Effect of Turbo charging On Volumetric Efficiency in an Insulated Di Diesel Engine For Improved Performance

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Abstract: *The world's rapidly dwindling petroleum supplies, their raising cost and the growing danger of environmental pollution from these fuels have led to an intensive search for an alternative fuels with concerned efforts to conserve the oil reserves. Among all the fuels, tested alcohol is proved best alternatives to the petroleum fuels because all these are derived from indigenous sources and are renewable. However, with the alcohols higher latent heat of vaporization and lower cetane number, the Insulated engine (IE) is used for the combustion in the diesel engines. The higher temperature in the combustion chamber decreases the ignition delay and aids combustion but drops the volumetric efficiency. The degree of degradation of volumetric efficiency depends on the temperatures in the combustion chamber and it further increases the frictional horsepower due to thinning of lubricant.*

Therefore, for improving the thermal efficiency of insulated engine, the volumetric efficiency drop is compensated by turbo charging in the present experimental work. This gave the better performance with reduction in smoke. With the turbo, charging the intake boost pressure is raised and its effect on the engine performance is also studied.

I. Introduction

In the diesel engines for about 30% of the total energy is lost to the cooling water. This lost energy can be recovered in the form of useful energy by expanding gases in the turbines. But due to lower temperature in the combustion chambers, the fuels which have high calorific value cannot be burned. This can be achieved with an insulated engine due to the availability of higher temperature at the time of fuel injection. The heat available due to insulation can be effectively used for vaporizing alcohols. Some important advantages of the insulated engines are improved fuel economy, reduced HC and CO emission, reduced noise due to lower rate of pressure rise and higher energy in the exhaust gases [2 & 3]. However, one of the main problems in the insulated engines is the drop in volumetric efficiency. This further decrease the density of air entering the cylinder because of high wall temperatures of the insulated engine. The degree of degradation of volumetric efficiency depends on the degree of insulation.

In the present work for compensating the decrease in volumetric efficiency a single cylinder insulated DI diesel engine is turbocharged to different inlet pressures depending upon the load and the performance of the insulated engine under turbocharging condition is investigated.

II. Experimental Details

The single cylinder, four strokes 3.68 KW Kirloskar, water-cooled DI diesel engine with a bore of 80 mm and stroke of 110 mm and a compression ratio of 16.5:1 is used for the experiment. The engine load is applied with eddy current dynamometer. For the reduction of heat to the cooling water, an air gap insulated piston and liner and ceramic-coated cylinder head and valve (BP9) is used for this experimental investigation. The emissions are measured with exhaust analyzer. The air gap insulated piston and the experimental set up used for the experiment is as shown in the Fig.1 & 2 respectively

Fig. 1: Photographic view of Aluminum piston Crown with an air-gap insulation

Fig. 2. Experimental set up of Insulated Engine Test Rig

III. Turbocharging Equipment

To pressurize the inlet air, internally powered turbocharging equipment with closed loop lubrication is fabricated. The schematic diagram of the turbocharging equipment is shown in Fig: 3. in the turbocharging the high temperature exhaust gases are expanded in a low-pressure turbine for the power generation and this is further coupled to motor of the compressor [4, 5]. This compressor compresses the inlet air and supplies to the engine at slightly higher pressure. By controlling the inlet air, the engine is turbocharged at different inlet pressures.

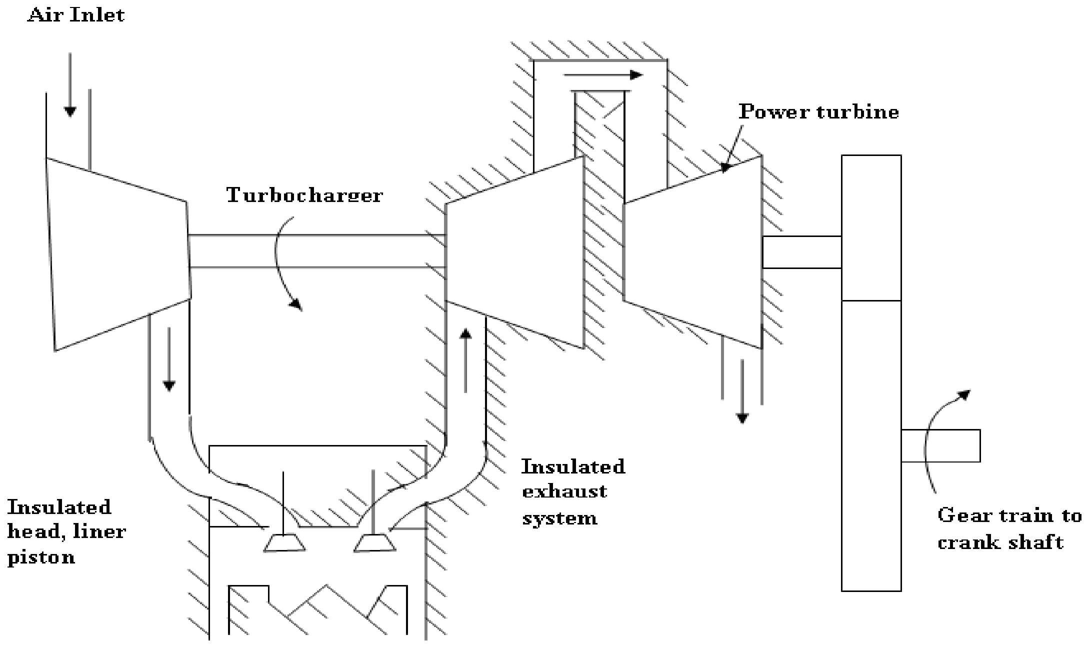

Fig. 3 Turbocharged Insulated Diesel Engine

IV. Results and Discussions

Initially the tests are performed at a constant speed of 1500 rpm with constant injection timing (29^0 bTDC) in a normal diesel engine. All the performance parameters and emissions are measured. For the insulated engine, due to higher operating temperatures and further lower ignition delays with insulation in the combustion chamber, the injection timing of 27 ^{0}bTDC is found to give the optimum performance. So all the tests are performed in the insulated engine with alcohol as fuel at the above optimum injection timing.. For testing the engine under turbocharging conditions, the specially fabricated turbocharging equipment is used.

Effect of Insulation on the Volumetric Efficiency

The volumetric efficiency drop mainly depends on the cylinder temperatures in an insulated engine, which in turns depends upon the type and degree of insulation employed. In the present work air-gap insulation both for the piston and liner and PSZ coating for the cylinder head and valve have been incorporated. Fig: 4 shows the variation of the volumetric efficiency drop of the insulated alcohol engine compared with normal diesel engine (NE). The volumetric efficiency drop of an insulated engine is about 10% compared to normal engine at rated load.

Effect of Turbocharging on the Volumetric Efficiency

The variation of volumetric efficiency with power output with intake boost pressure is shown in Fig: 5. With the increase of boost pressure more air is available for the combustion which further increases the combustion efficiency. At higher boost pressures excess air doesn't improve the combustion efficiency [5]. So it is concluded that 790 mm of Hg is the optimum boost pressure at which the drop in volumetric efficiency is compensated with turbocharger.
Because of the increased backpressure with turbocharging conditions, the inlet boost pressures are higher for compensating the volumetric efficiency drop in normal engine. It requires nearly 4% of intake boost pressure under turbocharging conditions for compensating the maximum efficiency drop of 10% in the normal engine. Comparison of percentage of boost pressure required for volumetric efficiency compensation with power output is shown in Fig: 6.

Brake Thermal Efficiency

The variation of brake thermal efficiency with power output for turbocharged condition is shown in Fig:7. When the engine is turbocharged with volumetric efficiency compensation thermal efficiency is improved continuously with load. The maximum improvement is about 4.3% over insulated engine. The improvement in thermal efficiency under turbocharging conditions is marginal due to following reasons: (1) In the present work inlet boost pressures in turbocharging are moderate, because they were selected on the basis of volumetric efficiency compensation. At higher pressures still higher thermal efficiency could be obtained. (2) Higher frictional losses due to increase in gas pressures. (3) The engine had stability problem at higher intake pressures.

V. Combustion Parameters

With the turbo charging more air will be available for the combustion and this will change the combustion parameters. The effect of turbocharging on the engine performance is shown in the following figures.

Peak Pressure

The peak pressure variation of turbocharging with power output is shown in Fig:8. The peak pressures of normal engine, Insulated engine and turbocharged Insulated engines are compared in the same figure. It is observed that the peak pressures are higher with turbocharged engine and is about 82 bar at the rated load.

Ignition Delay

The variation of ignition delay with power output for turbocharging conditions is shown in Fig: 9. With the turbocharging more amount of air enters into the chamber which increases the combustion process and reduces the ignition delay. But at higher loads due to the high latent heat of alcohol, the ignition delay is slightly increased [6]. It is concluded that there is a reduction of 6.2^0 CA for the turbocharged insulated engine compared to normal engine at rated load. So it will be beneficial to increase the turbocharging pressures in order to have a shorter ignition delays.

Exhaust Temperature and Emissions

The increase in the exhaust temperatures are 20^0C to 50^0C with turbocharging. Fig: 10 shows the variation of exhaust temperatures with power output. This is due to the increase of mass flow rate of air, reduction in the ignition delay and hotter combustion chamber which further increases the combustion process.

Fig: 11 shows the variation of exhaust smoke number with power output for turbocharging condition. It is concluded from the same figure that there is a significant reduction in smoke level in turbocharged engine compared to normal engine at rated load condition due to complete combustion.

VI. Conclusions

The following conclusions are drawn based on the experimental investigations on an insulated diesel engine under turbocharging conditions:

1. The increase in the in take boost pressure improves the brake thermal efficiency of the engine.
2. For the compensation of drop in volumetric efficiency of the insulated engine 4% intake boost pressure is required for turbocharging.
3. Though the higher temperatures are available in the combustion chamber due to insulation, the increase in exhaust gas temperature is marginal. This is attributed to the higher latent heat of vaporization of alcohol.
4. As the alcohol contains oxygen and more air is available in the turbocharging for combustion, the ignition delay is reduced.
5. Due to the complete combustion of alcohol at higher temperatures the smoke emissions are also marginal.

References

[1] R.D.Barnes, - Effect of a supplementary fuel in turbo charged diesel engine- SAE 750469, 1975
[2] R.Kamo and W.Bryzik," Adiabatic Turbocompound Engine Performance Prediction", SAE 1978, paper 780068.
[3] R. Kamo, et al," Cummins- TARADCOM Adiabatic Turbocompound Engine program", SAE 1981, Paper 810070.
[4] Michael C. Brands," Vehicle Testing of Cummins Turbocompound Diesel Engine", SAE 1981, Paper 810073.
[5] N.Sivarama Prasad Rao, S.Jabez Dhinagar, B.Nagalingam and K.V.Gopalakrishnan, "Compensating the Volumetric Efficiency drop of an adiabatic diesel engine for improved performance", Third International Conference on I.C. Engines, IIT, Chennai, Vol.II, pp 288-299, 1986.
[6] Ozer Can, smet Çelikten and Nazım Usta," Effects of ethanol addition on performance and emissions of a turbocharged indirect injection Diesel engine running at different injection pressures ", SAE Technical paper,2004.
[7] Arunachalam M , "Investigations on the performance of a diesel engine with ceramic thermal barrier coating on parts of the combustion chamber surface", Proc. of the QIP short term course on recent developments in I.C. engines, IIT, Madras,1988
[8] Sutor P, Bryzik W, "Laboratory Development and Engine Performance of New High–Temperature Diesel Engine Lubricants", SAE Technical Paper 890145
[9] Wang J C," High temperature Liquid Lubricant Development-Part Ii: Bench Test Development", SAE Paper No. 932843.
[10] Wallance F J et al, "Thermally insulated diesel engine", Proc. Of the Institution of Mech. Engrs., vol 198A, No.: 5, PP 97-105.2000

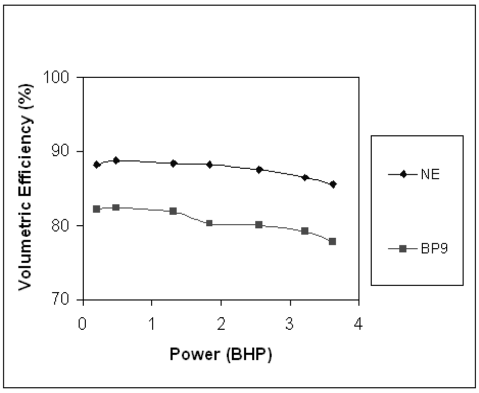

Fig: 4 Variation of Volumetric Efficiency with Power Output

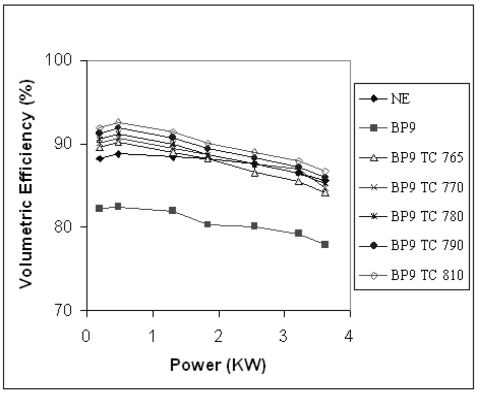

Fig: 5 Variation of Volumetric Efficiency with Turbocharging

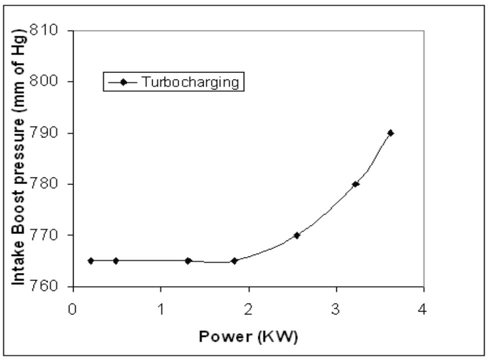

Fig: 6 Comparison of Intake Boost Pressure Required for Volumetric Efficiency Compensation with Power Output in Turbocharging

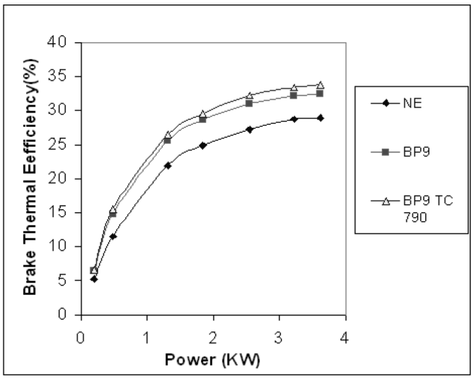

Fig: 7 Comparison of Brake thermal Efficiency with Power Output for Volumetric Efficiency Compensation with Turbocharging

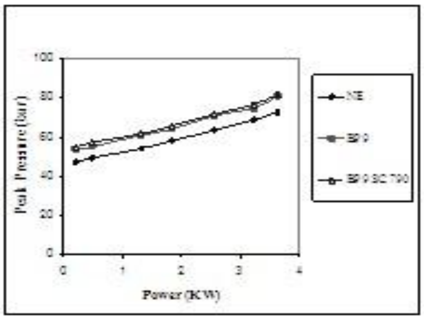

Fig: 8 Comparison of Peak Pressure with Power Output for Volumetric Efficiency Compensation with Turbocharging

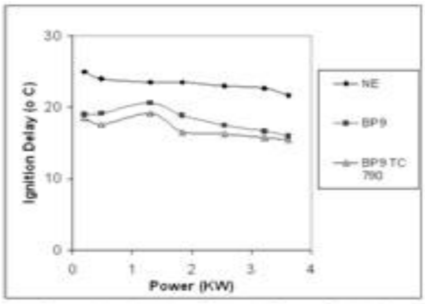

Fig: 9 Comparison of Ignition Delay with Power Output for Volumetric Efficiency Compensation with Turbocharging

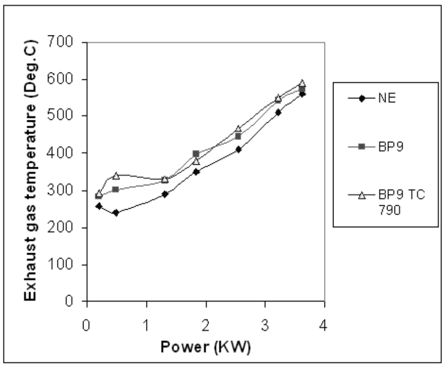

Fig: 10 Comparison of Exhaust Gas Temperature with Power Output for Volumetric Efficiency Compensation with Turbocharging

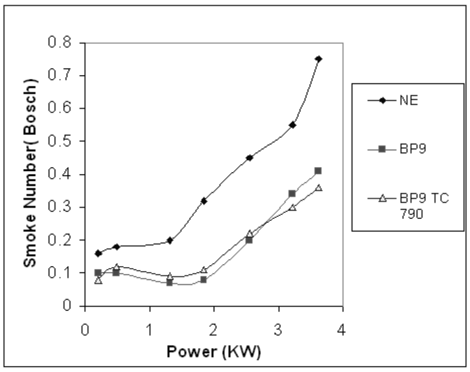

Fig: 11 Comparison of Smoke Emissions with Power Output for Volumetric Efficiency Compensation with Turbocharging