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PERFORMANCE EVALUATION AND EMISSION ANALYSIS OF VARIABLE COMPRESSION RATIO DIRECT INJECTION DIESEL ENGINE

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Abstract

With the advent of enhancing environmental and fossil energy concerns, sustainability that can be done with the effective utilization of presently used energy sources, is of major concern. The world of today is working hard to solve energy related problems, such as, energy supply security, *emission control, economy and conservation of energy etc. A great potential lies in the hand of automotive engineers and scientists to use these exhisting reserves of petrolium products effectively. In this present study, effect of compression ratio on the performance and emissions of the diesel engine at various loads is done. While conducting the experiment compresssion ratio range is kept from 18 to 22. It is observed that compression ratio 21 is giving maximum Brake thermal efficiency at part as well as full load. Brake specific fuel consumption and Brake specific energy consumption is found minimum at compression ratio 21.*

Keywords

VCR, Brake Thermal Efficiency, BSFC, BSEC, Smoke

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1. Introduction

Energy is most important entity for the economic development of any country in the world especially in large and developing country such as India where a high fraction of the world's population is in need of satisfying their energy need. These large populations have increased the demand of energy rapidly in the recent years due to accelerated pace of industrial and economic growth. Considering the environmental protection and in the context of great uncertainty in future energy supplies, awareness is concentrated on the sustainable utilization of energy sources and the energy conservation methodologies.

Diesel engines are widely used for satisfying energy demand of vehicles, power generation units in many industries, hospitals, CHP, residential sectors, commercial and institutional facilities. Main advantages of these are quick startups, have good part load efficiencies, and highly reliable. However, diesel is a non-renewable energy source and takes millions of years for its formation. Indiscriminate extraction of fossil fuels and lavish consumption of them have led to mitigation of conventional reserves. The world is confronted with the twin crisis of fossil fuel depletion and environmental degradation and the situation is expected to exfoliate more in the coming years.

One way to solve this problem is to use Alternate fuels and another one is, to use existing fuels effectively. In this research paper second method is focused. It is well known that efficiency of a diesel engine is increased by increasing compression ratio (Ganesan, 2015), (Mathur,2015). A VCR diesel engine is used to find the optimum compression ratio for a diesel engine.

2. Literature Review

Raut et al (2014) in this paper studied the impact of blend, load, speed, injection timing, brake power etc on thermal performance and emission characteristics by performing the experiment on a four stroke variable compression ratio diesel engine using Jatropha blends. This paper aims to optimize the engine exhaust emission based on compression ratio, load, and blend to find the optimum operating conditions. It has been found that with increasing compression ratio, the performance of Jatropha oil blends is similar to that of diesel operated engine operating at full loads especially at compression ratios of 17 and 18. But at higher compression ratios, NO_x emission increases remarkably. He had suggested to find out the optimum blend using GA (Genetic Algorithm). SayiLikhitha et al (2014) conducted experiments on a single cylinder, four stroke, variable compression ratio diesel engine connected with eddy current dynamometer. The compression ratio was varied from 14 to 18 and different blends (5%, 7.5% and 10%) of DEE were made. By introduction of DEE blend, BTE increases and specific fuel consumption decreases. Best efficiency was obtained at 18 CR and with 5% DEE blend. The author observed that when DEE increased beyond 15%, high knocking sound were used and also as the concentration of DEE was increased viscosity of fuel decreased. K. Muralidharan et al (2011)conducted experiments on a single cylinder four stroke VCR multi fuel engine when fuelled with waste cooking oil methyl ester and 20%, 40%, 60% and 80% blends with were investigated. The compression ratio was varied from 18:1 to 22:1 and the analysis was done at 50% load. The author observed that performance of B40 blend was superior when compared with neat diesel at CR 21. NOx emissions were comparable with that of neat diesel, by increasing the compression ratio HC emissions were increased and also CO emissions were comparable.

3. Experimental Set-up

3.1 Engine

A single cylinder, four stroke, water cooled, DI, variable compression ratio diesel engine designed to develop a rated power of 3.5 kW at 1500 rpm was used to carry out the present research work.Specifications of the engine are enlisted below:

Table 1: *Engine Specifications*

Sr. No.	Specifications	Rating
1.	No. of cylinder	1 (single)
2.	Bore x Stroke	87.5 X 110 (mm)
3.	Capacity	661 cc
4.	Diesel mode (Rated Output)	3.5 kW
5.	Compression Ratio range	18-22
6.	Rated Speed (constant)	1500 rpm
7.	Injection Timing Variations	0^0-25^0 BTDC
8.	Valve timing	IVO 4.5^0 BTDC IVC 35.5^0 ABDC EVO 35.5^0 BBDC EVC 4.5^0 ATDC

Figure 1: Engine

3.2 Gas Analyzer-

To measure the engine exhaust emissions two analysers were used

3.2.1 AVL Digas 444 Exhaust Gas Analyser

It is used to measure the emissions like carbon monoxide, carbon dioxide, hydro carbons, oxygen and oxides of nitrogen.

Figure 2: AVL Gas Analyser (DIGAS 444)

3.2.2 AVL DITEST CDS 450

It is used to measure smoke density of the smoke. It measures the smoke opacity in % HSU (Hartridge Smoke Unit). It can also be used to measure exhaust emissions of carbon monoxide, carbon dioxide, oxides of nitrogen, hydrocarbons and oxygen. It has following components:

- AVL DITEST CDS main unit with integrated engine speed recording
- Fuel Module AVL DITEST Gas 1000
- Diesel module AVL DISMOKE 480 with wireless link
- EOBD interface AVL DITEST OBD 1000 with Bluetooth connectivity
- Laser printer s/w
- Frame mount

Figure 3: AVL Gas Analyser (DITEST CDS 450)

3.3 Compression ratio Adjustment

This modified engine can be operated in Diesel as well as in gasoline mode. For Diesel mode compression ratio can be varied from 18-22. For Gasoline mode compression ratio can be varied from 6-10. To change the compression ratio of the engine, first of all allen bolts were loosen with the help of allen key. Compression ratio adjustor (CR adjustor) is provided on one side of the engine. Predefined grading is marked on the CR adjustor. CR adjustor is used to change the compression ration by rotating the locknut clockwise and anti-clockwise. Anti-clockwise rotation of the locknut increases the compression ratio and Clockwise rotation decreases the compression ratio. This method of changing compression ratio is based on tilting the cylinder block of the engine.

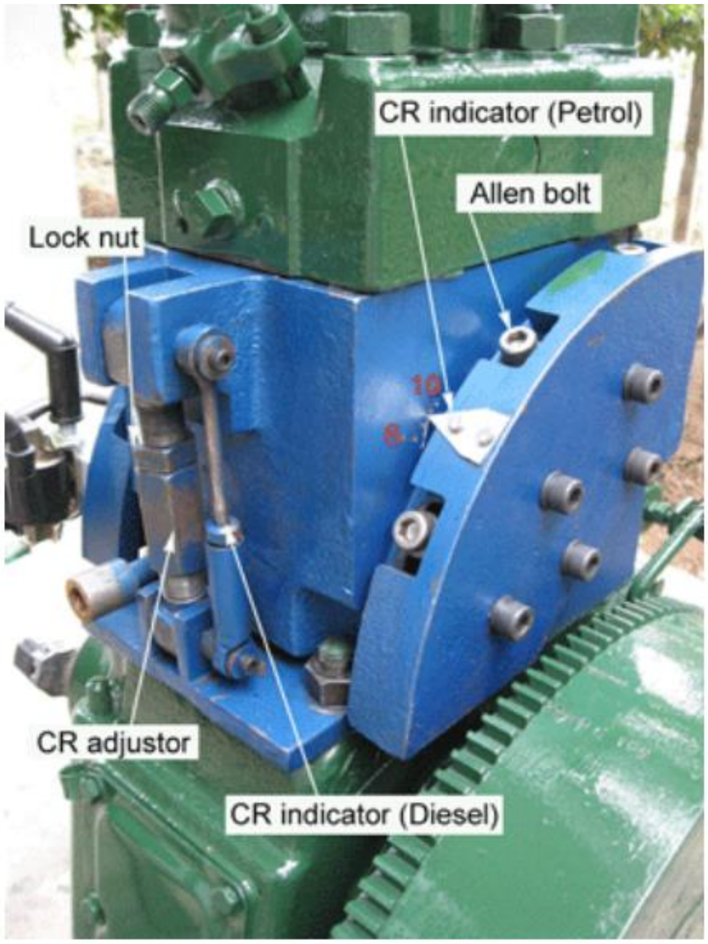

Figure 4: Compression ratio adjustment

4. Results and Discussions

Engine performance parameters which include Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC) and Brake Specific Energy Consumption (BSEC) were analyzed. Exhaust gas Emissions were also recorded during the experiment to study the effect of variation of compression ratio.

4.1 Brake Thermal Efficiency

Brake thermal efficiency increases with the increase in load. Also BTE increases with increase in compression ratio for a CI engine, as there is no restriction of knocking (unlike SI engine) caused by very high increase in temperature while high inlet temperature is desirable for CI engine. Highest BTE was achieved at compression ratio 21 and it was found to be 25.84544 at full load.On further increasing compression ratio BTE decreases as heat generated is not dissipated properly.

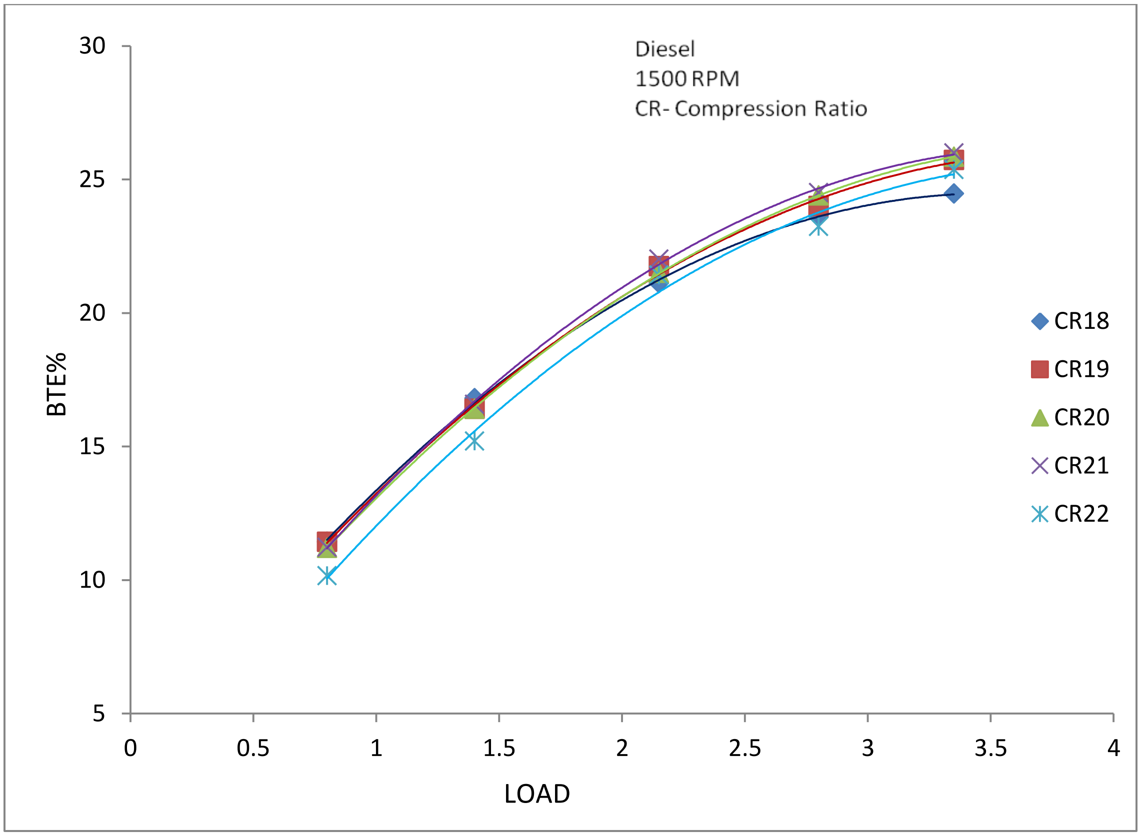

Figure 5: Variation of BTE with load at different compression ratio

4.2 Brake Specific Fuel Consumption (BSFC)

Brake specific fuel consumption decreases with increase in load initially but at full load, it increases slightly. At CR18 minimum BSFC is found to be 0.357 kg/kW-hr at 3.35 kW. At CR21 BSFC is minimum, which is 0.335 kg/kW-hr. BSFC, decreased with increase in compression ratio, reached minimum at CR 21 but it slightly increased for CR22.

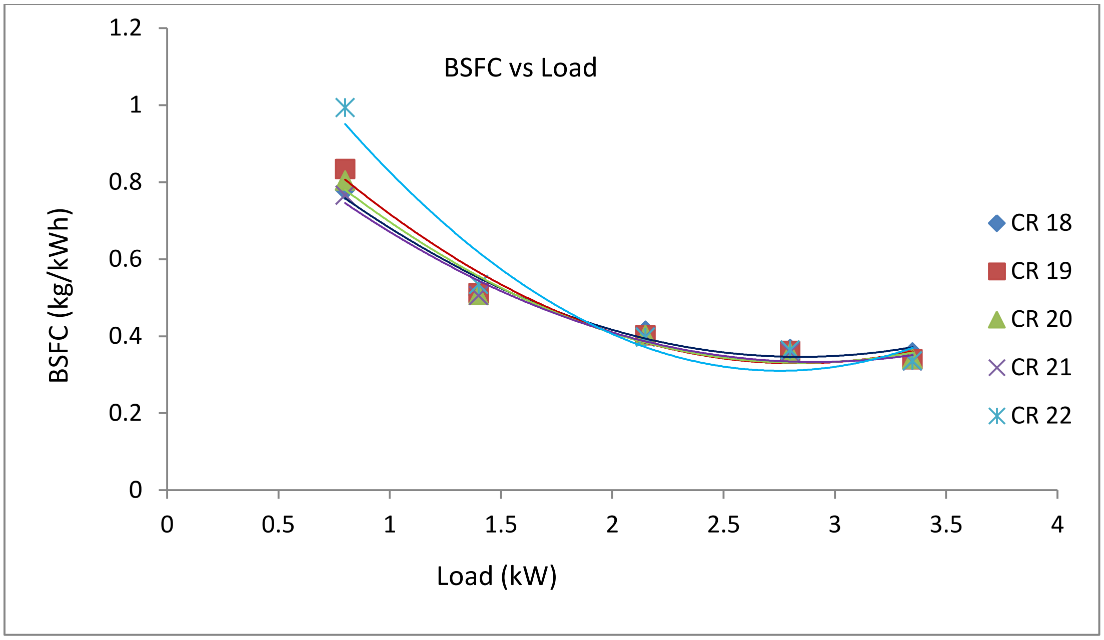

Figure 6: Variation of BSFC with load at different compression ratio

4.3 Brake Specific Energy Consumption (BSEC)

Brake specific energy consumption decreases with increase in load initially but at full load, it increases slightly. At CR21 BSEC is minimum, which is 13853.73 kJ/kW-hr. BSEC decreased with increase in compression ratio, reached minimum at CR 21 but it slightly increased for CR22. Figure 4.3 shows variation of BSEC with respect to compression ratio at different loads.

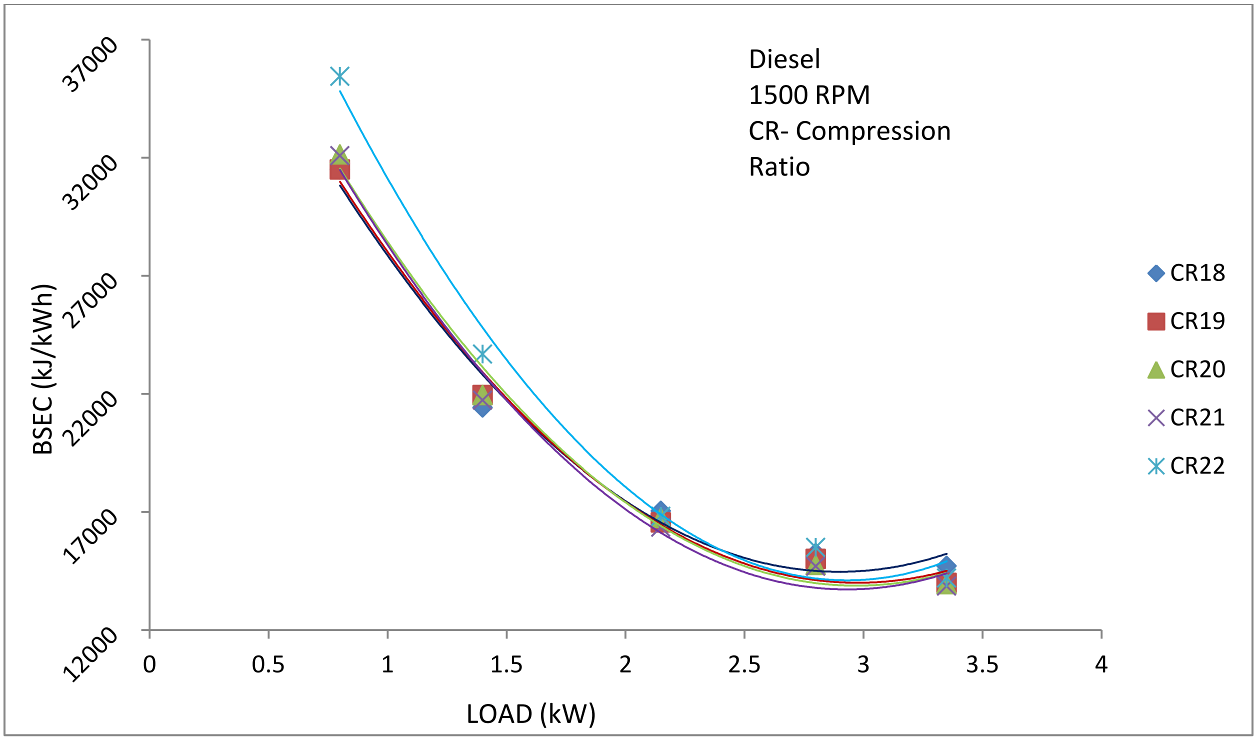

Figure 7: Variation of BSEC with load at different compression ratio

4.4 CO emissions

CO emissions decreases with increase in load for diesel engine, it is due to the proper combustion of fuel at high loads. In the experiment it is found that CO emissions are decreasing by increasing compression ratio from 18-22.

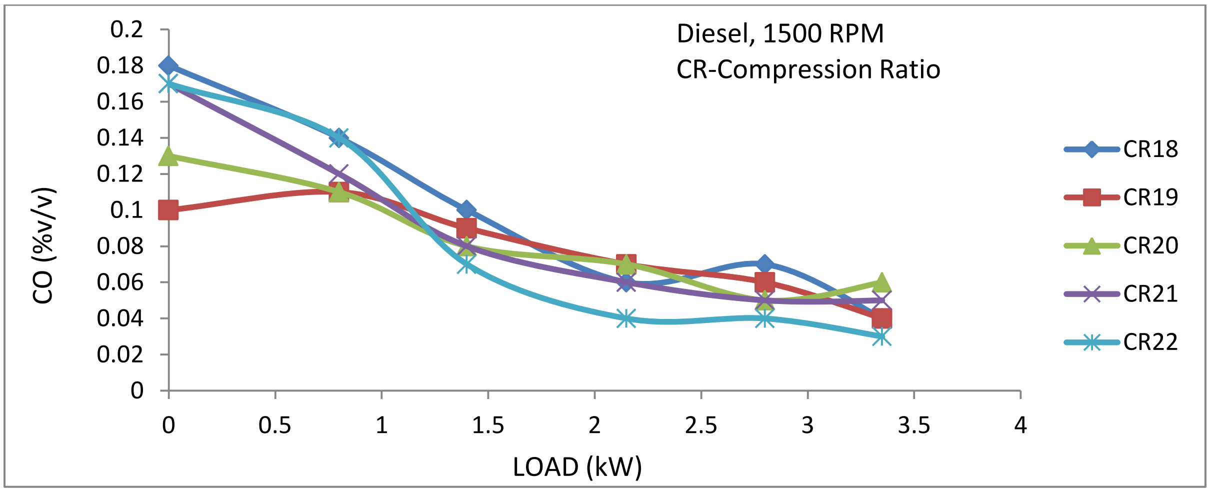

Figure 8: Variation of CO emissions with Load at different compression ratio

4.5 HC emissions

HC emissions decrease with increase in load for diesel engine. As by increasing load, turbulence increases, which results in proper mixing of the fuel mixture and hence lowers the HC emissions. In the experiment it is found that HC emissions are decreasing by increasing compression ratio from 18-22. As by increasing the compression ratio, the temperature of the cylinder wall increases, which burns the HC present in crevicesof the engine. It is found minimum for CR22 and it is found maximum for CR18.

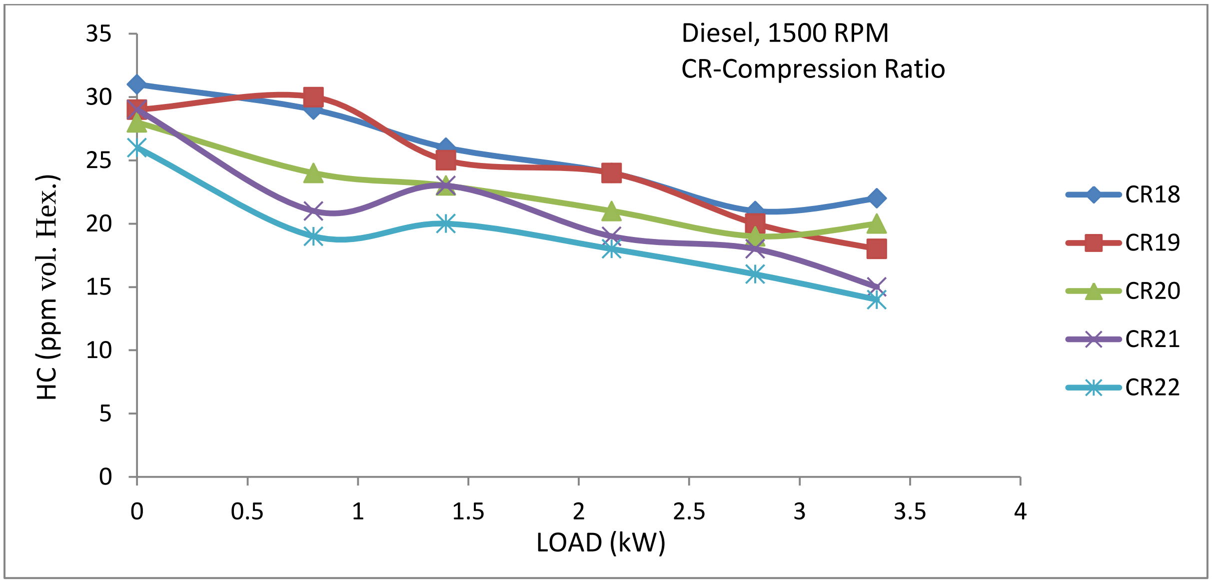

Figure 9: Variation of HC emissions with Load at different compression ratio

4.6 Nox emissions

Nitrogen and Oxygen reacts at comparatively high temperature. NO_x formation in an engine depends on many factors which are temperature during reaction, Oxygen availability in the reaction and time period for which oxygen is available. NO_x emissions are increased by increasing load as by increasing load rich mixture of fuel will enter into the combustion chamber due to this more NO_x emissions will be formed. At full load it is slightly decreased.

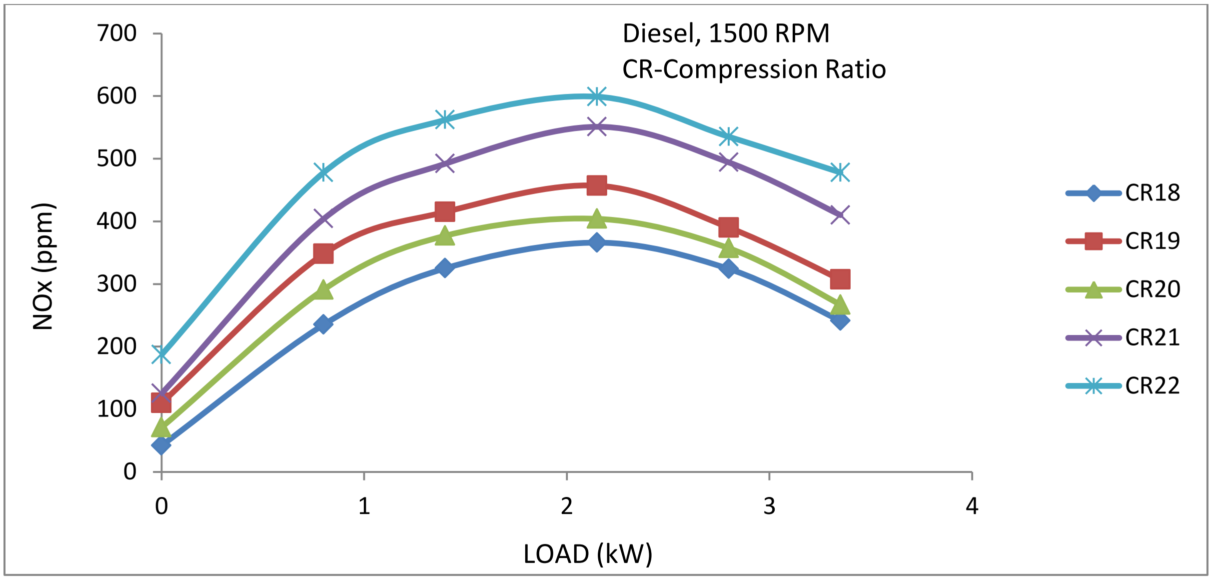

Figure 10: Variation of NOx emissions with Load at different compression ratio

4.7 Smoke

Smoke is measured in % Hartridge Smoke Unit (HSU). Smoke opacity increases with increase in load as by increasing load high in-cylinder temperature is obtained due to rich fuel mixture and that will ultimately increase pyrolysis of hydrocarbon which is the main cause of smoke formation. Smoke opacity decreased by increasing compression ratio.

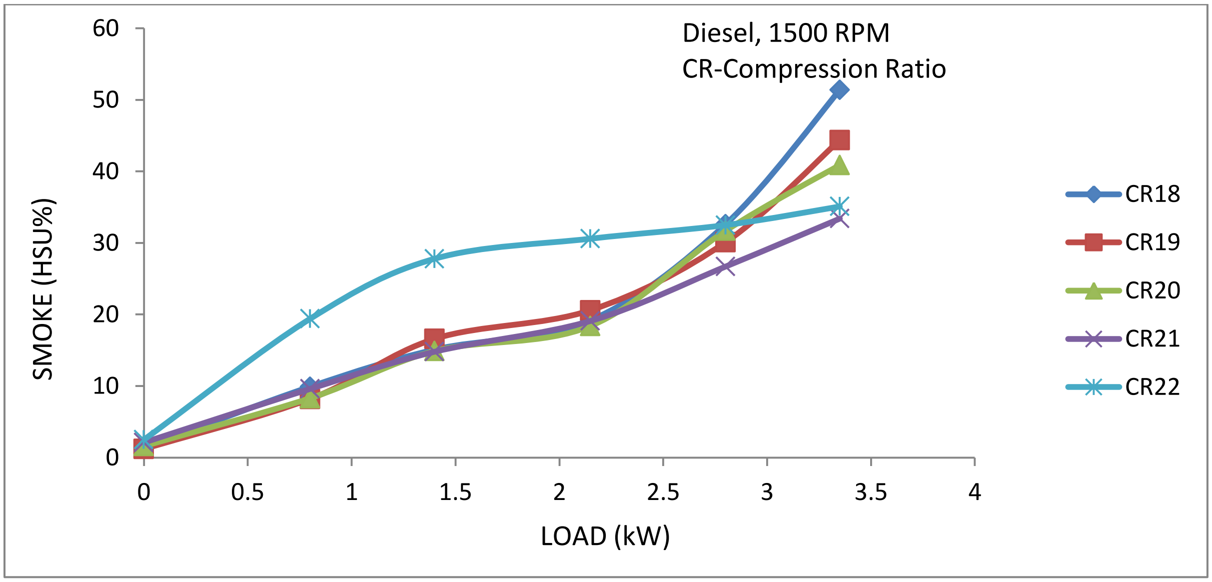

Figure 11: Variation of Smoke emissions with Load at different compression ratio

5. Conclusion

In the present research work it is obtained that CR21 is the nest for present engine from Brake thermal efficiency, BSFC and BSEC point of view. Emissions are also reduced by increasing compression ratio. Generally it is found minimum for CR22 but it is almost similar to CR21 it can be concluded that CR21 is the optimum for the presently used VCR diesel engine. BTE is 24.46 % at CR18 which increases to 25.85% at CR21 so it is clear that 1.39% efficiency increase is obtained in BTE. Minimum BSEC is 14709.6 kJ/kW-hr at CR18, which decreases to 13928.96 kJ/kW-hr at CR21 so it can be understood that BSEC is decreased by 5.30%.

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