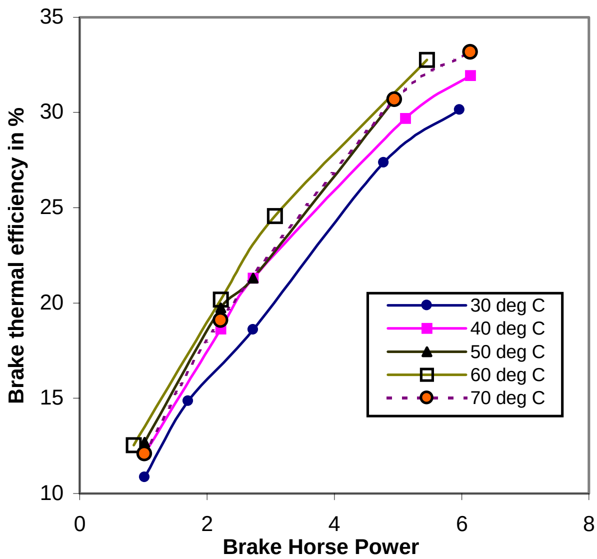

Fig.2 Performance of the base engine at various inlet air temperatures

It is evident from the Fig.2, which shows the performance at various inlet air temperatures of the base engine that the brake thermal efficiency increases as the inlet air temperature increases. This is due to the fact that since the air is preheated, the compression temperature will be correspondingly more, due to this the delay period is expected to be reduced and the rate of pressure raise may be more. This helps out in increasing the thermal efficiency as the inlet air temperature is increased.

But in all the cases the brake thermal efficiency suddenly drops if the air temperature is increased to more than 60 ˚ C. As the air temperature increases the volumetric efficiency decreases, correspondingly the power developed also becomes less. So after 60 ˚ C the rate of reduction in volumetric, efficiency becomes more than the gains due to reduction in delay period and increase in rate of pressure raise. That’s why the Brake thermal efficiency reduces as the inlet air temperature is increased to more than 60 ˚ C.

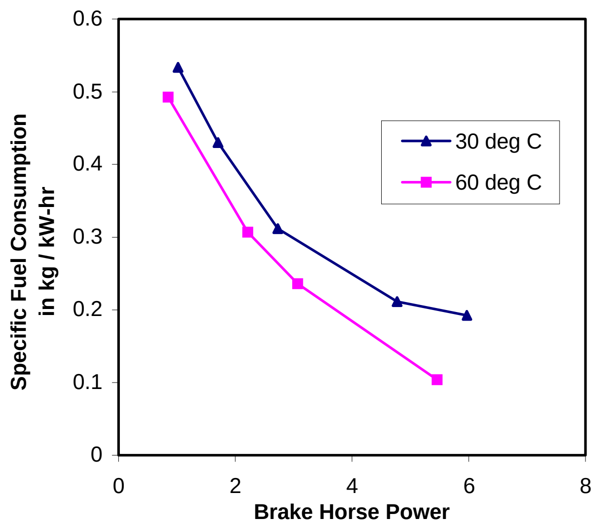

Fig.3 Specific fuel consumption of the base engine at 30 & 60 deg C inlet air temperatures

Fig.3 shows the Specific fuel consumption (SFC) at 30 & 60 deg C inlet air temperatures. More reduction in SFC is noticed at higher loads. Heating the inlet air at higher loads increases the compressed air temperatures to higher values which in turn will quicken the combustion process avoiding after burning, there by contributing to increase in thermal efficiency of the engine. The increase in inlet air temperature decreases the self-ignition temperature. This reduces the delay period besides contributing to faster combustion.

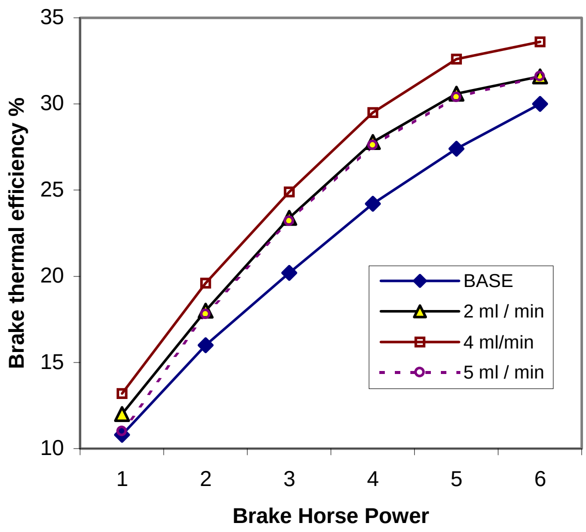

Fig.4 Performance at various secondary injections without inlet air heating

From the test date of different constant inlet air temperatures for various secondary fuel quantity rates, it is evident that the efficiency increases as the amount of secondary fuel injection increases at all inlet air temperatures. For the same amount of secondary fuel injection the efficiency increases as the inlet air temperature increases.

It is seen from Fig.4 and Fig.5 that without heating the efficiency increases up to 4ml/min of secondary fuel injection but drops if the secondary injection is raised to 5ml/min. But at the higher inlet air temperatures such 40,50,60 etc. the efficiency increases up to 5ml/min of secondary injection and it drops if the secondary injection is raised to 6ml/min. The5ml/min is approximately 20% of fuel consumption of the engine at 80% of load.

Table 5.1 shows the value of the brake thermal efficiency for various quantities of secondary fuel injections and Table 5.2 shows the corresponding values of the Total Fuel Consumption expressed in kg/hr. From Table 5.1 and 5.2 the following observations are made: Without inlet heating the most economical secondary injection is found to be 4ml.min. The maximum increase in efficiency is 5.2% when the engine produces 5BHP. From table 5.2 it is evident that almost 130ml is saved if the engine is operated for one hour at this condition.

Table 5.1 Brake Thermal Efficiency (%) At Various Amounts Of Secondary Injections

BHP	Secondary injection in ml/min													
	Nil		1ml / min		2ml / min		3ml / min		4ml / min		5ml / min		6ml / min	
	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C
1	10.8	13.2	11.0	13.4	12.0	14.0	12.8	14.6	13.2	14.9	11.0	15.1	10.6	13.3
2	16.0	19.0	16.4	19.0	18.0	21.0	18.8	21.8	19.6	22.2	17.8	22.8	16.6	20.2
3	20.2	24.6	21.4	24.8	23.4	27.0	24.0	28.0	24.9	28.4	23.2	28.9	21.6	26.6
4	24.2	29.0	24.8	29.4	27.8	31.8	28.4	32.8	29.5	33.4	27.6	34.2	26.0	31.8
5	27.4	32.0	29.4	33.6	30.6	35.4	31.8	36.4	32.6	37.5	30.4	37.2	29.4	35.8
6	30.0	34.0	32.0	36.2	31.6	36.8	32.8	38.0	33.6	38.3	31.6	38.9	30.6	37.6

Table 5.2 Total Fuel Consumption (ml / hr) at Various Amounts of Secondary Injections

BHP	Secondary injection													
	Nil		1ml / min		2ml / min		3ml / min		4ml / min		5ml / min		6ml / min	
	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C	30°C	60°C
1	660	530	650	530	600	510	575	500	565	490	625	480	630	550
2	860	740	850	740	775	680	760	670	755	665	800	660	825	710
3	1040	915	1020	910	945	840	925	805	910	800	950	800	1010	825
4	1175	1060	1150	1050	1095	975	1075	925	1050	910	1105	890	1160	980
5	1305	1190	1290	1180	1220	1100	1205	1030	1175	1015	1245	1005	1290	1090
6	1410	1300	1380	1280	1325	1190	1310	1150	1290	1135	1355	1120	1400	1160

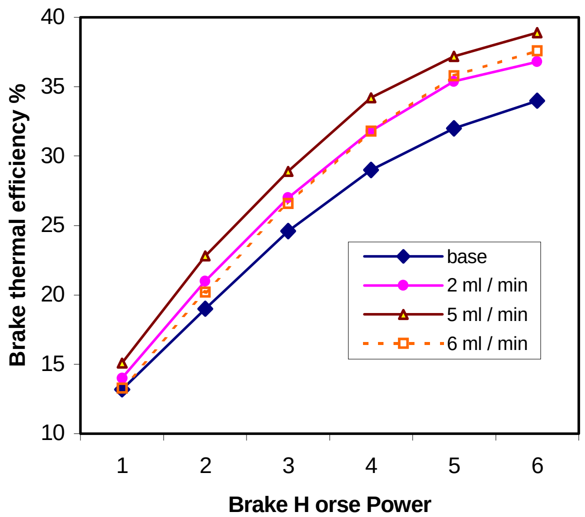

Fig.5 Performance at various secondary injections with inlet air heated to 60 deg C

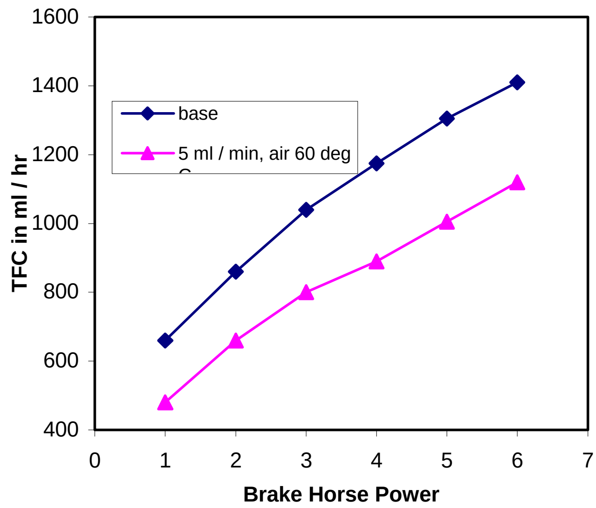

Fig.6 Comparison of TFC at 5 ml/ min secondary injection and inlet air at 60 deg C

The inlet air heating without the secondary injection gives maximum increase in efficiency of 4.8% when the engine power is 4 BHP and the inlet air temperature is 60 C. The economical operation is 3 BHP. 125 ml is saved if the engine runs at this power for one hour.

With the inlet air heating and secondary injection the maximum gain in efficiency is 9.8%, when the engine BHP is 5. The inlet air temperature is 60 C and the amount of secondary injection is 5ml/min. 300 ml per hour is saved at this condition. Figure 6 shows that more fuel is saved when the BHP is higher compared to the lower level operation.

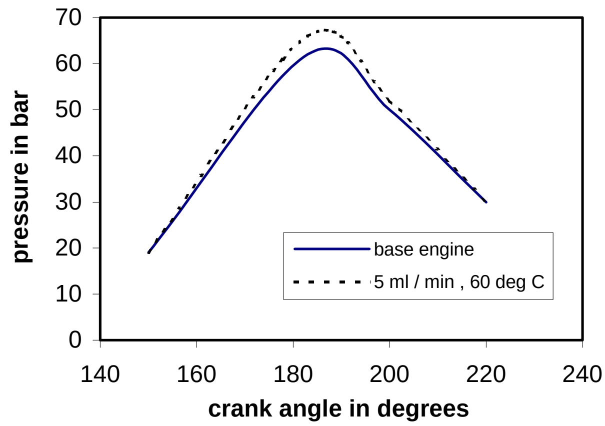

Fig.7 Comparison of pressure crank angle diagram

Figure 7 shows the comparison of pressure at various crank angle during combustion for the base engine as well as the fumigated engine with secondary injection of 5 ml/min and inlet air temperature of 60 deg C. It is evident from the figure that the pressure of the fumigated engine is more than the base engine due to the better combustion taking place in it. When the pressure crank angle diagram was magnified with the facility available in the storage type oscilloscope it was found that the pressure impulses were smoother in the modified engine with manifold fumigation compared to the base engine. Reduction in delay period was also noticed in the modified engine.

CONCLUSION

Secondary fuel without inlet air heating gives only slight increase in thermal efficiency under all load conditions. With secondary fuel injection without inlet air heating the optimum value of the secondary fuel which gives better performance is about 4 ml/min which is approximately 12% of the fuel consumption of the tested engine at 80% of full load operation.

Injecting the secondary fuel with inlet air heating gives increase in thermal efficiency from medium load to higher load conditions and the best condition is 5 ml/min which is 20% of 80% full load fuel consumption at 60 ˚C of inlet heating.

It is desirable to extend this scheme to the diesel engine vehicles and obtain operational data under bench test and service conditions. For heating inlet air exhaust gas has to be utilized by incorporating a heat exchanger. The cost of the additional components such as secondary fuel pump, injector etc. can be justified in a longer duration of operation.

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