Experimental Investigation Of Re Entrant Bowl Piston Using Diesel Additives in CI DI Diesel Engine

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Abstract: **Re-entrant bowl induces better squish motion in the combustion chamber which enhances mixing of the fuel with air, results in significant improvement in engine performance and reduces the emissions. Compression ratio is increased by 6% from the conventional engine with hemispherical bowl piston.**

Keywords: **Re-entrant bowl, hemispherical bowl, Compression ratio**

Introduction

Re entrant bowl assists to gain sufficient momentum to the injected fuel jets for adequate fuel distribution and rates of mixing with the compressed air in the combustion chamber. The tangential velocity of the fuel jet is increased due to re entrant angle which is set as15° at the lip. Compression ratio of the engine with this re entrant bowl piston and it is 18.7 as against 17.5 with the conventional piston engine. Figure 1 illustrates the re entrant bowl piston. The details of diesel additives and test matrix are shown in the Table 2 and Table 3 respectively. Kirloskar TV 1 type engine and its specification is listed in the Table 1. Experimental setup is shown in the figure 2. Experiment is conducted as listed in the Table 2. Optimal results are used for the discussion.

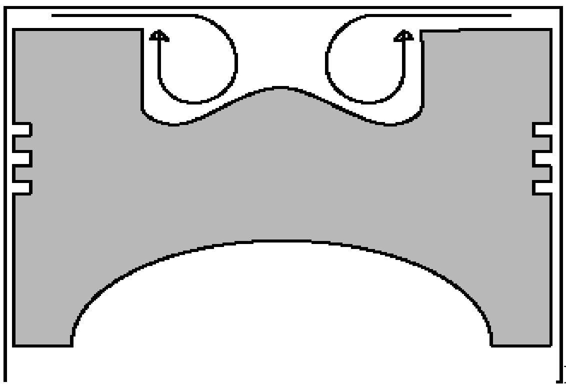


Figure 1 Re entrant bowl

Table 1 Engine specification

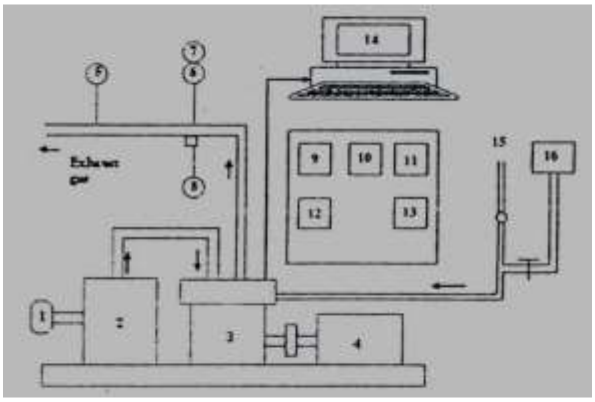
Make	Kirloskar TV 1
No. of cylinder	One
Type of cooling	Water cooling
Ignition	Compression
Fuel	Diesel
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5
Speed	1500 rpm
Rated power	5.2kW
SFC	252 g/kW h

Table 2 Test Matrix

FUEL	BLENDING PARAMETERS	QUANTITY	REMARKS
DIESEL	CYCLOHEXYL AMINE	2.5 ML 5.0ML 7.5 ML	Performance Emissions
DIESEL	DEE	2.5 ML 5.0ML 7.5 ML	Performance Emissions
DIESEL	METHYL ACETATE	2.5 ML 5.0ML 7.5 ML	Performance Emissions
DIESEL	AMYL ALCOHOL	2.5 ML 5.0ML 7.5 ML	Performance Emissions

Table 3. Properties of Additives

	Diesel	Cyclo hexyl amine	DEE	Methyl Acetate	Amyl Alcohol
Chemical formula		C6H13N	C4H10O	C3H6O2	C5H12O
Molecular weight		99.17	74.8		88
Density @15°C	0.8325	0.8328	0.8334	0.8317	0.8327
Gross calorific value (kJ/kg)	41845	44840	42335	41695	46064
Flash point (°C)	52	54	38	50	43
Fire point (°C)	62	66	50	60	
Cetane Index	51	52	50	53	56
Auto ignition temp.°C	257	293	180	454	350



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

Fig . 2 Experimental setup

Brake Thermal Efficiency

Variation of Brake Thermal Efficiency with different additives with diesel is due to different calorific value of DEE, Methyl Acetate ,Amyl alcohol and Methyl acetate which is indicated the Table 3.For DEE and Amyl alcohol it is 23.7% and 22.9% at 60% load and at full load it is 26.2% for DEE and 25.8% for Amyl alcohol and for Methyl acetate with Diesel it is 23.7% at 60% load conditions and at full load it is 25.3% whereas for Diesel it is 22.8%a at 60% load conditions and 25.2% at full load conditions. Variation of Brake Thermal Efficiency with load is illustrated in the Figure 3.

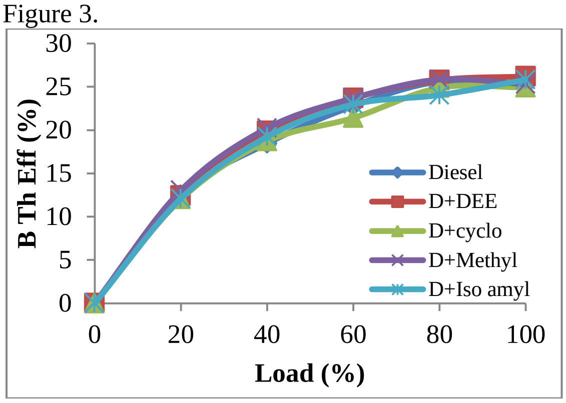


Fig. 3 Variation of Brake Thermal Eff with load

Specific Fuel Consumption

For higher the Brake Thermal Efficiency corresponding SFC is always lesser at that load conditions. SFC is lesser at 60% load is 0.36 kg/kWh and at full load it is 0.32 kg/kWh for DEE with Diesel and for Methyl Acetate with Diesel it is 0.36 kg/kWh at 60% load and 0.33 kg/kWh at full load respectively.

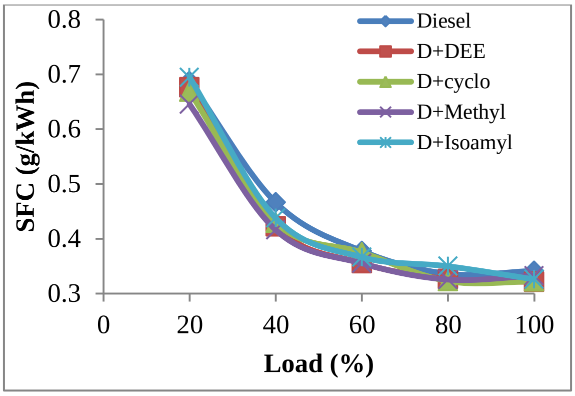


Fig.4 Variation of SFC with Load

SFC is lesser for Iso Amyl alcohol and it is 0.37 kg/kWh at 60% load and at full load it is 0.32 kg/kWh. For Diesel it is 0.38 kg/kWh at 60% load and 0.34 kg/kWh at full load. SFC is higher at lower load conditions and it reduces as the load increases due to higher brake power output.

Peak Pressure

Variation of Peak pressure with load is shown in the figure 5. Mass burning rate of fuel varies with Additives with Diesel which may be the reason for significant difference in peak pressure among the additives with Diesel against Diesel when it is used as a sole fuel. At 60% load conditions, DEE with Diesel peak pressure is 73.1 bar. At full load conditions it is 79.8 bar for the same additive with Diesel. Amyl alcohol, Methyl acetate and Cyclohexyle amine with Diesel at 60% load is 72.2 bar,70.2 bar and 71.4 bar and at Full Load conditions it is 79.1 bar,78.6 bar and 77.5 bar respectively. Auto ignition temperature of these additives is related to ignition delay and fuel air mixture variations with load conditions are the basic cause for peak pressure variations.

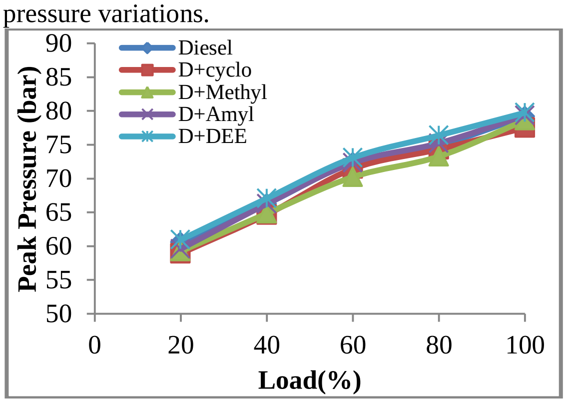


Fig.5 Variation of Peak Pressure with Load

Exhaust Gas temperature

Exhaust gas temperature for DEE with Diesel is 288°C at 60% load conditions and it is 424°C at full load conditions. This is lower by 6% at 60 % load conditions (308°C) for Diesel and it is (427°C) 1% lesser at full load conditions.For Methyl acetate at 60% load conditions it is 308°C and at full load conditions it is 423°C. Amyl alcohol wit Diesel EGT is 300°C and 428°C at 60% load conditions and at full load conditions respectively. For Cyclo hexyl amine at 60% load conditions it is 306°C and at full load conditions EGT is 419°C. Variation of EGT with load is illustrated in the figure 6. Mass Burning rate is increasing since the fuel quantity is also correspondingly increases due to constant amount of mass flow for air for a constant speed application engine.

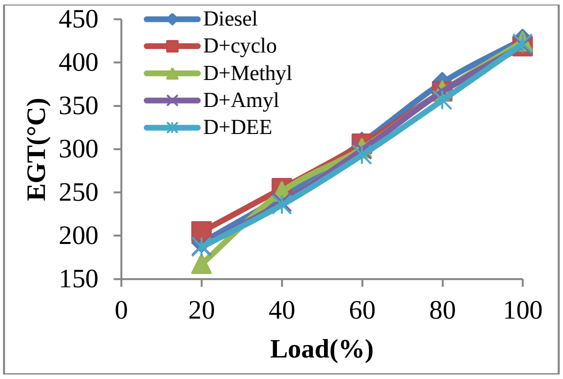


Fig.6 Variation of EGT with load

Heat Release Rate

Heat release rate with respect to Crank Angle is illustrated in the fig. 7.Maximum Heat release rate for Diesel is 140.3 kJ/kcal °C at 60% load conditions. For Amyl Alcohol it is 148.4 kJ/ k cal °C. DEE ,Methyl acetate and Cyclo hexyle amine it is 135.5 kJ/kcal °C, 132.9kJ/kcal °C and 133.5 kJ/kcal °C respectively. Increase in Compression pressure due to re entrant bowl configuration induces faster swirl effect which reduces the ignition delay for the fuel with air for better homogeneous combustion. Inter molecular structure of the fuel gains temperature well in advance from TDC is one of the additional reasons for the increase in peak pressure with the usage of additives in Diesel which is the most relevant factor for the Maximum Heat Release. Ignition delay period is shortened by 1° CA towards TDC for all the additives when it is compared with Diesel as sole fuel.

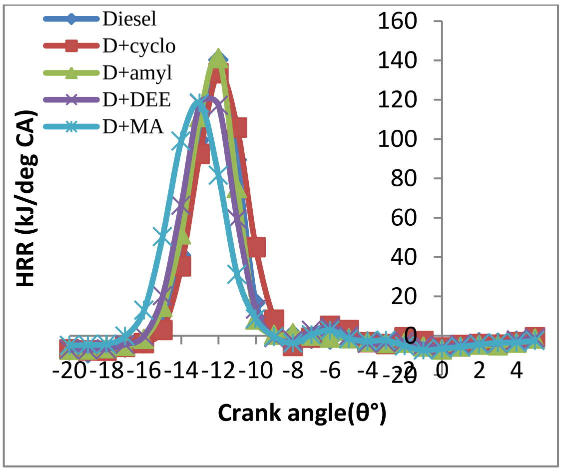


Fig.7 Variation of Heat Release Rate with Crank Angle

Emissions

Oxides of Nitrogen

Ignition delay depends on the rate of fuel injection during that cycle. As the load increases fuel injection quantity is also more as the mass flow rate of air remains constant for constant speed application. It leads to shorten the burning time of the fuel with air which contains insufficient quantity of Oxygen This may be the factor for reduction in NOx at higher loads. Variation of NOx with load is depicted in the figure 8. Higher the NOx level at 20% load conditions. At 60% load conditions, for Diesel it is 14.28 g/kWh, for DEE with Diesel it is 9.9 g/kWh, Methyl acetate with Diesel NOx level is 12.3 g/kWh, Cyclohexyl amine with Diesel it is 10.8 g/kWh and Amyl alcohol it is 10.3 g/kWh and reduction in NOx level with these additives is due to homogenous combustion occur at multi level zones in the combustion chamber. A significant reduction in NOx level at full load conditions with that of Diesel is due to rich fuel air mixture with in sufficient burning time at that load conditions.

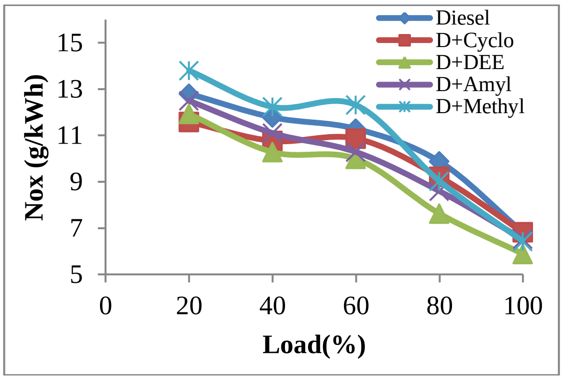


Fig.8 Variation of NOx with load

Carbon monoxide

Formation of Carbon monoxide is due to in complete combustion. Re combination reaction between CO and various oxidants is in complete CO is formed. Low gas temperature and fuel rich mixture at lower load conditions are the reasons for CO emission. At full load conditions, fuel rich mixture and in sufficient rate of combustion are the cause for CO emissions. This variation is depicted in the figure 9. CO emission level forDiesel at 60%load condition is 0.082 g/kWh and at full load condition it is 0.91 g/kWh. CO.

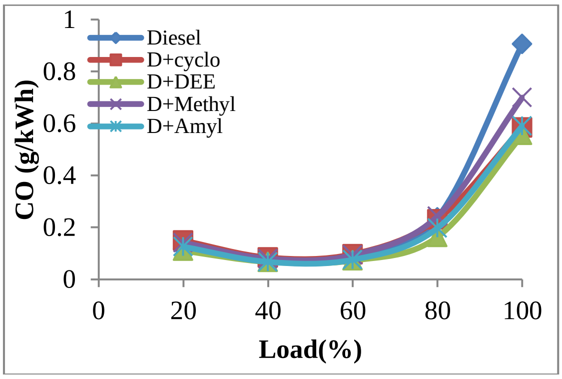


Fig.9 Variation of CO with load

Emission for Cyclo hexyl with Diesel is 0.09 g/kWh at 60% l0ad conditions and 0.6 g/kWh at full load conditions. CO emission for Diesel with Amyl alcohol is 0.08 g/kWh at 60% load conditions and at full load it is 0.97 g/kWh. DEE with Diesel CO level is 0.07 g/kWh at 60 % load conditions and at full load it is 0.56 g/kWh. Methyl acid with Diesel has CO level as 0.09 g/kWh at 60% load conditions and 0.7 g/kWh at full load conditions. Additives DEE, Amyl alcohol and Methyl acetate have lesser CO emission than Diesel at 60 % load conditions and at full load conditions.

Carbon di Oxide

Complete combustion with high oxidants in the air at intermediate load conditions,

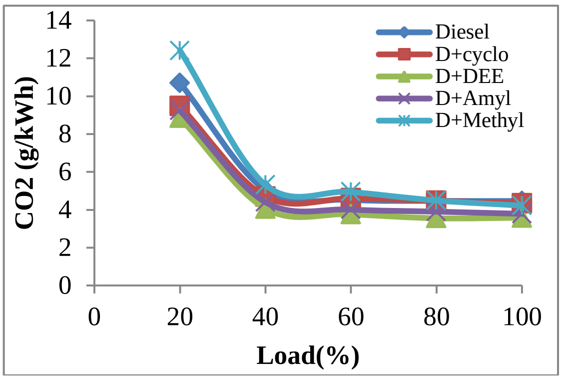


Fig.10 Variation of Carbon di oxide with load

Converts the CO emission into CO_2. At 60 % load conditions for Diesel CO_2 level is 4.53 g/kWh and at full load it is 4.47 g/kWh. CO_2 level is lesser for DEE, it is 3.8 g/kWh at 60 % load conditions and it is 3.58 g/kWh at full load conditions. CO_2 level for Amyl alcohol is 4.02 g/kWh at 60% load conditions and at full load it is 3.8 g/kWh. For Cyclo hexyl amine ,CO_2 level is not very much significant and it is 4.6 g/kWh at 60 % load conditions and at full load conditions it is 4.35 g/kWh. Diesel with Methyl acetate CO_2 level is 4.95 g/kWh at 60 % load conditions and the same is 4.22 g/kWh at full load conditions. Variation of CO_2 with load is illustrated in the figure 10.

Hydrocarbon

Variation of HC with load is shown in the figure 11.

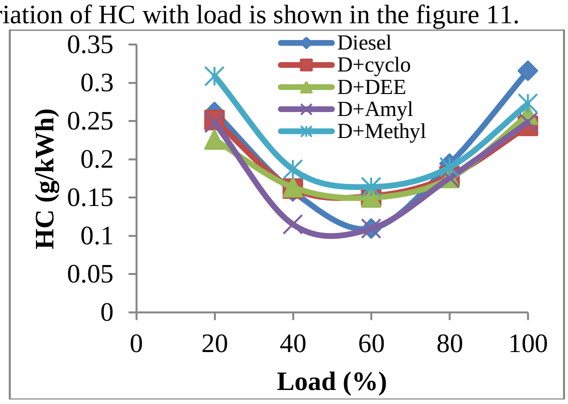


Fig. 11 Variation of Hydrocarbon with load

Swirl speed improves the mixing and hydro carbon oxidation process. The shorter ignition delay reduces HC emissions. Partial Oxidation products nearer to the Lean Flame Out Region is producing more HC emissions. At full load conditions and at lower load conditions HC emission level is more due to this effect. HC emissions for Diesel at full load conditions is 0.32 g/kWh and for DEE it is 0.26 g/kWh. HC emissions for Cyclohexyl amine is 0.24 g/kWh and for Amyle alcohol it is 0.25 g/kWh. HC emissions for Methyl acetate with Diesel is 0.27 g/kWh. At 60% load conditions, HC emissions for Diesel is 0.11 g/kWh and it is the same for Amyl alcohol with Diesel, otherwise for DEE, Cyclohexyle amine and Methyl acetate it is more and the variation of HC emissions for these additives with Diesel is 0.15 g/kWh, 0.15 g/kWh and 0.16 g/kWh respectively.

Smoke

Figure 12 illustrates the variation of smoke with load. In complete combustion causes smoke. Density variation of the additives with Diesel contains more carbonaceous structure which has lesser residence time during the combustion process for better oxidation and forms a carbonaceous particles escapes thorough the engine exhaust in the form of a smoke.

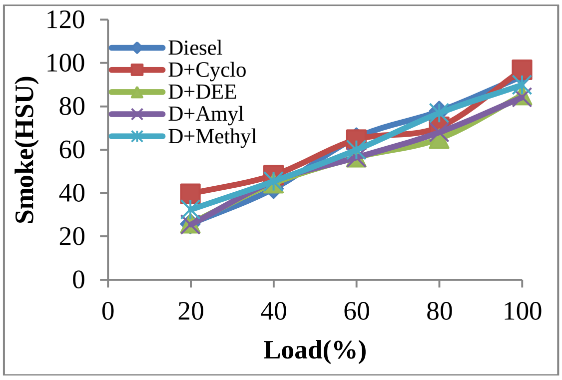


Fig.12 Variation of Smoke with load

For Diesel smoke leveel is 65.6 HSU at 60% load conditions and at full load it is 93.1 HSU. Smoke level for the additives with Diesel is lesser and at 60% load conditions and it is 57 HSU, 56.43 HSU, 59.9 HSU and 56.43 HSU for cyclohexyle amine, Amyl alcohol, Methyl acetate and DEE respectively.It is lesser for Cyclohexyl amine,Amyl alcohol Methyl acetate and DEE respectively. At full load conditions, smoke level is 87.5 HSU, 54.17 HSU, 59.9 HSU and 56.43 HSU for Cyclohexyla amine, Amyl alcohol, Methyl acetate and DEE respectively.

Oxygen

Variation of Oxygen with load is shown in the figure 13.For Diesel at 60% load conditions O_2 level is 14.72 g/kWh and at full load conditions it is 6.65 g/kWh. O_2 formation for Cyclohexyl amine is 14.73 g/kWh at 60 % load conditions and at full load conditions it is 7.63 g/kWh. For DEE and Amyl alcohol it is 15.7 g/kWh and 15.42 g/kWh respectively at 60% load conditions. It is 8.38 g/kWh and 8.1 g/kWh for both DEE and Amyl alcohol respectively at full load conditions.

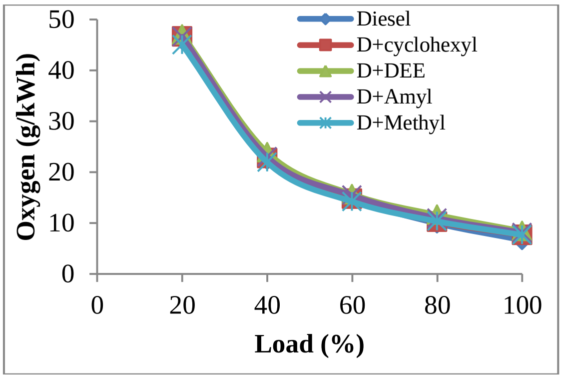


Fig.13 Variation of O2 with Load

It is lesser than that of Diesel for Methyl acetate as additive with Diesel at 60% load conditions and at full load conditions and it is 14.72 g/kWh and 7.67 g/kWh respectively.Better oxidation of CO and HC emission levels for Methyl acetate as additive with Diesel

Conclusion

Each additive has its own influence on Diesel and the performance and emissions are varying with respect to their properties. All the cumulative results are tabulated in the Table 4.

Table 4 Cumulative results of additives

Parameters	Diesel		Cyclohexylamine	
	60 (%)	100(%)	60(%)	100(%)
B TH Eff (%)	27.8	25.2	21.4	24.93
SFC (g/kWh)	0.38	0.34	0.38	0.32.94
Peak Pressure (Bar)	72.4	79.2	71.45	77.5
NOx (g/kWh)	11.3	6.8	10.9	6.82
CO (g/kWh)	0.08	0.11	0.097	0.5837
CO2 (g/kWh)	4.53	4.47	4.61	4.35
HC (g/kWh)	0.11	0.32	0.15	0.24
Smoke (HSU)	65.6	93.9	64.7	96.97
Parameters	**Methyl acetate**		**Amyl alcohol**	
	60(%)	100(%)	60(%)	100(%)
B TH Eff (%)	23.7	25.3	22.96	25.82
SFC (g/kWh)	0.36	0.33	0,37	0.32
Peak Pressure (Bar)	70.2	78.6	72.35	79.35
NOx (g/kWh)	12.31	6.42	10.3	6.52
CO (g/kWh)	0.09	0.699	0.08	0.59
CO2 (g/kWh)	4.49	4.22	4.02	3.79
HC (g/kWh)	0.16	0.27	0.11	0.25
Smoke (HSU)	59.9	89.9	56.4	84.1

Parameters	DEE	
	60(%)	100(%)
B TH Eff (%)	23.7	**26.2**
SFC (g/kWh)	0.36	0.32
Peak Pressure (Bar)	71.52	77.39
NOx (g/kWh)	9.99	5.89
CO (g/kWh)	0.072	0.56
CO2 (g/kWh)	4.01	3.79
HC (g/kWh)	0.15	0.26
Smoke (HSU)	56.5	85.2

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