To Study the Performance of Oxygen Enriched Diesel Engine by Varying Compression Ratios

Jitin Yadav[1], Dr. Prof. Dhananjay Gupta[2], Dr. Prof. Manu Gupta[3]

[1]*Ph.D. Scholar, Sunrise University, Alwar, Rajasthan, India*
[2]*Professor, Arya College of Engineering and I.T., Jaipur, Rajasthan, India*
[3]*Professor & Principal, Arya College of Engineering and I.T., Jaipur, Rajasthan, India*
Email - jtinrao@gmail.com

---***---

Abstract – *In current study, a single cylinder variable compression ratio diesel engine was used with an eddy current dynamometer to learn more about the effects of changing in compression ratios in two different intakes oxygen enrichment levels. Two individual oxygen cylinders were used in these tests which were connected to intake system by gas flow regulator. The objective of this test setup is to analysis the difference of performance at two compression ratios at same level of oxygen intake. Tests were conducted to study performance by recording the exhaust gas temperature, brake power, specific fuel consumption and mechanical efficiency. The results make clear that the optimum outcome lies in between 70 to 80% of load and compression ratio from range 16.5 to 17.5.*

Key Words: Variable Compression Ratio Engine, Diesel Engine, Oxygen Enrichment, Compression Ratio, Engine Performance.

1. INTRODUCTION

Operation in diesel engine combustion depends on elevated Compression Ratio (C.R.) process to increase the temperature of air above self ignition temperature of liquid fuel. Higher temperature gives shorter ignition delay that means rapid burning of charge due to high temperature of intake air resulting higher combustion chamber pressure. These initial high pressure increases the NOx kinetics but when the temperature drops, the pressure also drops so the kinetics of NOx freezes resulting lower NOx level in exhaust. By lowering C.R. of engine, we can reduce the initial pressure and temperature [1].

To control the overall emissions from diesel and its engine interfacing are constantly chasing by researchers by expanding the approach towards operation conditions of engine, composition of diesel and their blends, chamber design and minimizing the emission while operating on Lean or extra lean engine operation by different approach [11][17].

Diesel operates on excess oxygen i.e. lean operations in combustions and produces Carbon Monooxide (CO), Hydrocarbon (HC), Particulate matter (PM), Smoke, Odour, Sulphur dioxide (SO2) and oxides of Nitrogen (NOx). Diesel engines are usually discharge large amount of PM and NOx as compared to CO and HC. [2]

To reduce these emission parameters and to follow the current emission legislations, operation in new diesel engines are evaluate by its thermodynamics approach and precisely controlled fuel atomisation and distribution in the chamber to react with oxygen [16]. The fuel must occupy minimum space in chamber and it should be high in specific mass energy, mixing and reaction of the fuel and air with sufficient inhalation in cyclic process with maximum possible efficiency near to thermodynamic cycle[10][15].

While considering the emission parameters, oxygen is the most prominent parameters to touch because the amount of oxygen can vary the different parameters of tail pipe emissions. Mass of oxygen, mixing of oxygen with fuel droplets, Kinetics of oxygen for reactivity, collision of oxygen particles with fluid droplets, oxidation of fuel, energy contribution during exothermic reaction are many parameters which can affect the performance of diesel engine [3].

Although, the different new design aspects and technologies are helpful in reducing emission but excess amount of oxygen volume can decrease the emission up to a certain level with limitation of reaction time of each fuel molecules with required oxygen [5][6]. Complete conversion of the carbon and hydrogen is impossible due to lack of oxygen.

Two types of oxygen enrichment methods are widely studied. One is fuel oxygenation and other is intake oxygen enrichment (I.O.E.). Studies in I.O.E. methods indicated that this methods can reduces CO and HC emission but it increases the NOx emission.[2] It can also increase the burning rate of fuel for the required mixture to complete combustion by reducing the delay and is also reduces the noise of engine operation. We can say in brief that IOR helps in using lower quality fuel with higher specific power output and its thermal efficiency.

Researchers introduced molecular sieve method to clean air instantly to get oxygen directly in combustion and showed lower brake specific power, low minimum cylinder pressure and high gross power. They also showed that NOx emission in tailpipe can be controlled by the emulsified diesel [1].

I.O.E. can also enhance the stability, velocity, temperature of flame as well lean combustible limits of charge with high available energy [13].

The volume of intake oxygen can be limited as I.O.E. can overall increases the flame propagation and its laminar burning velocity so it increase the maximum pressure inside cylinder and the rate of pressure. it is advisable by the [16] to keep the volume of oxygen maximum up to 30% so the combustion reactions can be controllable at all the stages to maintain the inside pressure.

In the study of multiple concentration of oxygen intake, it has been concluded that higher the concentration of oxygen will reduce the brake specific fuel consumption, Higher concentration favour the lower emission methodology as well as low PM and smoke density in tailpipe emission but increases the NOx level [7].

By reviewing different researches, it is clearly observable that I.O.E. is significantly increasing its recognition among another technology and decreasing compression ratio can also help in reducing emission studies. Thus the approach of this study is to investigate the effect of I.O.E. on performance of naturally aspirated four stroke single cylinder direct injection diesel engine with different concentration at different compression ratios.

2. Experimental Setup

Naturally aspirated water cooled single cylinder variable compression ration engine loaded with eddy current dynamometer & computerized data acquisition system was used in this test. Rests of details are shown in table - 1. Diesel fuel was tested before using in experiment. The properties of fuel are given in table – 2. Additional oxygen was delivered through gas flow regulator directly into intake manifold without any leakage before mixing with the atmospheric air. Gas flow regulator was able to send four waves of different amount from 1L to 4L per minute. Volumetric type of fuel gauge was used to deliver the 35 ml of fixed fuel in one time. A stop watch is used to calculate the time of consuming fuel. A cylindrical tank was used for air reservoir which was fitted with sharp edged orifice. The volume of the tank was large enough to feed sufficient air to the engine. It was assumed that the flashing suction formed by engine will not change the air pressure inside the air tank.

Table -1: Specification of Engine Used in Tests

Engine Specifications			
Make	Kirloskar TAF 1	Bore	87.5mm
Rated Power	5HP	Stroke	110mm
Speed	1500-2000 rpm	Type of ignition	Compression
No. of cycle	One	Method of loading	Eddy dynamometer
Compression ratio	Variable	Start	Manual Crank

Table -2: Properties of Diesel Fuel

Fuel Properties of Diesel Used in Tests	
Density at 15°C (kg/m³)	835
HHV (MJ/kg)	44.245MJ/kg
LHV (MJ/kg)	42.005MJ/kg
Viscosity (mm²/s)	3.523
Compression Ratio	17
Flash Point (°C)	62.6
Pour Point (°C)	-6.2
C (wt%)	86.0
H (wt%)	12.0
Sulphur Content (wt%)	0.85
Water Content (mg/kg)	94

3. Experimental Procedure

The tests were conducted in a cabin at the ambient temperature of 31⁰C. Readings were carried out only on two different compression ratios (CR) i.e. 16.5 and 17.5 CR at only on two concentrations of additional oxygen. Different loading of starting from zero loads to the rated capacity of the engine to the successive loading of increment of 20% is used after every change in CR at a constant speed of 1500 RPM which drops when the load increases. Stability and repeating of the conditions of procedure were ensured by primarily run the test rig for 15 minutes at 55% load for constant 1400 rpm until the exhaust gas temperature reached 180⁰C. The flow of water in engine jacket and calorimeter was fixed a 60 Litre per minute by the regulating rota-meter. It was ensured that the temperature of intake water was constant throughout in collecting data. Once these conditions were attained, the engine test rig was brought to the essential test conditions after cooling whole system and permitted it to run for 5 minutes to ensure to stabilize reading before collecting the records. The fuel injection timing and its injection pressure was untouched while experiment as per the given company's values.

4. Results and Discussion

The objectives of the study are to determine suitable value for an engine's compression ratio in which additional oxygen is used to lean the combustion. We took only two compression ratios and only two oxygen concentrations 16.5 to 17.5 and 1L/min to 2L/min respectively. Data were collected under the stabilized engine conditions for the basic performance parameters like specific fuel consumption, brake power, mechanical efficiency and exhaust gas temperature.

4.1 Specific Fuel Consumption

The term SFC is use to measure the capability of an engine which can produce work by using fuel. It is also defined as the fuel flow rate per unit power output [15] [16]. With reference to chart – 1, as the level of oxygen increases, the SFC decreases in the range of 9-18% at partial and full load conditions. As the compression ratio increases from 16.5 to 17.5 along with the oxygen concentration, graph of SFC become more flat initially at low load conditions than decreases by more 2 % at higher loads. Graph clearly shows that there is fluctuation in between 50% to 70% load and maximum dip was recorded in between 70 to 90% of load. As the level of oxygen increases in both the compression ratios, the SFC further decreases resulting better power output at low fuel consumption ratios.

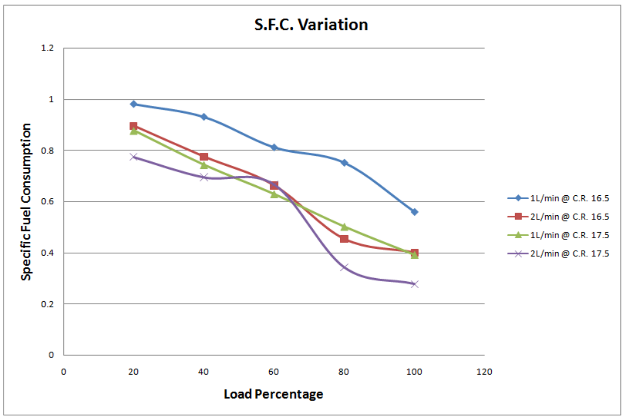

Chart -1: Variation in Specific Fuel Consumption at different Oxygen Concentrations and Compression Ratios.

4.2 Brake Power

The power which is available to produce work at output is brake power. It has been suggested that the higher level of oxygen in mixture increases the brake power output [9] [12]. The amount of oxygen increased in mixture than the specific heat of the mixture ratio increases [4]. This higher specific heat of the mixture increases the conversion rate of thermal into work energy. As shown in chart -2, the brake power increases as oxygen concentration increases. But the as the compression ratio increases, it increases the pressure inside the cylinder resulting higher magnitude of brake power. The brake power rises till 80% of load, than it started dropping. It may be because of poor scavenging, valve overlapping or exhaust gas back pressure at full load.

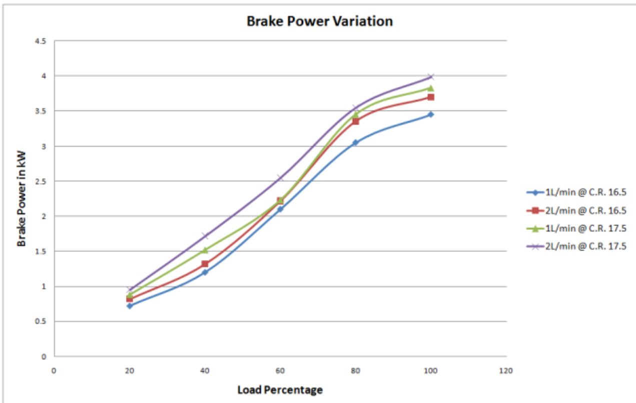

Chart -2: Variation in Brake Power at different Oxygen Concentrations and Compression Ratios.

4.3 Mechanical Efficiency

As the brake power rises, mechanical efficiency will also increase because the mechanical efficiency it ratio of brake power to indicated power [15]. It can be seen in the chart – 3, that as the level of oxygen is increases, the efficiency increases. But as the compression ratio increases, the mechanical efficiency decreases by 8 to 15%. It can be seen in the chart that the optimum values for both the compression ratios and oxygen enhancement is at 80% of load. It is also observed that efficiency increases by 10% at compression ratio17.5 for 2L/min oxygen concentration.

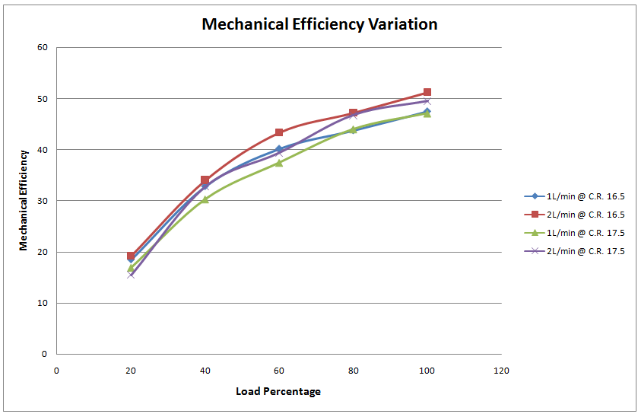

Chart -3: Variation in Mechanical Efficiency at different Oxygen Concentrations and Compression Ratios.

4.4 Exhaust Gas Temperature

Higher the exhaust gas temperature resulting higher combustion efficiency. Higher oxygen concentration of oxygen in mixture increases the exhaust gas temperature because to near to complete combustion because to ample oxygen availability for combustion [12]. Higher compression ratios increase the pressure inside the cylinder resulting increase in temperature [8].

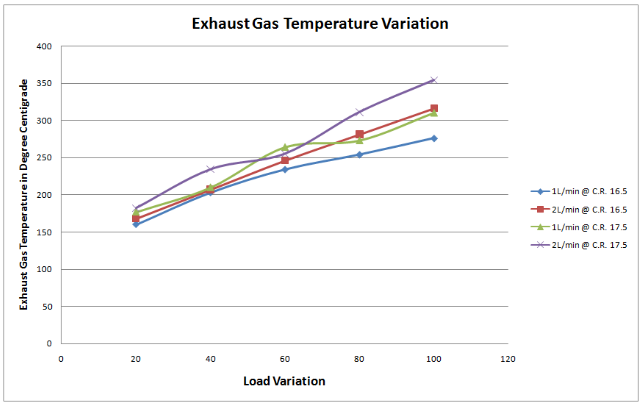

Chart -4: Variation in Exhaust Gas Temperature at different Oxygen Concentrations and Compression Ratios.

The conclusion was drawn from the data as shown in chart – 4, as the both compression ratio & higher oxygen concentration increase the temperature increases up to 40^{0}C at higher loads.

5. CONCLUSIONS

Based on tests, both higher values of oxygen concentration and higher compression ratio are favorable in terms of performance for a diesel engine and the conclusions are made:

1) The best possible value of SFC is at C.R. 17.5 with 2L/min in between 70 to 90% load conditions.
2) The brake power is increasing with increasing both values. So higher compression ratio and 2L/min oxygen concentration is found favorable at all load levels.
3) At 80% load and 2L/min of oxygen enrichment are the optimum values for best mechanical efficiency for a diesel engine.
4) In between 70% load to full load condition, 2L/min of additional oxygen with 17.5 compression ratio has shown the best output range for combustion efficiency.

ACKNOWLEDGEMENT

The researcher acknowledge the support given by the Management of the Institution (Arya College of Engineering and IT, Jaipur and Amity University, Noida) for providing opportunity to do research in their laboratory and he also acknowledge his guide Dr. Prof. Gupta for their valuable support in this research work.

REFERENCES

[1] R. B. Poola, R. Sekar, D. N. Assanis, and G. R. Cataldi, "Study of Using Oxygen-Enriched Combustion Air for Locomotive Diesel Engines," no. 1, 1996.
[2] J. Song, V. Zello, A. L. Boehman, and F. J. Waller, "Comparison of the impact of intake oxygen enrichment and fuel oxygenation on diesel combustion and emissions," *Energy and Fuels*, vol. 18, no. 5, pp. 1282–1290, 2004.
[3] G. R. Rigby and H. C. Watson, "Application of membrane gas separation to oxygen enrichment of diesel engines," *J. Memb. Sci.*, vol. 87, no. 1–2, pp. 159–169, 1994.
[4] P. Dinesha, V. Nayak, and P. Mohanan, "Effect of oxygen enrichment on the performance, combustion, and emission of single cylinder stationary CI engine fueled with cardanol diesel blends," *J. Mech. Sci. Technol.*, vol. 28, no. 7, pp. 2919–2924, 2014.
[5] H. Li, P. Biller, S. A. Hadavi, G. E. Andrews, G. Przybyla, and A. Lea-Langton, "Assessing combustion and emission performance of direct use of SVO in a diesel engine by oxygen enrichment of intake air method," *Biomass and Bioenergy*, vol. 51, pp. 43–52, 2013.
[6] Y. Liang, G. Shu, H. Wei, and W. Zhang, "Effect of oxygen enriched combustion and water-diesel emulsion on the performance and emissions of turbocharged diesel engine," *Energy Convers. Manag.*, vol. 73, pp. 69–77, 2013.
[7] P. Baskar and A. Senthilkumar, "Effects of oxygen enriched combustion on pollution and performance characteristics of a diesel engine," *Eng. Sci. Technol. an Int. J.*, vol. 19, no. 1, pp. 438–443, 2016.
[8] G. Reddy, N. Pratap Singh, K. R. V Sai Krishna, A. Priyedarshi, and S. Singh, "Effect Of Compression Ratio On The Performance of Diesel Engine at Different Loads," *J. Eng. Res. Appl.*, vol. 5, no. 102, pp. 2248–962262, 2015.
[9] K. Rajkumar, P. Govindarajan, C., "Experimental Investigation of Oxygen Enriched air intake on Combustion Parameters of a Single Cylinder Diesel Engine," *Int. J. Eng. Sci. Technol.*, vol. 2, no. 8, pp. 3621–3627, 2010.
[10] P. L. Perez and A. L. Boehman, "Performance of a single-cylinder diesel engine using oxygen-enriched intake air at simulated high-altitude conditions," *Aerosp. Sci. Technol.*, vol. 14, no. 2, pp. 83–94, 2010.
[11] S. H. Park, H. J. Kim, and C. S. Lee, "Effects of dimethyl-ether (DME) spray behaviour in the cylinder on the combustion and exhaust emissions characteristics of a high speed diesel engine," *Fuel Process. Technol.*, vol. 91, no. 5, pp. 504–513, 2010.
[12] K. Rajkumar and P. Govindarajan, "Impact of oxygen enriched combustion on the performance of a single cylinder diesel engine," *Front. Energy*, vol. 5, no. 4, pp. 398–403, 2011.
[13] G. Bisio, A. Bosio, and G. Rubatto, "Thermodynamics applied to oxygen enrichment of combustion air," *Energy Convers. Manag.*, vol. 43, no. 18, pp. 2589–2600, 2002.
[14] G. Yanfeng, L. Shenghua, G. Hejun, H. Tiegang, and Z. Longbao, "A new diesel oxygenate additive and its effects on engine combustion and emissions," *Appl. Therm. Eng.*, vol. 27, no. 1, pp. 202–207, 2007.
[15] J.B. Heywood, Internal combustion Engine Fundamental, Mc-Graw Hill, 1988.
[16] Charles E. Baukal, *Oxygen Enhanced Combustion*. CRC Press LLC, 1998.
[17] D. Lahiri, P. S. Mehta, R. B. Poola, and R. R. Sekar, "Utilization of Oxygen-Enriched Air in Diesel Engines: Fundamental Considerations," *Intern. Combust. engine 1997 fall Conf.*, 1997.
[18] M. S. Moghaddam, A. Zarringhalam, N. G. Zanjani, and E. Salimipor, "Improvement fuel properties and emission reduction by use of Diglyme-Diesel fuel blend on a heavy-duty diesel engine," *2nd Int. Conference Environ. Eng. Appl.*, vol. 17, pp. 210–214, 2011.