Optimization of Compression Ratio of Diesel Fuelled Variable Compression Ratio Engine

Y. B. Mathur[1], M. P. Poonia[2], A. S. Jethoo[3], R. Singh[4]

[1]Suresh Gyan Vihar University, Jaipur (INDIA)
[2]Department of Mechanical Engg., Malaviya National Institute of Technology, Jaipur (INDIA)
[3]Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur (INDIA)
[4]Department of Mechanical Engineering, Engineering College, Bikaner (INDIA)
[1]yashbansimathur68@gmail.com; [2] mppoonia11@gmail.com

Abstract- **Diesel engines due to their inherent fuel economy, easy operation, low maintenance and long life, find wide uses in the field of transportation, construction equipments, marine and stationary applications such as water pumping, power generation etc. In agriculture sector, diesel engines are widely used in tractors, thrashers, pump sets and other farm machineries. Diesel engines are also extensively used in transport sector. In consideration of some typical characteristics such as high power generation, low specific fuel consumption, reliability and durability of diesel engines, diesel engines would continue to dominate our agricultural and transport sector. In the present study optimum compression ratio for variable compression ratio diesel engine fuelled with diesel fuel has been determined at 203 bars injector opening pressure , 23° CA BTDC injection timing and at 1500 rev/min rated speed. The test results revealed that compression ratio 17 exhibited better performance and lower emissions and hence, was considered as optimum compression ratio.**

Keywords- Variable Compression Ratio Engine; Compression Ratio; Injection Timing; Injector Needle Lift Pressure

I. INTRODUCTION

Energy is the most important component of human life and is an essential input for every activity. With ever growing population, improvement in the living standard of humanity, industrialization of developing countries, the global demand for energy is expected to rise rather significantly in the near future [1, 2]. Petroleum fuels like diesel and gasoline are the primary source of energy. Diesel engines are one of the most efficient prime movers commonly available today. They move a large portion of world's goods, power much of the world's equipments, drive agriculture and rural sector and generate electricity more economically than any other device in their size range. Diesel engines are robust, durable and having lowest fuel consumption than any other prime movers. They are important part of public and private transport sector and their use will continue to grow in future. There is no doubt that the magnitude of the present fuel crisis is going to worsen in future because the fuel consumption rate had significantly increased in the transportation and rural agricultural sector of our country over the last few decades. The power used in the agricultural sector is essentially based on diesel fuels. Diesel engines are widely used in the agricultural sector whether the machinery is mobile, as in tractors, threshers, drills etc. or stationary, as in irrigation pumping units [3]. The diesel engine offers an efficient and reliable power source. It has been realized that the diesel engines form an indispensible part of industrial growth to modern civilization. They also play a vital role in modernized agriculture and rural sector. A better design of the engine can considerably improve the performance and exhaust emissions and in turn will lead to better break thermal efficiencies and low environmental impact [4-7]. In variable compression ratio diesel engine, the compression ratio is varied by raising the bore and the head of the engine. As the bore and the head of the engine is raised and lowered, the clearance volume is changed resulting in the change in the compression ratio [8-12]. The compression ratio significantly affects the performance and emission characteristics of diesel engine. The variable compression ratio provides an exceptional degree of control over engine performance and combustion and optimal compression ratio can improves fuel economy and reduce tail pipe emissions [13-19].

In the present research study, the effect of different compression ratios on engine performance and emission behavior of diesel engine fuelled with diesel fuel was studied and optimum compression ratio was determined. The tests were conducted at 203 bars injector needle lift pressure and injection timing of 23° CA BTDC at 1500 rev/min for entire load range. The compression ratios set for study were ranging from 15 to 19. The present study focuses on investigating the better compression ratio for the diesel fuelled variable compression ratio diesel engine at variable load and constant speed operation.

II. EXPERIMENTAL SETUP

A single cylinder, direct injection, four-stroke, vertical, water-cooled, naturally aspirated variable compression ratio diesel engine, with a bore of 80 mm and a stroke of 110 mm was selected for the present study. This test engine is manufactured by Legion Brothers, Bangalore (India) and having rated output of 3 to 5 HP. The nozzle opening pressure recommended by the manufacturer is 203 bars. The view of the experimental setup and instrumentation are depicted in the Fig. 1. The detailed technical specifications of engine are given in Table I.

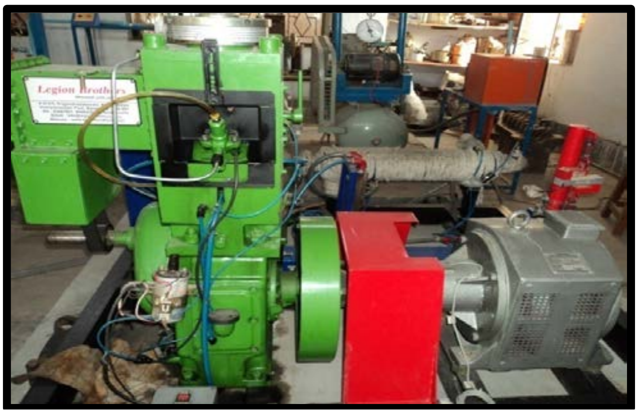

Fig. 1 Overall view of experimental setup

TABLE I TECHNICAL SPECIFICATIONS OF TEST ENGINE

Description	Specifications
Make	Legion Brothers, Bangalore (India)
Type	Single Cylinder, Direct Injection, Four-Stroke, Vertical, Water-Cooled, Naturally Aspirated Variable Compression Ratio Multi-Fuel Diesel Engine
Power	3 to 5 HP
Rated Speed	1500 rev/min (Governed Speed)
Number of Cylinders	One
Compression Ratio	5:1 - 20:1 (Variable Compression Ratio)
Bore	80 mm
Stroke	110 mm
Injector Pressure	203 bars

III. RESULTS AND DISCUSSION

In order to determine optimum compression ratio for variable compression diesel engine fuelled with diesel fuel, tests were carried out at entire load range and compression ratios of 15, 16, 17, 18 and 19 while maintaining 203 bars injector needle lift pressures and 23° CA BTDC injection timing at rated speed of 1500 rev/min. The optimization is done on the basis of maximum brake thermal efficiency.

A. Brake Thermal Efficiency

Fig. 2 shows the variations of brake thermal efficiency with respect to load at different compression ratios for diesel fuel engine operation. The thermal efficiency increases with increase in load. The maximum brake thermal efficiency is obtained at a compression ratio of 17, due to the superior combustion and better intermixing of the fuel. The brake thermal efficiency at 18 compression ratio is also very close to that of maximum brake thermal efficiency, particularly at higher loads. The least brake thermal efficiency is obtained at a compression ratio of 15. The maximum thermal efficiency can be attributed to the superior combustion and better intermixing of the fuel and air at optimum compression ratio. The comparatively low brake thermal efficiency at high compression ratios can be credited to the dilution of charge at higher compression ratios.

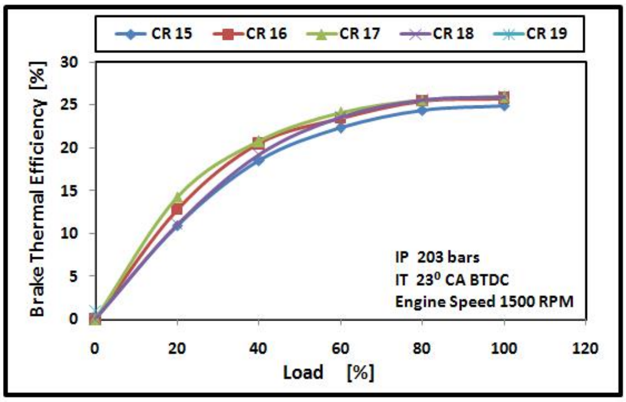

Fig. 2 Variation of brake thermal efficiency with respect to load at different compression ratios

B. Brake Specific Fuel Consumption

The comparison of brake specific fuel consumption with varying load is presented in Fig. 3 at 1500 rev/min. The least fuel consumption is obtained at compression ratio of 17. The higher and lower compression ratios than 17, resulted in high fuel consumptions. The fuel consumption at 18 compression ratio was found very close to optimum value. At the lower sides of the compression ratios, the fuel consumption is high due to incomplete combustion of the fuel. The high fuel consumption at higher compression ratios can be attributed to the effect of charge dilution.

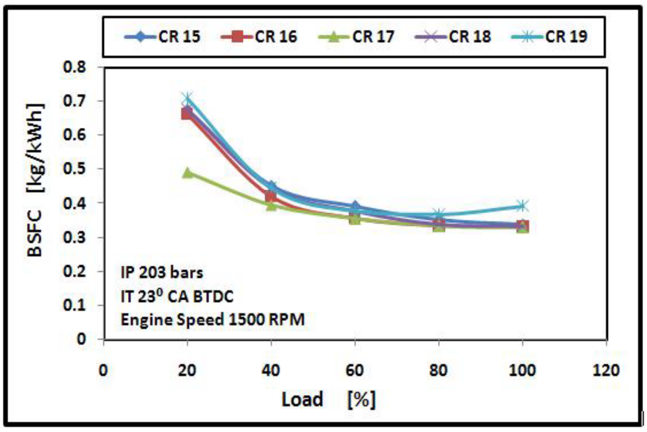

Fig. 3 Comparison of brake specific fuel consumption with load at different compression ratios

C. Exhaust Gas Temperature

Exhaust gas temperatures were found to be increasing with the increase in load and compression ratio as shown in Fig. 4. The maximum exhaust gas temperature was recorded for the compression ratio 19, while the least was for 15. The difference between exhaust gas temperatures at low and medium loads at different compression ratios was found very petite.

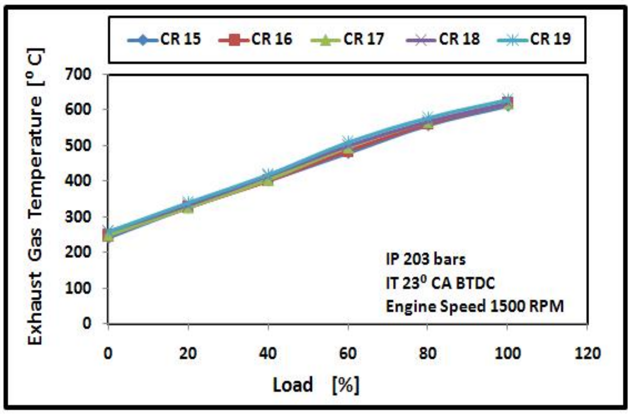

Fig. 4 Variation of exhaust gas temperature with load at different compression ratios

D. Smoke Opacity

The smoke emission at various compression ratios with respect to load is presented in Fig. 5. Smoke opacity increases with increase in load. This may be due to improper mixing at fuel rich region and rising of combustion temperature. Smoke opacity at compression ratio 17 was found lowest and this is because of better combustion at optimum compression ratio.

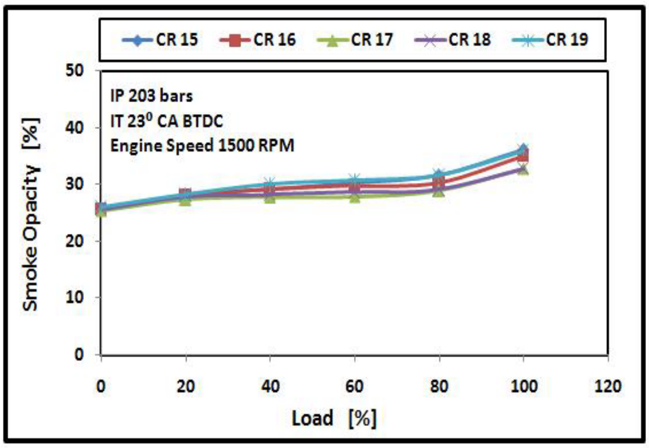

Fig. 5 Smoke opacity with load at different compression ratios

E. Carbon Monoxide Emission

The variation of carbon monoxide emission with load at different compression ratios is presented in Fig. 6. It was observed that the carbon monoxide emission at compression ratio 17 was found least. This is due to superior combustion which takes place at optimum compression ratio.

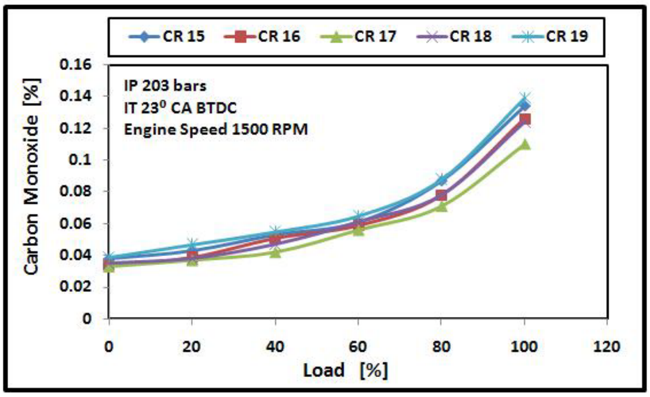

Fig. 6 Carbon monoxide emission with load at different compression ratios

IV. CONCLUSIONS

The following are the main conclusions drawn after extensive tests results on neat diesel fuel operation on variable compression ratio diesel engine.

- At rated speed of 1500 rev/min, the compression ratio 17 showed highest brake thermal efficiency, and hence, may be considered as optimum compression ratio for variable compression ratio diesel engine. Compression ratio 18 exhibited marginally lower brake thermal efficiency compared to optimum compression ratio.
- Better fuel economy was observed at 17 compression ratio compared to other compression ratios.
- Moderate exhaust gas temperature was obtained at 17 compression ratio.
- Lowest smoke opacity and carbon monoxide emissions were observed at compression ratio of 17 for diesel fuel operation. Hence, the test results show that the compression ratio 17 seems to be over all optimum compression ratio for diesel fuel operation.

REFERENCES

[1] BP Statistical Review of World Energy, U.K., 2010/2011.

[2] International Energy Outlook 2010/2011, Energy Information Administration (EIA), Office of Integrated Analysis and Forecasting, U.S. Department of Energy, U.S.A., 2010/2011.

[3] Agricultural Statistics at a Glance, Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, 2002-2011.

[4] Heywood J. B., *Internal Combustion Engine Fundamentals*, McGra-Hill Inc., New York, 1998.

[5] Ganesan V., *Internal Combustion Engines*, Tata McGraw-Hill, New Delhi, 1998.

[6] Tripathi R. K. and Sahoo P. K., "Performance Evaluation of a Low Speed IDI Engine Fueled with Diesel and Jatropha Straight Vegetable Oil", *International Journal of Science Technology & Management*, Volume 2, Issue 2, April 2011.

[7] Avinash Kumar Agarwal, "Biofuels (Alcohols and Biodiesel): Applications as Fuels for Internal Combustion Engines", *Progress in Energy and Combustion Science*, Volume 33, 2007, Pages 233–271.

[8] Pesic R. B., Milojevic S. T. and Veeinovic S. P., "Benefits and Challenges of Variable Compression Ratio at Diesel Engines", *Journal of Thermal Science*, 2010, Volume 4, Pages 1063-1073.

[9] Suyin Gan, Hoon Kiat Ng and Kar Mun Pang, "Homogeneous Charge Compression Ignition (HCCI) combustion: Implementation and Effects on Pollutants in Direct Injection Diesel Engines", *Journal of Applied Energy*, Volume 88, 2011, Pages 559–567.

[10] Xavier Tauzia, Alain Maiboom and Samiur Rahman Shah, "Experimental Study of Inlet Manifold Water Injection on Combustion and Emissions of an Automotive Direct Injection Diesel Engine", *Journal of Energy*, Volume 35, 2010, Pages 3628-3639.

[11] B. K. Venkanna, Swati B., Wadawadagi and C. Venkataramana Reddy, "Effect of Injection Pressure on Performance, Emission and Combustion Characteristics of Direct Injection Diesel Engine Running on Blends of Pongamia Pinnata Linn Oil (Honge oil) and Diesel Fuel", *Agricultural Engineering international, The CIGR E-journal*, Manuscript Number 1316, Volume. XI, May, 2009.

[12] Venkatraman M. and Devaradjane G., "Effect of Compression Ratio, Injection Timing and Injection Pressure on a DI Diesel engine for better performance and emission fueled with diesel diesel biodiesel blends", *International Journal of Applied Engineering Research, Dindigul*, Volume 1, No 3, 2010, pages 288-298.

[13] Elango T. and Senthilkumar T., "Effect of Methyl Esters of Neem and Diesel Oil Blends on the Combustion and Emission Characteristics of a C.I. Engine", *ARPN Journal of Engineering and Applied Sciences*, Volume 5, No. 10, 2010, Pages 80-85.

[14] Tamilvendhan D. and Ilangovan V., "Performance, Emission and Combustion Characteristics of a Methyl Ester Sunflower Oileucalyptus Oil in a Single Cylinder Air Cooled and Direct Injection Diesel Engine", *International Journal of Engineering Science and Technology*, Volume 3, 2011, Pages 1977-1985.

[15] Ekrem Buyukkakaya and Muhammet Cerit, "Experimental Study of NOx Emissions and Injection Timing of a Low Heat Rejection Diesel Engine", *International Journal of Thermal Sciences*, volume 47, 2008, pages 1096- 1106.

[16] Kamal Kishore Khatri, Dilip Sharma, S. L. Soni, Satish Kumar and Deepak Tanwar, "Investigation of Optimum Fuel Injection Timing of Direct Injection CI Engine Operated on Preheated Karanj-Diesel Blend", *Jordan Journal of Mechanical and Industrial Engineering*, Volume 4, Number 5, 2010, Pages 629-640.

[17] T. K. Kannan and R. Marappan, "Study of Performance and Emission Characteristics of a Diesel Engine using Thevetia Peruviana Biodiesel with Diethyl Ether Blends", *European Journal of Scientific Research*, Volume 43, 2010, Pages 563-570.

[18] S. Sundarapandian and G. Devaradjane, "Performance and Emission Analysis of Bio-Diesel Operated CI Engine", *Journal of Engineering, Computing and Architecture*, Volume 1, Issue 2, 2007, Pages 1-22.

[19] M. Pugazhvadivu and G. Sankaranarayanan, "Experimental Studies on a Diesel Engine Using Mahua Oil as fuel", *Indian Journal of Science and Technology*, Volume 3, 2010, Pages 787-791.