Performance and Emission in a Single Cylinder CI DI Diesel Engine Using Dee with Different Piston Bowl

1K.Balasubramanian, 2Rahul Surendran, 3Shravanth Bharadwaj.C
1Professor, 2,3Student
MSEC, Chennai, Tamilnadu

Abstract: **This research work is conducted with an optimal quantity of 5 ml of DEE in a litre of Diesel gives significant improvement in both performance and better control over Emission levels when it is tested by replacing the piston with standard bowl, Re entrant and stud button bowl in Kirloskar make single cylinder Diesel engine. Brake Thermal Efficiency, SFC Peak Pressure, EGT and HRR have better variations with each other by using these configurations. NOx, HC, CO and smoke emissions level are also significantly reduced.**

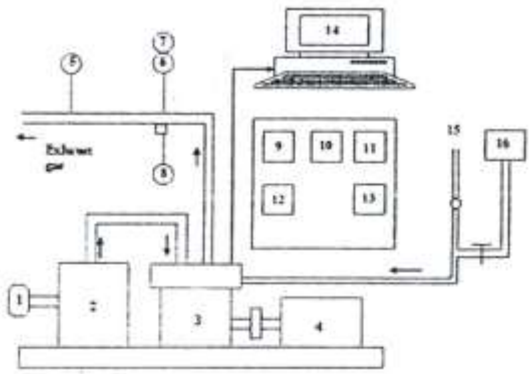
Keywords: **B.Th Eff, HRR, NOx, HC, CO**

Introduction

While going through the table 2 under properties of additives, it is observed that the Auto ignition temperature of DEE is lesser than that of Diesel which assists early combustion. Complete combustion is affected due to higher calorific value of DEE, results in reduction in emission level. Kirloskar TV1 single cylinder engine is chosen for conducting the research work. Various parameters are checked with standard hemisphere bowl piston for baseline analysis. Performance and emission characteristics are compared with that of, by replacing re-entrant bowl piston and button stud bowl piston in the same engine and it is discussed in detail under results and discussion sessions. Experimental set up is illustrated in the figure 1.

Table 1 Engine specification

Make	Kirloskar TV 1
No. of cylinder	One
Type of cooling	Water cooling
Ignition	Compression
Fuel	Diesel
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5
Speed	1500 rpm
Rated power	5.2kW
SFC	252 g/kW h



1. Air flow meter
2. Air vessel
3. Engine
4. Dynamometer
5. Smoke meter
6. CO, HC, analyzers
7. NO analyzer
8. Thermocouple (exhaust)
9. Speed indicator
10. Temp. Indicator (exhaust gas)
11. Temp. Indicator (coolant outlet)
12. Temp. indicator (coolant inlet)
13. Stopwatch 14. Printer
15. Burette 16. Fuel tank

Fig. 1 Experimental set up

Table 2. Properties of Additives

	Diesel	DEE
Chemical formula		$C_4H_{10}O$
Molecular weight		74.8
Density @15°C	0.8325	0.8334
Gross calorific value (kJ/kg)	41845	42335
Flash point (°C)	52	38
Fire point (°C)	62	50
Cetane Index	51	50
Auto ignition temp.°C	257	180

Results and Discussion

Brake Thermal Efficiency

At full load conditions, Brake Thermal Efficiency is 26.2% for re entrant bowl piston with DEE as fuel additive and it is significantly higher than that of Diesel 25.19% with the same piston configuration and it is due to higher compression ratio for re entrant bowl piston. Brake Thermal Efficiency is 30.21% for Standard bowl piston using DEE as additive with Diesel. It is higher at full load conditions where as it is 25.19%, 26.2% and 22.96% with Diesel, Re entrant bowl and Button stud bowl respectively. Combustion duration is more and rich fuel mixture is the cause for lesser Brake thermal Efficiency. This is shown in the figure 2.

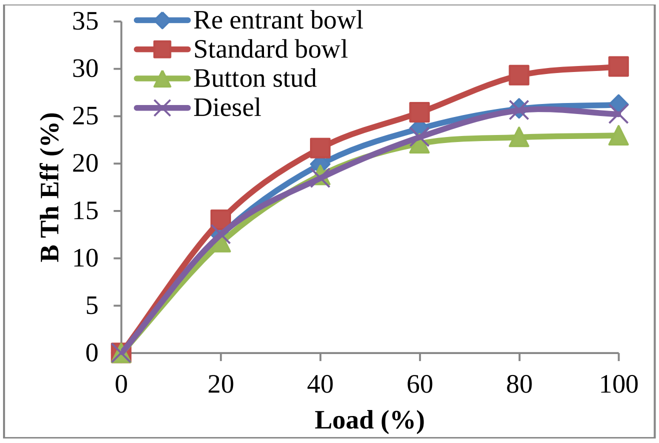


Fig.2 Variation of B Th Eff with Load

Specific Fuel Consumption

Chemical delay is reduced significantly with the addition of DEE which is depicted in the figure 3. 60% load conditions and at higher load conditions SFC is on an average of 0.36 kg/kWh. Better oxidation of fuel air mixture leads to complete combustion consequently liberates more thermal energy results in lesser SFC.

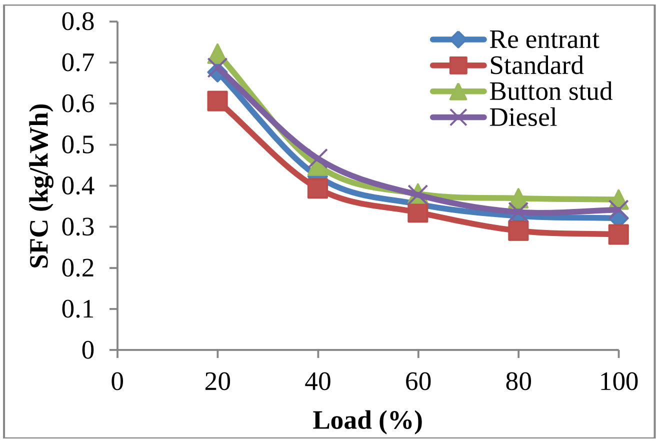


Fig. 3 Variation of SFC with Load

Exhaust Gas Temperature

Figure 4 illustrates variation of EGT with load. Excess air and clean fuel mixture tends to reduce the EGT at 60% load conditions with DEE. At full load conditions, it is almost the same for all the bowl configurations in the piston. 285°C is the EGT at full load conditions with Button stud bowl piston whereas it is 427°C at full load conditions with Re entrant bowl piston when Diesel is used as a sole fuel. Oxidation of fuel droplets is sufficient to complete combustion, leads to higher EGT.

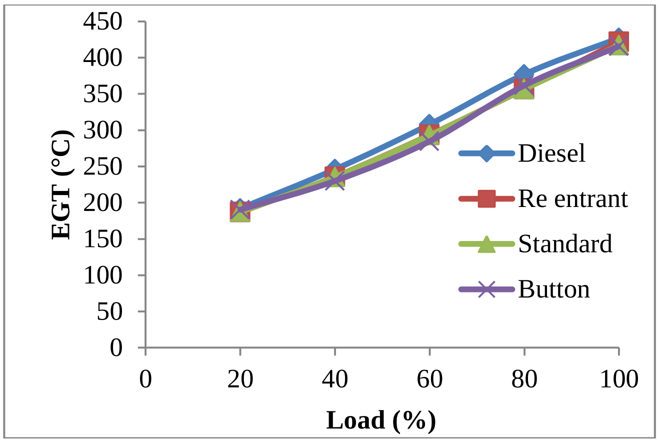


Fig. 4 Variation EGT with Load

Peak Pressure

Linear increase in peak pressure is illustrated in the figure 5. Heterogeneous combustion in CI engine causes fluctuations in peak pressure. Swirl due to compression affects the squish effect at the end of compression stroke.

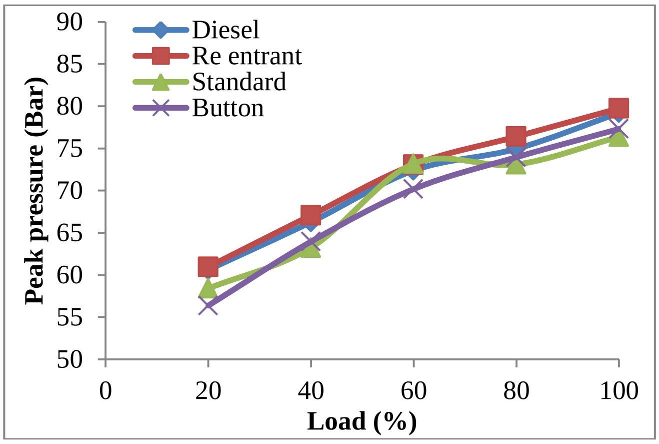


Fig. 5 Variation of Peak Pressure with Load

Heat Release Rate

Ignition delay is shortened by 3° CA for re entrant bowl piston and it is reduced by 1° CA for button stud type piston bowl. Calorific value of fuel is related to higher pressure and higher heat release rate and it is 140 kJ/kg°CA with sole Diesel in Re entrant bowl piston configuration. Figure 6 indicates the variation of HRR with load.

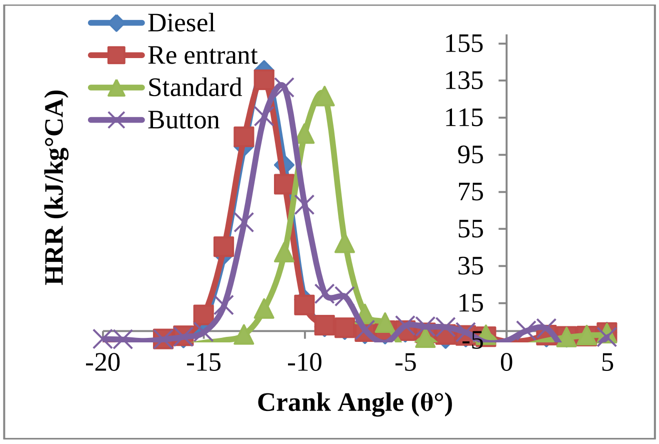


Fig 6 Variation of HRR with Load

Oxides of Nitrogen

At 60% load conditions, NOx level is 11.3 g/kWh, 9.99 g/kWh, 4.49 g/kWh and 6.15 g/kWh for Diesel sole fuel with re entrant bowl configuration, Diesel with DEE for re entrant, Standard and Button stud bowl respectively. This is shown in the figure 7. At full load conditions, it is 6.8 g/kWh, 5.89 g/kWh, 3.29 g/kWh and 2.7 g/kWh for Diesel, DEE with Diesel re entrant, standard and button stud respectively.

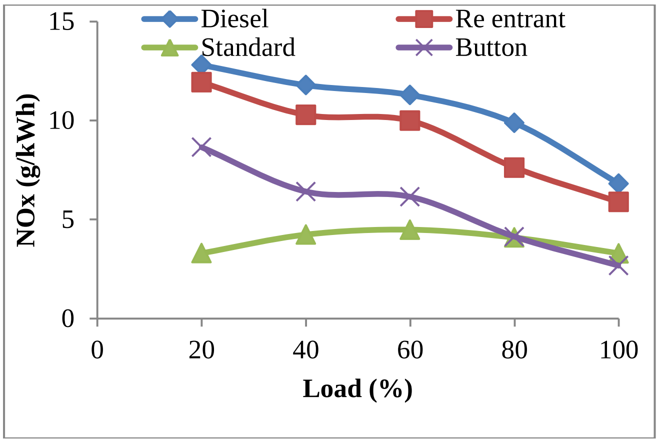


Fig 7. Variation of NOx with Load

Carbon monoxide

Rich fuel mixture variation with respect to load conditions is the cause for formation of Carbon monoxide. It is 0.08 g/kWh, 0.07 g/kWh, 0.027 g/kWh and 0.08 g/kWh for Diesel, re entrant bowl, standard bowl and button stud bowl respectively. Lower CO level at 20 5 load conditions and higher CO level as the load increases is illustrated in the figure 8.

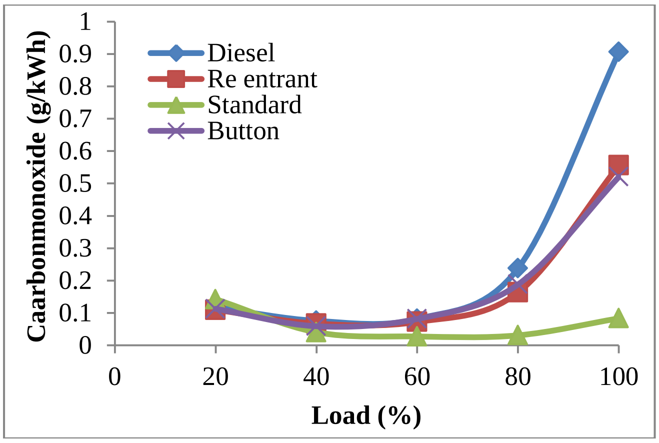


Fig.8 Variation of Carbon monoxide with load

Carbon dioxide

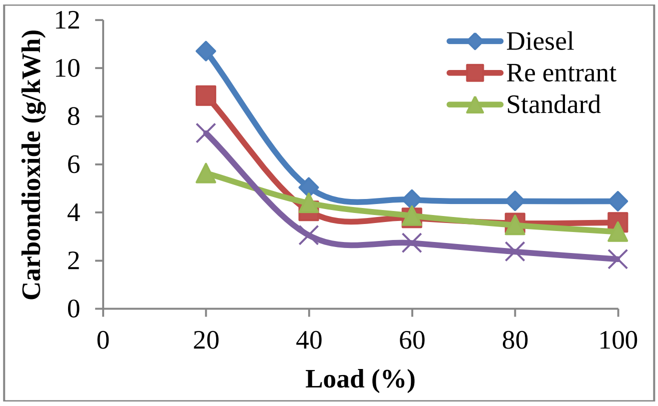


Fig 9 Variation of Carbondioxide with load

Oxidation of Carbon monoxide with excess Oxygen in the air reduces the CO emissions and increases the CO2 emissions. Physical delay period is more at 20% load conditions which resulted in more CO emissions at this load conditions irrespective of the piston bowl configurations. Correspondingly CO2 emissions also higher at this load conditions which are illustrated in the figure 9.

Hydrocarbon

Variation of HC with load is shown in the figure 10.Lip angle and button stud are the major locations for the formation of HC. 0.11 g/kWh at 60% load conditions for Diesel and 0.18 g/kWh at full load conditions for button stud bowl piston configuration DEE with Diesel. Quench volume is 2.8% lesser than the standard bowl piston which reduces the HC emissions significantly by using DEE as additive with Diesel.

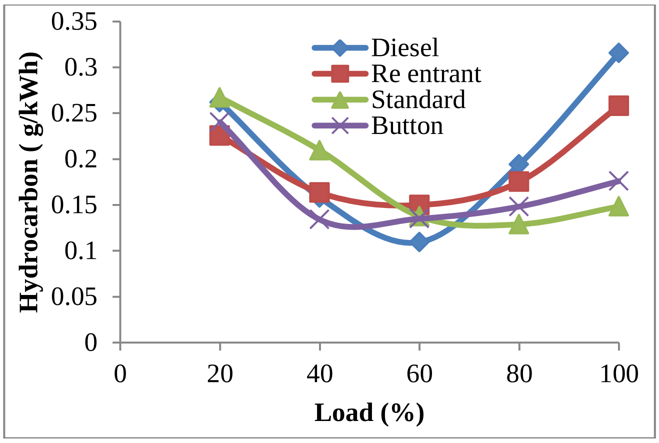


Fig 10 Variation of Hydrocarbon with Load

Smoke

Swirl effect due to re entrant bowl piston and button stud bowl reduces the smoke level and it is 56.5 HSU and 57.5 HSU at 60% load conditions. At full load conditions it is 85.2 HSU and 89.9 HSU which lesser with Diesel with Re entrant bowl and it is 93.9 HSU. Better coagulations of carbonaceous contents with oxygen in the air reduces the CO level as it is converted into CO2 by oxidation. It is depicted in the figure 11.

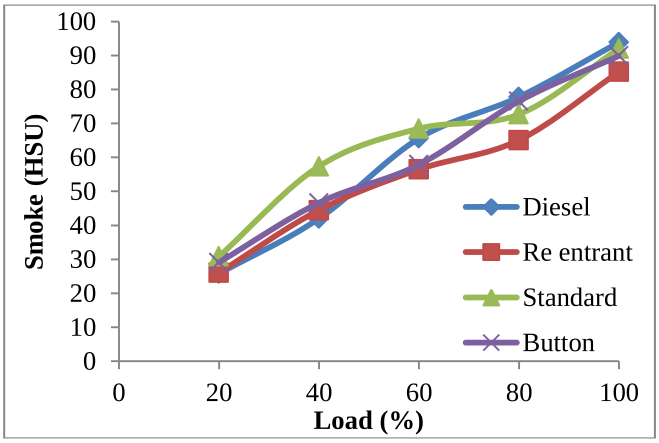


Fig 11 Variation of Smoke level with Load

Conclusion

Table 3 gives a cumulative result analysis of the research which indicates the following inferences.

Brake Thermal Efficiency is 30.21% and it is the maximum at full load conditions with re entrant bowl piston with DEE as diesel additive.

SFC is 0.28 kg/kWh is the lowest for the same test conditions.

Peak pressure is 79.3 bar at full load conditions with Diesel as sole fuel with re-entrant bowl piston combinations.

EGT is 285° C and it is the lowest with button stud bowl piston at 60% load conditions.

HRR is 140 kJ/kg°CA with Diesel as sole fuel at 60% load conditions for Re-entrant bowl piston.

NOx emission is lower at full load conditions with button stud bowl piston and it is 2.7 g/kWh.

Table 3 Cumulative Analysis

Parameters		Diesel	Re entrant	Standard	Button stud
B.Th Eff (%)	60	27.79	25.39	23.69	22.11
	100	25.19	30.21	26.3	22.96
SFC(kg/kWh)	60	0.36	0.34	0.36	0.38
	100	0.32	0.28	0.32	0.37
Peak Press(bar)	60	72.4	73.1	73.2	70.2
	100	79.3	79.8	76.4	77.3
EGT (°C)	60	308	293	293	285
	100	427	421	417	416
HRR(kJ/kg°CA)	60	140	136	126	131
NOx(g/kWh)	60	11.3	9.99	4.49	6.15
	100	6.8	5.89	3.29	2.7
CO(g/kWh)	60	0.08	0.07	0.027	0.08
	100	0.91	0.56	0.83	0.52
CO2(g/kWh)	60	4.53	3.77	3.87	2.73
	100	4.47	3.58	3.19	2.06
HC(g/kWh)	60	0.11	0.15	0.14	0.13
	100	0.32	0.26	0.15	0.18
Smoke(HSU)	60	65.6	56.5	68.5	57.9
	100	93.9	85.2	91.9	89.9

CO emission is lower at full load conditions with Re entrant bowl piston and it is 0.52 g/kWh.

HC is 0.11 g/kWh at 60% load conditions for re entrant bowl piston using Diesel as sole fuel.

Smoke level is 57.9 HSU at 60% load conditions with button stud bowl piston.

References

[1] Hiroshi Yamaguchi, Satoshi Takizawa, Hiroshi Sanbuichi, Kenji Ikeura” Analysis on Idle Speed Stability in Port Fuel Injection Engines” 1986-10-01 Technical Paper 861389.

[2] Gianpietro E. Cossali, Gianni Brunello, Aldo Coghe“ LDV Characterization of Air Entrainment in Transient Diesel Sprays” 1991-02-01 Technical Paper 910178.

[3] R.J. Brisley, R.D. O'Sullivan, A.J.J. Wilkins “ The Effect of High Temperature Ageing on Platinum-Rhodium and Palladium-Rhodium Three Way Catalysts” 1991-02-01 Technical Paper 910175.

[4] Marty A. Barris, Susan B. Reinhart, Fred H. Wahlquist “The Influence of Lubricating Oil and Diesel Fuel on Ash Accumulation in an Exhaust Particulate Trap” 1991-02-01 Technical Paper 910131.

[5] J.M. Perez, C.S. Ku, S.M. Hsu “ High Temperature Liquid Lubricant for Advanced Engines” 1991-02-01 Technical Paper 910454

[6] P. J. Whiston, R. J. Abdel-Gayed, N. S. Girgis, M. J. Goodwin “ Turbulent Burning Velocity of a Simulated Biogas Combustion in a Spark Ignition Engine” 1992-10-01Technical Paper 922166.

[7] Thomas G. Holland, Matthew N. Swain, Michael R. Swain “ Using Ethanol/Diesel Mixtures in a Compression Ignition Engine with Ignition Improver Additives” 1992-10-01 Technical Paper 922191.

[8] R. B. Rhodes “ Diesel Injector Shear Stability of Engine Oil - Factors Affecting Reproducibility and Relevance to Engine Performance” 1992-10-01 Technical Paper 922193.

[9] Ahmed Soliman, Giorgio Rizzoni “The Effects of Various Engine Control System Malfunctions on Exhaust Emissions Levels During the EPA I/M 240 Cycle” 1994-03-01 Technical Paper 940448.

[10] Minggao Yang, Spencer C. Sorenson “Survey of the Electronic Injection and Control of Diesel Engines” 1994-03-01 Technical Paper 940378.

