Performance And Emission Characteristics of A Single Cylinder Direct Injection Four Stroke Diesel Engine With Mickey Piston

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This study examines the performance and emission characteristics of a single-cylinder, direct injection (DI), four-stroke diesel engine equipped with a Mickey piston, using ethanol and n-butanol as alternative fuels. The Mickey piston design enhances in-cylinder air-fuel mixing by introducing grooves on the piston crown, which improve swirl and turbulence. Experimental analysis was conducted to evaluate brake thermal efficiency (BTE), brake-specific fuel consumption (BSFC), and emissions, including carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NOx), and opacity. Results showed that ethanol and n-butanol blends with diesel improved BTE and reduced BSFC compared to conventional diesel. Emissions analysis indicated reduced CO and HC levels but increased NOx emissions with higher ethanol and n-butanol blends. These findings demonstrate the potential of modified piston geometries and alternative fuels to improve diesel engine performance and reduce emissions.
Ethanol and n-butanol, known for their cleaner combustion properties, were used as blends with conventional diesel to assess their impact on engine performance.
Keywords: Mickey piston, diesel engine, ethanol, n-butanol,

1. INTRODUCTION

The increasing demand for energy and environmental concerns associated with fossil fuels necessitate the exploration of alternative fuels and engine design modifications. Internal combustion (IC) engines play a crucial role in energy production but face challenges related to efficiency and emissions. Biodiesel and alcohol-based fuels, such as ethanol and n-butanol, have emerged as promising alternatives due to their renewable nature and lower emissions.The design of the combustion chamber significantly influences fuel-air mixing and combustion efficiency. Piston geometry, particularly the use of grooves on the piston crown, can enhance in-cylinder turbulence and improve combustion. The Mickey piston design, characterized by its distinctive grooves, creates optimal swirl intensity, facilitating better fuel-air mixing and combustion.

This study focuses on the performance and emission characteristics of a DI diesel engine using ethanol and n-butanol blends with a Mickey piston. The analysis aims to evaluate the potential of these fuels and the modified piston design to improve engine performance while reducing harmful emissions.

2. LITERATURE REVIEW

S Karthikeyan and A Prathima : were conducted an experimental investigation to establish the performance and emission characteristics of a Compression Ignition engine while using aluminium oxide nanoparticles as additive with pure diesel. In the first phase, they conducted the experiments with pure diesel and in second phase, they conducted with combination of diesel and nanoparticles in a four cylinder four stroke engine. The aluminium oxide acted as an oxygen donating catalyst and provided oxygen for the oxidation of CO and absorbed oxygen for the reduction of NO_X.

They were found some of the better results. Mechanical efficiency of the engine was enhanced by 20% and specific fuel consumption was decreased by 0.5 kg/kWhr for diesel mixed with cerium oxide of 30 ppm. However brake thermal efficiencies were higher for neat diesel than the fuel mixed with nanoparticles. But there was a significant reduction in the amount of exhaust emissions.

Harish Sivasubramanyam: were carried out the research work on alternate fuels to reduce the demand of fossil fuels and to reduce harmful emissions. The Papaya seed oil was used as an alternative fuel with diesel in two proportions of 15 and 20%. The blends were tested in a single cylinder DI diesel engine at different loads and running at a rated speed of 1500 rpm. They observed the performance and emission characteristics of the blends and compared with the pure diesel fuel.

They were conducted experiments successfully and analyzed the results. At 25% load conditions, B15 and B20 blends produced lower NO_X emissions compared to pure diesel. But at full load diesel produced lower emissions compared to the two blends. The emissions of HC were increased with the addition of Apricot oil at all load conditions. At full load condition, B15 blend had lower brake specific fuel consumption and higher brake thermal efficiency compared with diesel. As a result, B15 blend significantly showed the improvement in the performance and ecofriendly for Direct Injection diesel engine.

Abbas AlliTaghipoorBafghi, HoseinBakhoda, and FatemeKhodaeiChegeni : were conducted an experimental investigation to know the effects of cerium oxide nanoparticles as additive in pure diesel and diesel-biodiesel blends on the performance characteristics of a CI Engine. The addition of cerium oxide to the diesel and blends, it acted as an oxygen donating catalyst and provided oxygen for combustion. The activation energy of cerium oxide helped in complete combustion of carbon deposits which results in reduction of hydrocarbon emissions.

They were described the results. Out of all the experiments conducted, B5D95-15 had the highest and B20D80-5 had the lowest specific fuel consumption. The tests were revealed the use of nano additives to improve complete combustion of fuel significantly.

Prabhu L, S. Satish Kumar, A. Anderson and K. Rajan : were conducted an investigation of performance and emission analysis of TiO_2 nanoparticle as an additive for biodiesel blends on single cylinder diesel engine at various load conditions. The concentration of nano particles used was 250 and 500 ppm, which were blended with 20% of biodiesel blend.

The results obtained were the brake thermal efficiency was increased and the amount of carbon monoxide (CO), hydrocarbon (HC) and smoke emissions were reduced significantly but the amount of NO_X emissions were increased.

S. Manibharti, B. Annadurai and R. Chandraprakash : were conducted an experimental investigation of CI engine performance by rhodium oxide nano additive with pongamia biofuel. The nano additives were added with pongamia biodiesel to improve an anti-wear behavior and to reduce carbon deposit in engine cylinder.

The addition of nano additives in biofuel reduced the NO_X emissions up to 37% and unburnt hydrocarbons up to 45%. Nano particles reduced the energy consumption and improved the brake thermal efficiency.

Krishnan V and AnbarasuG :were conducted a review on emission control strategy by adding nano additives in CI engine. In order to get an idea about the effect of nano additives such as Aluminium oxide, Copper oxide, Cerium oxide, Titanium oxide, Zirconium oxide, Ferric chloride, Silicon dioxide, Cobalt oxide, Zinc oxide and Nickel oxide.

3. EXPERIMENTAL INVESTIGATION

A setup is made for the experiment with the necessary instrumentation to evaluate the performance, emission and combustion parameters of the compression ignition engine at different operating conditions. The view of the experimental setup is shown in Fig.3.1 Basically the piston has 2 grooves which are commonly generated by the manufacturer. The main use of grooves on piston crown is to change the fuel motion, which is called as swirl motion. And by changing or by making grooves on piston crown is leads to change in both performance characteristics (like BP ,IP, FP, SFC, MEP, ITE, BTE, ME & VE) and emission characteristic(like CO, CO_2 ,NO_X ,HC, O_2, OPACITY & ABSERVITY).

Fig: 3.1 Four Stroke Single Cylinder Diesel Engine

3.1 MANUAL 2D PISTON DESIGN

For making grooves on piston crown there is a need of 2D design that shows the basic view of the groove on piston crown, and gives a better knowledge on the groove.

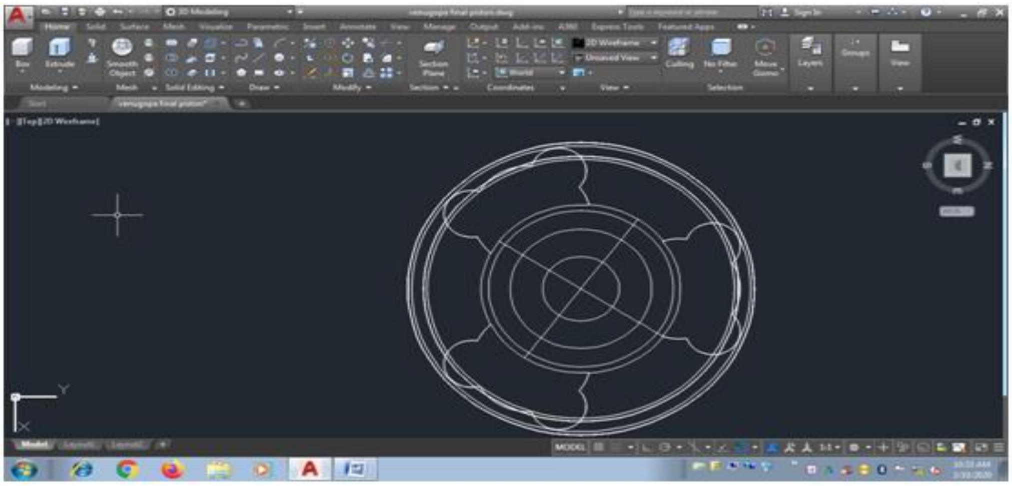


Fig 3.1.1 2D Top view

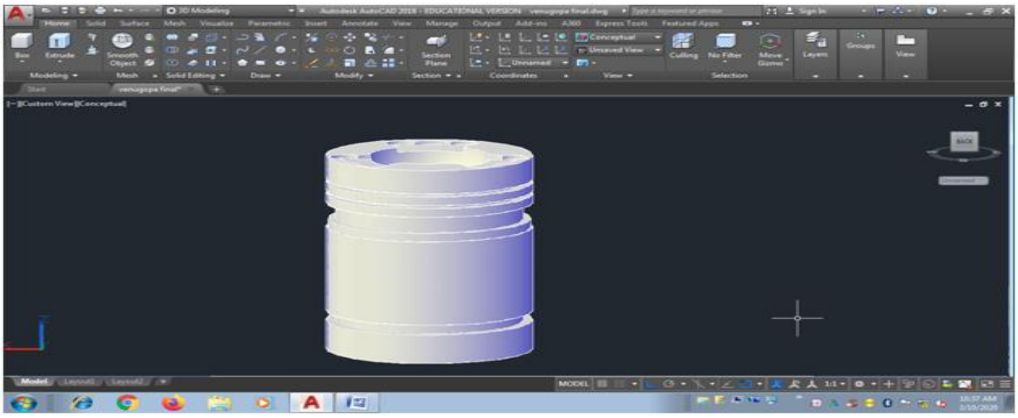


Fig 3.1.2 3D Side view

3.2 MAKING OF GROOVES

By the use of auto CAD design we can easily generate the grooves on that piston crown. The design which is prepared in auto cad can be transferred into SOLID WORKS software, and that solid works software is interlinked with a CNC MILLING machine. By the help of this machine we can generate grooves on piston crown.

Fig 3.2.1Photographs taken while making grooves on piston crown

3.3 EXPERIMENTAL WORK

The piston crown of 87.5 mm diameter of base line engine is modified by producing three grooves. In the

S NO	Load in kg	speed in rpm	Fuel consumption In cc/min	Total mass of fuel consumption kg/hr	BP kW	SFC in kg/kWh	BMEP	IP (kW)	BTHE (%)	ITHE (%)	Mech Eff. (%)
1	0.2	1554	12	0.66	0.10	6.69	0.12	2.34	1.37	32.37	4.23
2	3	1538	13	0.72	0.95	0.76	1.12	3.46	12.09	44.04	27.46
3	6	1520	1	0.89	1.83	0.48	2.18	4.28	18.93	44.32	42.70
4	9	1501	18	1.00	2.55	0.39	3.08	4.98	23.43	45.84	51.12
5	12	1480	22	1.22	3.40	0.36	4.17	5.84	25.60	43.96	58.22

present experiment , grooves of length 28mm at the crown and 39mm at the outer diameter with a width of 15 mm is produced on piston of 87.5 mm diameter and maintaining a depth of 1.5 mm at outer and 2mm at inner in each groove. The experiments are conducted with these pistons by a blends of B10, B20, B30 and waste lube oil and their performance and emissions are compared with each other. The grooved piston used in this performance and emission characteristics test is shown in below fig.3.3.1

Fig: 3.3.1 Piston After Combustion

4 PERFORMACE READINGS

Table 4.1 Modified piston with B10% CR16

S No	Load in kg	speed in rpm	Fuel consumption In cc/min	Total mass of fuel consumption kg/hr	BP kW	SFC in kg/kWh	BMEP	IP kW	BTHE(%)	ITE (%)	Mec Eff. (%)
1	0.2	1581	9	0.50	0.06	8.04	0.07	2.52	1.14	46.48	2.45
2	3	1558	12	0.66	0.90	0.74	1.05	3.57	12.42	49.30	25.19
3	6	1529	15	0.83	1.75	0.48	2.07	4.43	19.28	48.96	39.38
4	9	1509	19	1.05	2.63	0.40	3.17	5.31	22.97	46.27	49.65
5	12	1485	24	1.33	3.42	0.39	4.17	6.06	23.59	41.85	56.36

Table 4.2 Modified piston with B10% CR18

S No	Load in kg	speed in rpm	Fuel consumption In cc/min	Total mass of fuel consumption kg/hr	BP (kW)	SFC in kg/kWh	BMEP	IP (kW)	BTHE (%)	ITHE (%)	Mech Eff. (%)
1	0.2	1564	11.00	0.56	0.10	5.59	0.12	2.50	1.60	40.23	3.97
2	3	1543	12.00	0.61	0.95	0.64	1.12	3.43	14.02	50.63	27.68
3	6	1520	15.00	0.76	1.75	0.43	2.09	4.12	20.69	48.63	42.55
4	9	1492	18.00	0.91	2.54	0.36	3.09	5.00	24.97	49.16	50.80
5	12	1456	22.00	1.11	3.40	0.33	4.24	5.83	27.37	46.87	58.41

Table 4.3 Modified piston with B20% CR16

S No	Load in kg	speed in rpm	Fuel consumption In cc/min	Total mass of fuel consumption kg/hr	BP (kW)	SFC in kg/kWh	BMEP	IP (kW)	BTHE (%)	ITHE (%)	Mech Eff. (%)
1	0.2	1578	9.00	0.45	0.07	6.42	0.08	2.67	1.39	52.52	2.65
2	3	1538	11.00	0.56	0.97	0.57	1.15	3.53	15.67	56.83	27.58
3	6	1515	13.00	0.66	1.79	0.37	2.14	4.32	24.33	58.79	41.39
4	9	1485	18.00	0.91	2.53	0.36	3.10	5.07	24.90	49.85	49.96
5	12	1460	76	0.7768	3.32	0.4501	4.13	2.9858	18.81	32.55	57.43

Table 4.4 Modified piston with B20% CR 18

S No	Load in kg	speed in rpm	Fuel consumption In cc/min	Total mass of fuel consumption kg/hr	BP (kW)	SFC in kg/kWh	BMEP	IP (kW)	BTHE (%)	ITHE (%)	Mech Eff. (%)
1	02	1462	15	0.76	0.10	7.97	0.12	2.47	1.12	29.09	3.85
2	3	1461	16	0.81	0.76	1.07	0.94	3.17	8.38	35.04	23.92
3	6	1459	17	0.86	1.81	0.47	2.25	4.25	18.82	44.20	42.58
4	9	1449	18	0.91	2.50	0.36	3.13	4.91	24.59	48.23	51.00
5	12	1421	21	1.06	3.25	0.33	4.14	5.75	27.34	48.44	56.45

Table 4.5 Modified piston with B30% CR16

S No	Load in kg	speed in rpm	Fuel consumption In cc/min	Total mass of fuel consumption kg/hr	BP (kW)	SFC in kg/kWh	BMEP	IP (kW)	BTHE (%)	ITHE (%)	Mech Eff. (%)
1	0.2	1557	9.00	0.45	0.07	6.32	0.08	2.61	1.46	53.46	2.73

2	3	1540	11.00	0.55	0.92	0.60	1.08	3.33	15.33	55.86	27.45
3	6	1495	14.00	0.70	1.74	0.40	2.11	4.15	22.90	54.57	41.97
4	9	1472	16.00	0.80	2.51	0.32	3.09	4.99	28.88	57.52	50.20
5	12	1438	22.00	1.10	3.29	0.33	4.15	5.71	27.57	47.81	57.67

Table 4.6 Modified piston with B30% CR18

B10 CR18							
Load	CO	HC	CO2	O2	NOX	opacity	ABSERVITY
0	0.05	6	0.5	20.16	11	3.8	0.09
3	0.04	10	0.8	19.63	41	2.8	0.06
6	0.05	14	1.8	18.05	173	5.2	0.12
9	0.08	22	3.3	15.74	407	6.9	0.16
12	0.17	33	4.5	13.95	469	7.3	0.17

4.1 EMISSION READINGS

Table 4.4.1 Modified piston with B10% CR18

B10 CR16							
Load	CO	HC	CO2	O2	NOX	opacity	ABSERVITY
0	0.2	31	0.7	19.7	0	16.3	0.41
3	0.18	21	1.1	18.97	8	9.2	0.22
6	0.08	14	1.5	18.52	55	18.2	0.46
9	0.08	32	2.2	17.41	152	20.9	0.54
12	0.13	34	3.3	15.04	307	13.2	0.32

Table 4.4.2 Modified piston with B10% CR16

B20 CR 18							
Load	CO	HC	CO2	O2	NOX	opacity	ABSERVITY
0	0.07	15	0.3	20.3	0	6.6	0.15
3	0.06	16	0.9	19.38	40	6.2	0.14
6	0.03	13	0.9	19.45	66	7	0.16
9	0.06	22	2.4	17.01	259	15.3	0.38
12	0.09	31	3.8	15.3	397	12.1	0.29

Table 4.4.3 Modified piston with B20% CR18

B20 CR 16							
Load	CO	HC	CO2	O2	NOX	opacity	ABSERVITY
0	0.22	26	0.7	19.59	0	14.5	0.36
3	0.16	23	0.8	19.49	3	6.2	0.14
6	0.09	17	1.1	19.08	22	18	0.46
9	0.07	23	1.8	18.13	85	24	0.63
12	0.1	28	3.2	16	249	13.7	0.34

Table 4.4.4 Modified piston with B20% CR18

B30 CR18							
Load	CO	HC	CO2	O2	NOX	opacity	ABSERVITY
0	0.04	8	0.2	20.64	0	3.3	0.07
3	0.06	14	0.5	20.09	0	2.4	0.05
6	0.04	16	1.2	18.99	60	14.4	0.36
9	0.05	33	2.1	17.56	204	14.5	0.36
12	0.08	30	3.7	15.33	378	8.6	0.2

Table 4.4.5 Modified piston with B30% CR18

B30 CR16							
Load	CO	HC	CO2	O2	NOX	opacity	ABSERVITY
0	0.05	12	0.1	20.7	0	14.5	0.36
3	0.11	26	0.4	20.12	0	25.4	0.68
6	0.26	52	1.9	17.78	8	36.9	1.07
9	0.15	55	2.9	16.3	98	26.8	0.72
12	0.08	33	2.7	16.77	131	10.7	0.26

5. RESULTS AND DISCUSSIONS

Test were carried out by the modified piston with a blends of B10,B20 & B30 by maintaining constant pressure 250 and varying the compression ratios CR16 & CR18, with a loads of 0.2kg,3kg,6kg,9kg,12kg. In this test both performance and emission characteristics are compared with each other. In performance point of view we are considering indicating power, break power, indicating thermal efficiency, break thermal efficiency, specific fuel consumption, mechanical efficiency, volumetric efficiency and in emission point of you Co, Co_2, No_x, Hc, opacity all these parameters were compared.

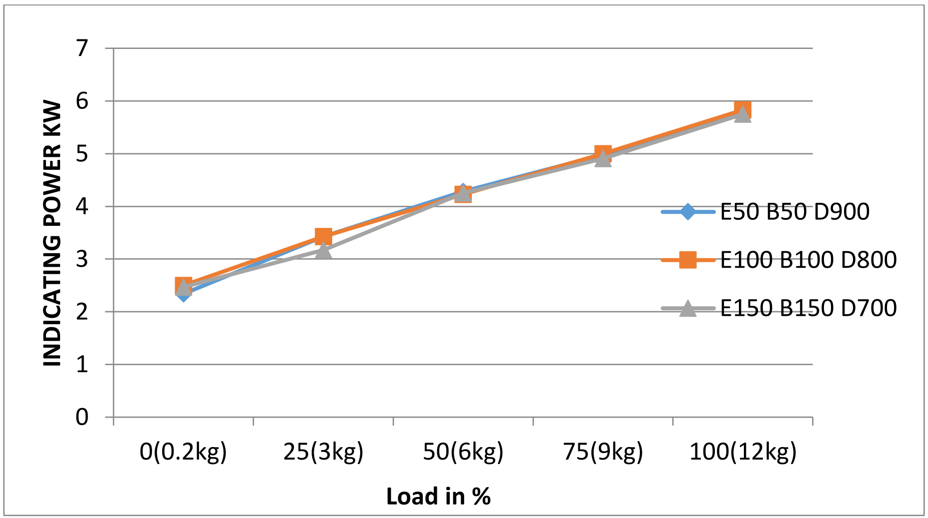
After comparing all the readings with each modified piston with B20 P250 CR16 will gives better results in both performance and emission conditions.

Modified Piston With B-10, B-20 And B-30 at P250 CR16:

5.1 Performance readings:

5.1.1 Indicating Power:

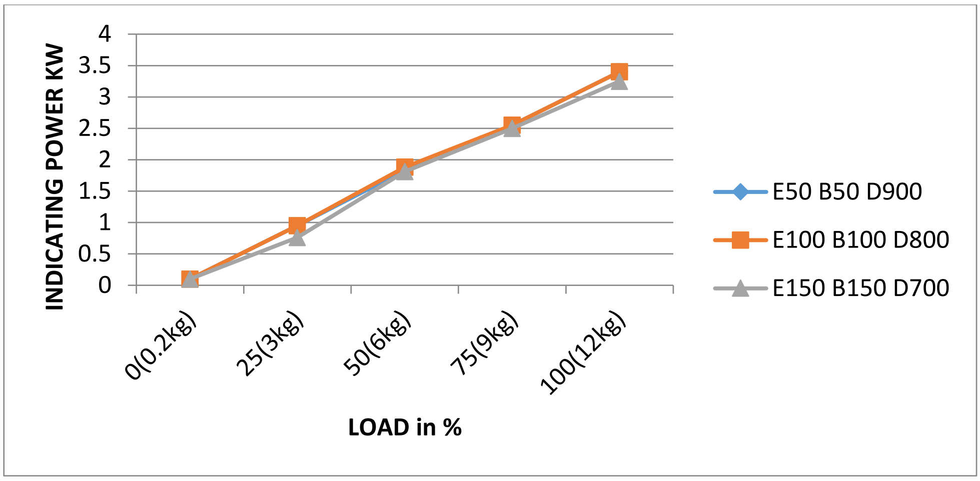
The Indicating power with load will conduct a performance test on modified piston with blends. The indicating power for the modified piston with B10 at full load is 5.82KW. The indicating power for the modified piston with B20 at full load is 5.83KW. The indicating power for the modified piston with B30 at full load is 5.75KW.The indicating power of B20 is maximum compare with remaining.



Graph 5.1 Variation of indicating power with respect to load

5.1.2 Break power:

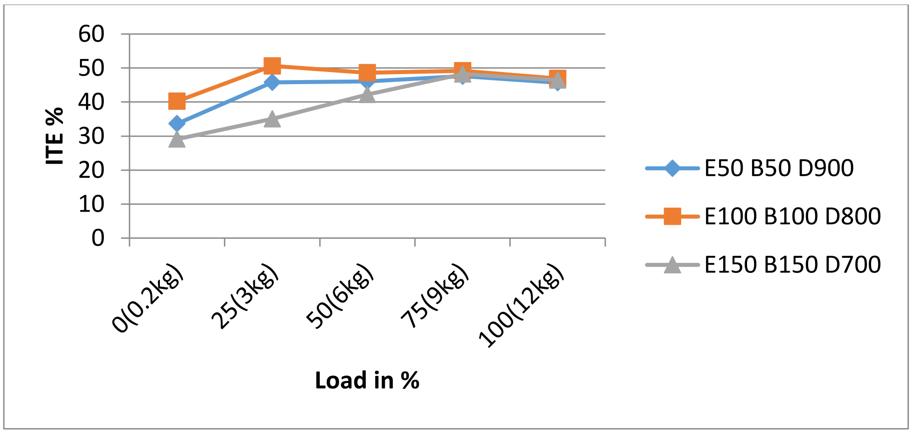
The Break power with load will conduct a performance test on modified piston with blends. The Break power for the modified piston with B10 at full load is 3.4KW. The Break power for the modified piston with B20 at full load is 3.4 KW. The Break power for the modified piston with B30 at full load is 3.25KW.The Break power of B20 is maximum compare with remaining.



Graph 5.2 Variation of break power with respect to load

5.1.3 Indicated Thermal Efficiency:

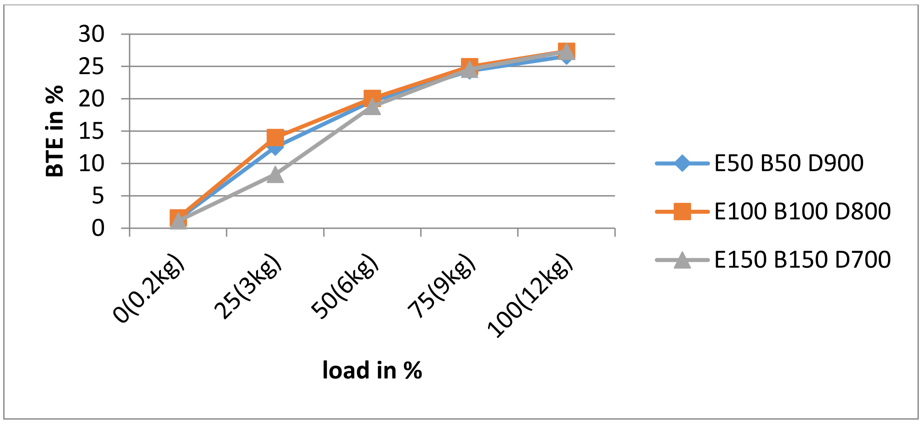
The Indicated Thermal Efficiency with load will conduct a performance test on modified piston with blends. The Indicated Thermal Efficiency for the modified piston with B10 at full load is 45.67%. The Indicated Thermal Efficiency for the modified piston with B20 at full load is 46.87%. The Indicated Thermal Efficiency for the modified piston with B30 at full load is 46.44%.The Indicated Thermal Efficiency of B20 is maximum compare with remaining.



Graph 5.3 Variation of indicated thermal efficiency with respect to load

5.1.4 Break thermal efficiency:

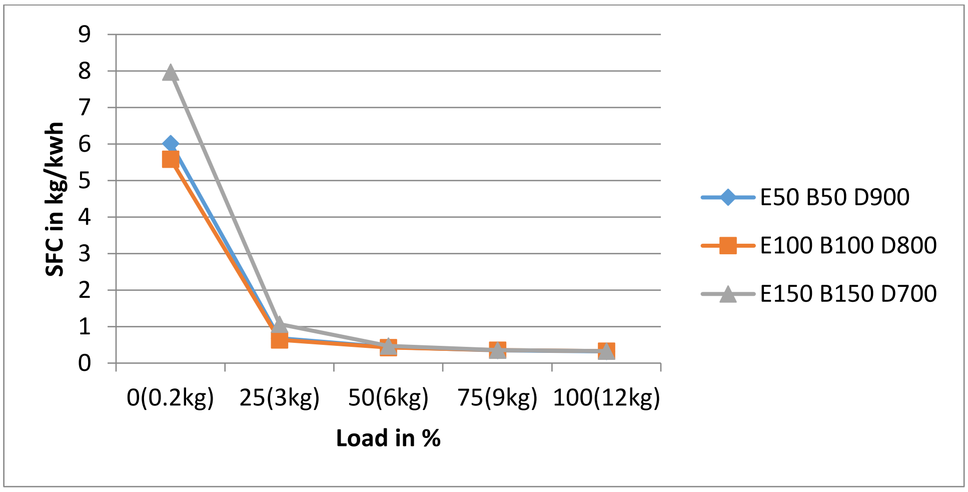
The Break Thermal Efficiency with load will conduct a performance test on modified piston with blends. The Break Thermal Efficiency for the modified piston with B10 at full load is 26.59%. The Break Thermal Efficiency for the modified piston with B20 at full load is 27.37%. The Break Thermal Efficiency for the modified piston with B30 at full load is 27.34%.The Break Thermal Efficiency of B20 is maximum compare with remaining.



Graph 5.4 Variation of Break thermal efficiency with respect to load

5.1.5 Specific Fuel Consumption:

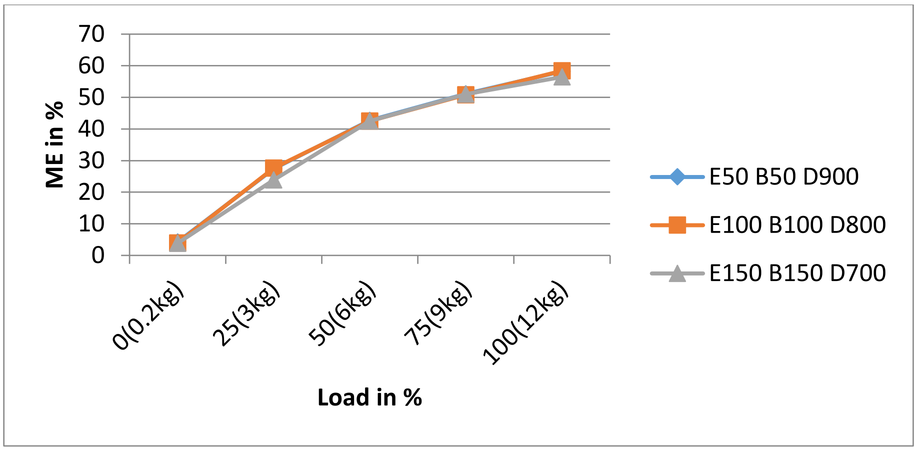
The specific fuel consumption with load will conduct a performance test on modified piston with blends. The specific fuel consumption for the modified piston with B10 at full load is 0.32. The specific fuel consumption for the modified piston with B20 at full load is 0.33. The specific fuel consumption for the modified piston with B30 at full load is 0.33.the specific fuel consumption of B20 is minimum compare with remaining.



Graph 5.5 Variation of specific fuel consumption with respect to load

5.1.6 Mechanical efficiency :

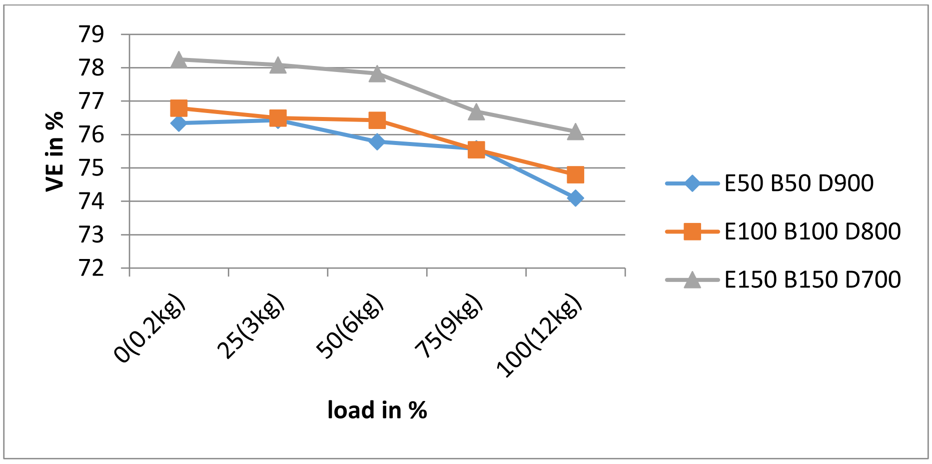
The Mechanical Efficiency with load will conduct a performance test on modified piston with blends. The Mechanical Efficiency for the modified piston with B10 at full load is 58.22%. The Mechanical Efficiency for the modified piston with B20 at full load is 58.41%. The Mechanical Efficiency for the modified piston with B30 at full load is 56.45%.The Mechanical Efficiency of B20 is maximum compare with remaining.



Graph 5.6 Variation of Mechanical efficiency with respect to load

5.1.7 Volumetric efficiency:

The volumetric efficiency with load will conduct a performance test on modified piston with blends. The volumetric efficiency for the modified piston with B10 at full load is 74.01%. The volumetric efficiency for the modified piston with B20 at full load is 74.08%. The volumetric efficiency for the modified piston with B30 at full load is 76.09%.The volumetric efficiency of B20 is in 2nd place compare with remaining.

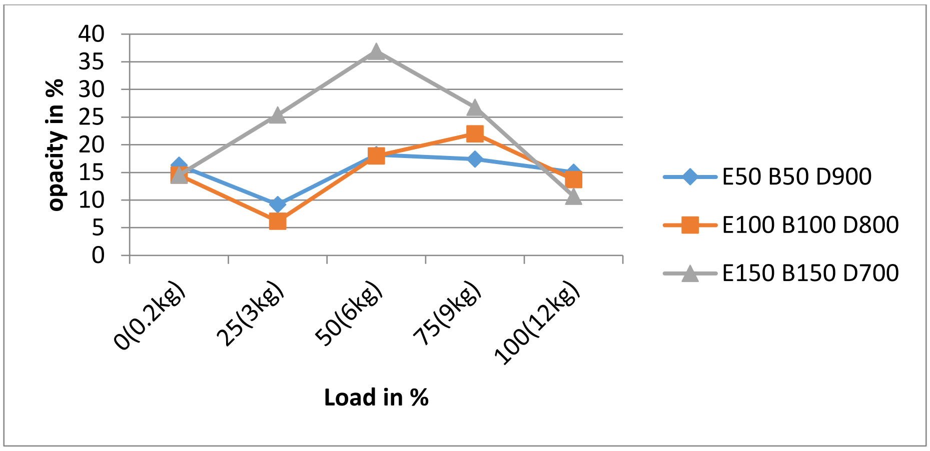


Graph 5.7 Variation of volumetric efficiency with respect to load

5.2 Emission Readings:

5.2.1 Opacity:

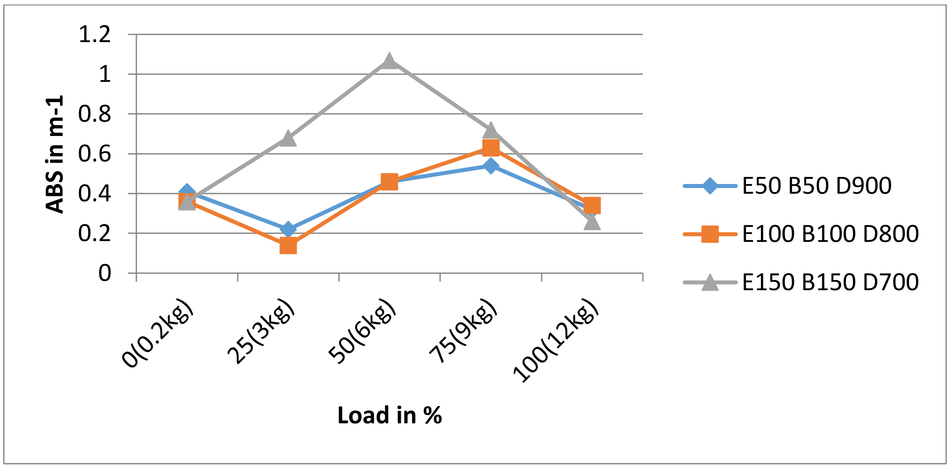
The Opacity with load will conduct a performance test on modified piston with blends. The Opacity for the modified piston with B10 at full load is 15.04%. The Opacity for the modified piston with B20 at full load is 13.7%. The Opacity for the modified piston with B30 at full load is 10.7%.The Opacity of B20 is in 2nd place compare with remaining.



Graph 5.8 Variation of opacity with respect to load

5.2.2 ABS in m^{-1}:

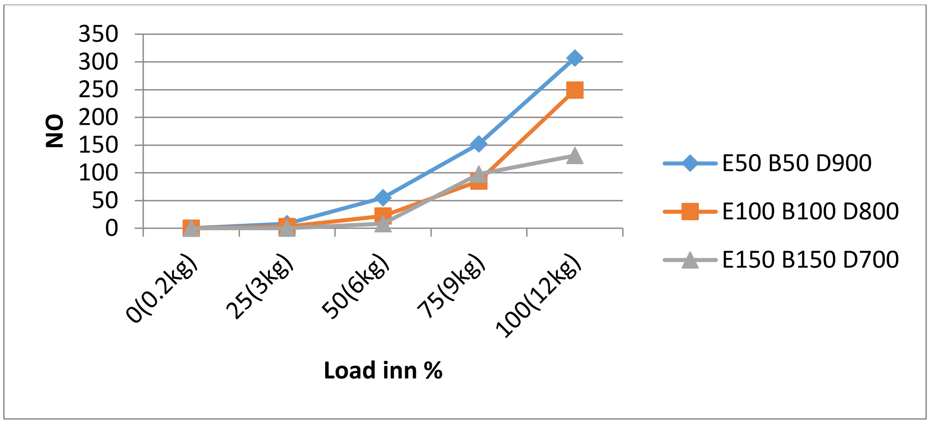
The ABS with load will conduct a performance test on modified piston with blends. The ABS for the modified piston with B10 at full load is 0.32. The ABS for the modified piston with B20 at full load is 0.34. The ABS for the modified piston with B30 at full load is 0.26.The ABS of B20 is in good condition compare with remaining.



Graph 5.9 Variation of ABS with respect to load

5.2.3 NO:

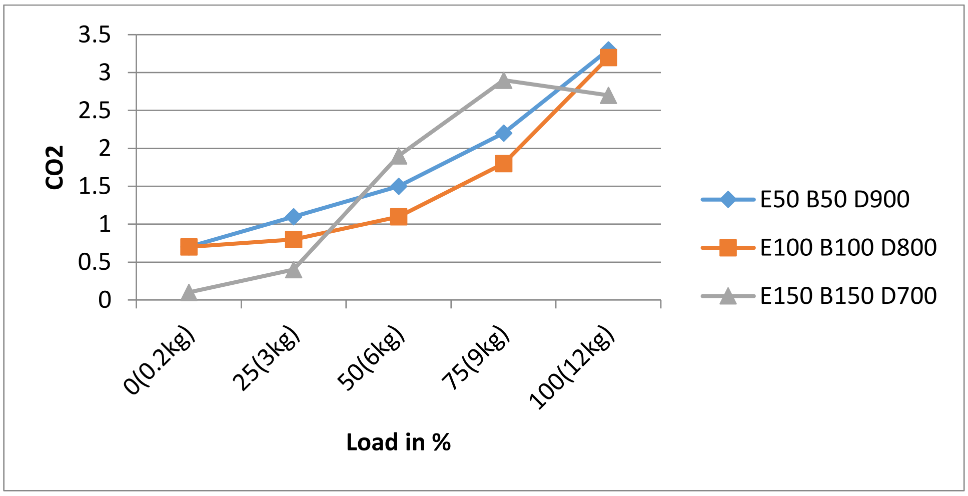
The No with load will conduct a performance test on modified piston with blends. The No for the modified piston with B10 at full load is 0.32. The NO for the modified piston with B20 at full load is 0.34. The No for the modified piston with B30 at full load is 0.26.The No of B20 is in good condition compare with remaining.



Graph 5.10 Variation of No with respect to load

5.2.4 CO_2:

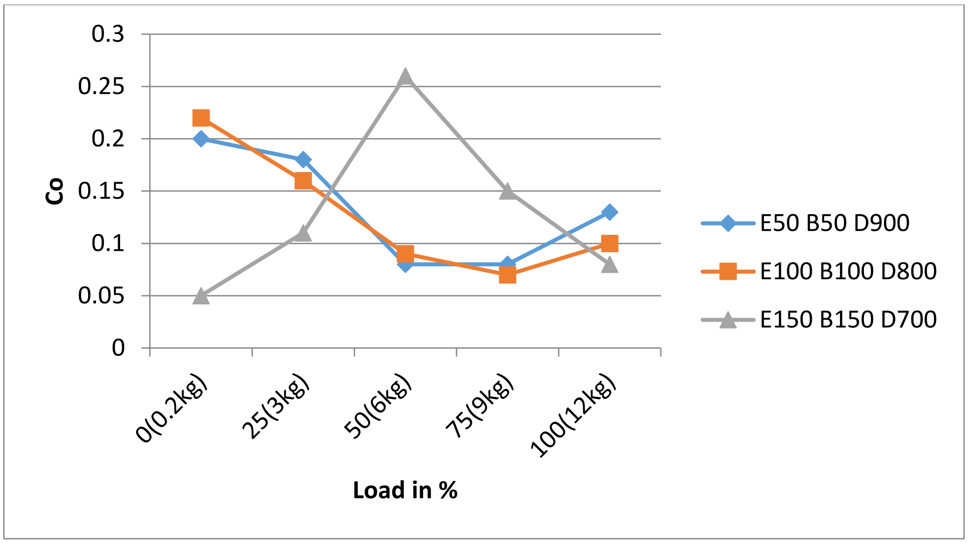
The Co_2 with load will conduct a performance test on modified piston with blends. The Co_2 for the modified piston with B10 at full load is 3.3. The Co_2 for the modified piston with B20 at full load is 3.2. The Co_2 for the modified piston with B30 at full load is 2.7.The Co_2 of B20 is in good condition compare with remaining.



Graph 5.11 Variation of CO_2 with respect to load

5.2.5 CO:

The Co with load will conduct a performance test on modified piston with blends. The Co for the modified piston with B10 at full load is 0.13. The Co for the modified piston with B20 at full load is 0.1. The Co for the modified piston with B30 at full load is 0.08.The Co of B20 is in good condition compare with remaining



Graph 5.12 Variation of Co with respect to load

6. CONCLUSION

Test were carried out by the modified piston with a blends of B10,B20 & B30 and in this blends we are maintaining constant pressure 250 and varying the compression ratios CR16 & CR18, with a loads of 0.2kg,3kg,6kg,9kg,12kg. In this test both performance and emission characteristics are compared with each other. In performance point of you we are considering indicating power, break power, indicating thermal efficiency, break thermal efficiency, specific fuel consumption, mechanical efficiency, volumetric efficiency and in emission point of you Co, Co_2, No_x, Hc, opacity all these parameters were compared.

After comparing all the readings with each modified piston with B20 P250 CR16 will gives better results in both performance and emission conditions.

- The Indicating power with load will conduct a performance test on modified piston with blends. The indicating power of B20 is maximum [5.83KW] compare with remaining.
- The Break power with load will conduct a performance test on modified piston with blends. The Break power of B20 is maximum [3.4KW] compare with remaining.
- The Indicated Thermal Efficiency with load will conduct a performance test on modified piston with blends. The Indicated Thermal Efficiency of B20 is maximum [46.87%] compare with remaining.
- The Break Thermal Efficiency with load will conduct a performance test on modified piston with blends The Break Thermal Efficiency of B20 is maximum [27.37%] compare with remaining.
- The specific fuel consumption with load will conduct a performance test on modified piston with blends Specific fuel consumption of B10 is minimum [0.32] compare with remaining.
- The Mechanical Efficiency with load will conduct a performance test on modified piston with blends. The Mechanical Efficiency of B20 is maximum [58.41%] compare with remaining.
- The volumetric efficiency with load will conduct a performance test on modified piston with blends. The volumetric efficiency for the modified piston with B30 is maximum at full load is 76.09%.
- The Opacity with load will conduct a performance test on modified piston with blends. The Opacity of B20 is in 2^{nd} place [13.7%] compare with remaining.

- The ABS with load will conduct a performance test on modified piston with blends. The ABS of B20 is in good [0.34] condition comparing with remaining.
- The No with load will conduct a performance test on modified piston with blends. The No of B20 is in good [0.34] condition comparing with remaining.
- The Co_2 with load will conduct a performance test on modified piston with blends. The Co_2 of B20 is in good [3.2] condition comparing with remaining.
- The Co with load will conduct a performance test on modified piston with blends. The Co of B20 is in good [0.1] condition compare with remaining

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