Advances in Automobile Engineering

Satyanarayana et al., Adv Automob Eng 2016, 5:2
DOI: 10.4172/2167-7670.1000146

Research Article Open Access

Performance and Emissions Characteristics of Variable Compression Ignition Engine

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Abstract

Variable Compression Ratio engine test rig is used to determine the effect of compression Ratio on the performance and emissions of the engine. The objective is to determine the optimum compression ratio for the better performance and lowering the emissions. In order to determine the optimum compression ratio, experiments were carried out on a single cylinder four stroke variable compression ratios of 16.5, 17.0, 17.5, 18.0 and 19.0 in a Diesel engine. The performance characteristics of the engine namely break power, brake thermal efficiency, brake specific fuel consumption and other parameters are studied and also conducted the emissions test namely Carbon monoxide, carbon dioxide, hydrocarbons, Nitrogen oxides and other emissions at various conditions. It is observed that a significant improvement in the performances and lowered the various emissions also at a compression ratio of 17.0 compared to other compression ratios due to the enhancement of the overall combustion process.

Keywords: Performance emissions; Variable compression ratio; Thermal efficiency; Specific fuel consumption engine

Introduction

The ultimate goal of emission legislation is to force technology to the point where a practically viable zero emission vehicle become a reality with formidable challenges [1]. The ever increasing demand for the conventional based fuels and their scarcity has led to extensive research on Diesel fuelled engines [2]. A better design of the engine can significantly improve the combustion quality and in turn may lead to better break thermal efficiency and hence saves fuel [3]. India though rich in coal abundantly and endowed with renewable energy in the form of solar, wind, hydro and bio-energy has a very small hydro carbon reserves, 0.4% of the world's reserve[4]. India is a net importer of energy and nearly 25% of its energy needs are met through imports mainly in the form of crude oil and natural gas [5]. The rising oil bill has been the focus of serious concerns due to the pressure it has placed on scarce foreign exchange resources and is also largely responsible for energy supply shortages [6]. The sub-optimal consumption of commercial energy adversely affects the productive sectors, which in turn hampers economic growth [7]. All over the world, reduction of automotive fuel consumption and CO_2 emissions is leading to the introduction of various new technologies in engines [8].

Diesel engine

The diesel engine is an internal combustion engine in which ignition of the fuel that has been injected into the combustion chamber is initiated by the high temperature which a gas achieves when greatly compressed [9]. This contrasts with spark-ignition engines such as a gasoline engine or gas engine, which use a spark plug to ignite an air-fuel mixture [10]. The diesel engine has the highest thermal efficiency of any standard internal or external combustion engine due to its very high compression ratio and inherent lean burn which enables heat dissipation by the excess air [11]. A small efficiency loss is also avoided compared to two-stroke non-direct -injection gasoline engines since un burnt fuel is not present at valve overlap and therefore no fuel goes directly from the intake/injection to the exhaust [12]. Low-speed diesel engines as used in ships and other applications where overall engine weight is relatively unimportant can have a higher thermal efficiency [13].

Variable compression ratio

Variable compression ratio (VCR) is technology to adjust the compression ratio of an internal combustion engine while the engine is in operation. This is done to increase fuel efficiency while under varying loads [14]. Higher loads require lower ratios to be more efficient and vice versa. Variable compression engines allow for the volume above the piston at 'Top dead centre' to be changed. For automotive use this needs to be done dynamically in response to the load and driving demands. Especially, gasoline engines have a limit on the maximum pressure during the compression stroke, after which the fuel/air mixture detonates rather than burns [15]. To achieve higher power outputs at the same speed, more fuel must be burned and therefore more air is needed [16]. To achieve this, turbochargers or superchargers are used to increase the inlet pressure. This would result in detonation of the fuel/air mixture at higher compression ratios [17]. However, optimal VCR expected to improve the performance of the Compression Ignition Engine at various conditions.

Experimental Setup

The VCR engine chosen to carryout experimentation is a single cylinder, water cooled, vertical, direct injection, constant speed, CI engine. This engine can with stand higher pressures encountered and also used extensively in agricultural and industrial sectors [18-22]. Therefore this engine is selected for conducting experiments. Moreover necessary modifications on the piston and the cylinder head can easily be made. The engine has a eddy current dynamometer to measure its output. it consists of stator on which are fitted with a number of electromagnets and a rotor disc made of a copper or steel and coupled to shaft of engine . When the rotor rotates eddy currents are produced in the stator due to magnetic flux set up by the passage of field current in the electro magnets. This eddy current opposes the rotor motion thus loading the engine (Figure 1).

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Received June 01, 2016; **Accepted** July 05, 2016; **Published** July 08, 2016

Citation: Satyanarayana K, Naik RT, Uma-Maheswara Rao SV (2016) Performance and Emissions Characteristics of Variable Compression Ignition Engine. Adv Automob Eng 5: 146. doi:10.4172/2167-7670.1000146

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Performance of the engine

Brake specific fuel consumption (BSFC): Brake Specific fuel consumption (BSFC) or sometimes simply Brake specific fuel consumption, BSFC, is an engineering term that is used to describe the fuel efficiency of an engine design with respect to thrust output. Brake Specific Fuel Consumption may also be thought of as fuel consumption generally in grams/sec.

Brake thermal efficiency: Brake Thermal Efficiency is defined as brake power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy.

Figure 1: Experimental setup of VCR diesel engine.

Figure 2: Smoke meter.

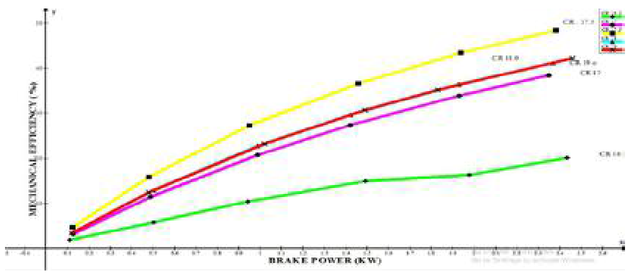

Figure 3: Effect of brake power with mechanical efficiency.

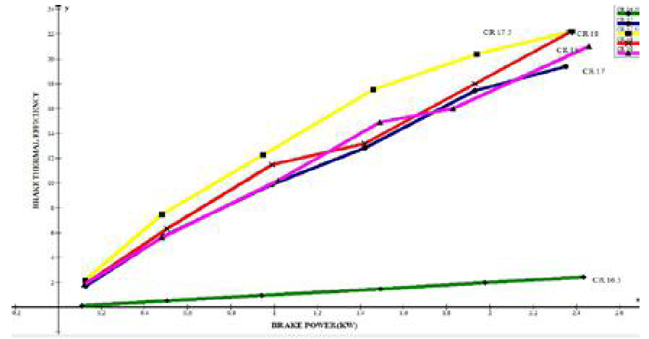

Figure 4: Effect of brake power with brake thermal efficiency.

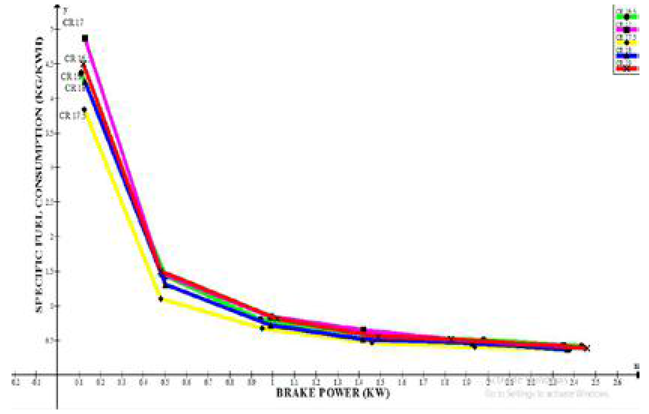

Figure 5: Effect of brake power with specific fuel consumption.

Emission gas analyser

Exhaust Gas Analyzer is a non-dispersive infrared Fuji gas analyzer is used to measure the various emissions namely CO, CO_2 , HC, NOx, O_2 and smoke test also carried out with smoke meter as shown in Figure 2.

Results and Discussion

The various performance and emissions of the VCR engine with different compression ratios discussed.

Performance analysis

The variation in mechanical efficiency at different loads for different compression ratios is shown in Figure 3. It is observed that mechanical efficiency increases with the increase of the load. It is observed that mechanical efficiency is low for compression ratio of 16.5 and it is almost similar trend for 18 and 19 for a given load. But, mechanical efficiency is higher for compression ratio of 17 compared to other compression ratios due to efficient combustion (Figure 4). The variation in break thermal efficiency at different loads for different compression ratios. It is observed that break thermal efficiency is lower for compression ratio of 16.5, it is almost similar for all other compression ratios at all loads. However, thermal efficiency is more for compression ratio of 17 compared to other compression ratios due to proper combustion (Figure 5). The variation in Specific fuel consumption at different loads for different compression ratios is shown in Figure 5. It is observed that at higher loads the Specific fuel consumption of all the compressions ratios are almost at higher break power. But, fuel consumption is lower for the compression ratio of 17 compared to other compression ratios due to the proper combustion. The variation in Air fuel ratio at different loads for different compression ratios is shown in (Figure 6). It is observed that air fuel ratio is almost similar pattern for all compression ratios at higher loads But, at lower loads of air fuel ratios is lower for the compression ratios of 17 compared to other compression ratios due to efficient combustion (Figure 7). The variation between relative air fuel ratio and efficiency ratio. It is observed that efficiency ratio is less for the compression ratio of 16.5 and it increases with other compression ratios also. But, maximum efficiency ratios observed for the compression ratios of 17 compared to other compression ratios due to proper air fuel mixture and efficient

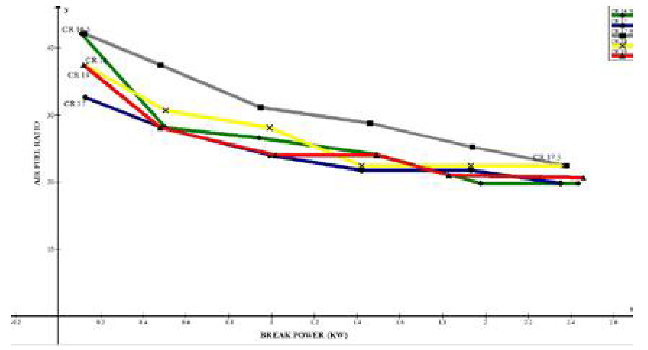

Figure 6: Effect of brake power with air fuel ratio.

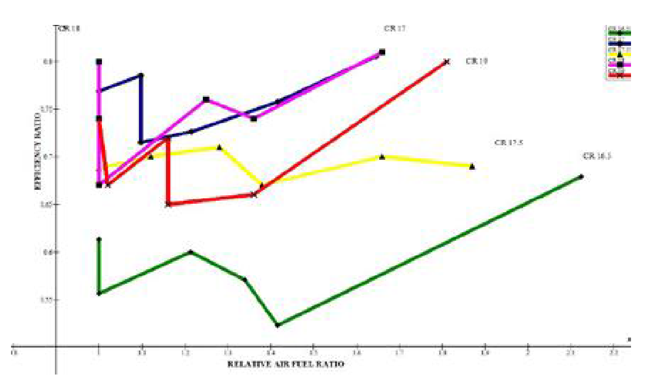

Figure 7: Effect of relative air fuel ratio with efficiency ratio.

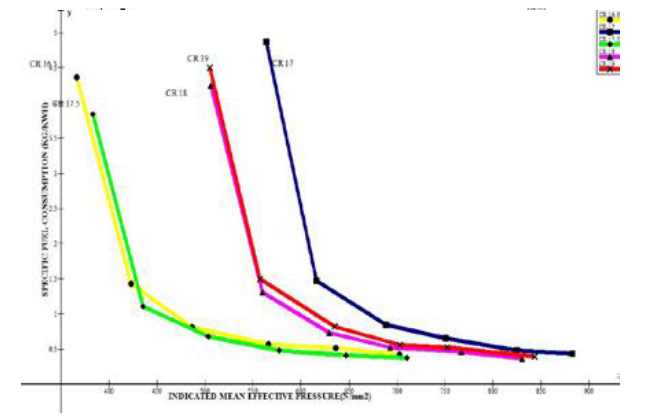

Figure 8: Effect of indicated mean effective pressure with specific fuel consumption.

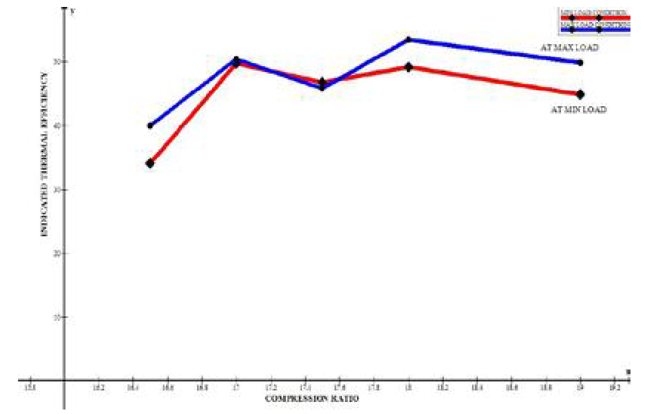

Figure 9: Effect of compression ratio with indicated thermal efficiency.

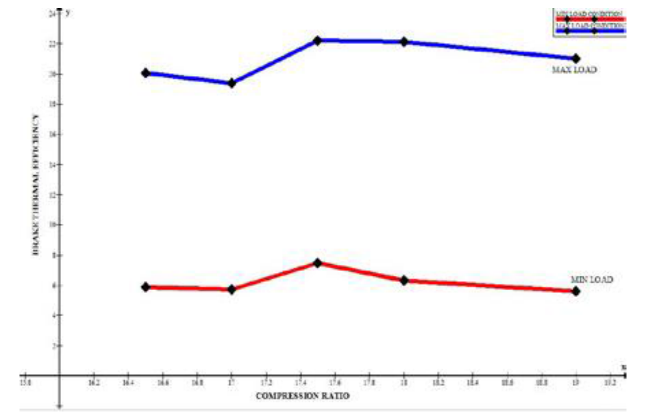

Figure 10: Effect of compression ratio with break thermal efficiency.

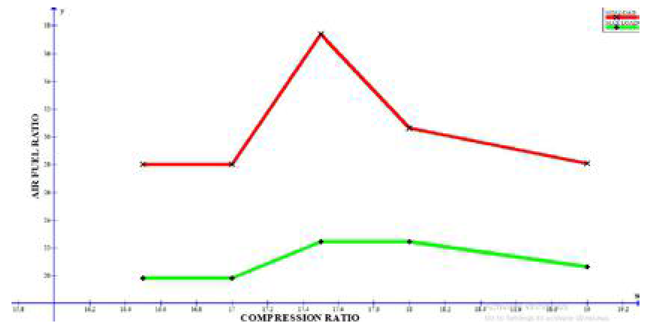

Figure 11: Effect of compression ratio with air fuel ratio.

combustion (Figure 8). The variation of specific fuel consumption with indicated mean effective pressure is shown in Figure 8. It is observed that specific fuel consumption is almost equal for all the compression ratios at higher indicated pressure due to smooth combustion. The variation between compression ratio and indicated thermal efficiency is shown in (Figure 9). It is observed that for a given compression ratio indicated thermal efficiency is higher for maximum load and lower for minimum loads due to proper combustion. The variation between compression ratio and break thermal efficiency is shown in Figure 10. It is observed that for a given compression ratio break thermal efficiency is higher for maximum load and lower for minimum load due to efficient combustion. The variation between compression ratio and air fuel ratio is shown in Figure 11. It is observed that for a given

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compression ratio air fuel ratio is higher for maximum load and lower for minimum load due to proper combustion (Figure 12).

Emission analysis

The variation of percentage of Carbon Monoxide (CO) with the air fuel ratio is shown in Fig.12. CO emissions are reduced by lowering the compression ratios. But, CO emission is lower for the compression ratio of 17 due to efficient combustion compared to other compression ratios. The variation of Carbon Dioxide (CO_2) with the variation of air fuel ratio is shown in Figure 13. It is observed that at lower loads, CO_2 is similar trend for all other compression ratios. But, CO_2 is lower for the compression ratio of 17 due to efficient combustion compared to other compression ratios (Figure 14). The variation of Oxygen (O_2) with the air fuel ratio. It is observed that oxygen is lower for all the compression ratios. But, Oxygen is higher for the Compression ratio of 17 compared to other compression ratios which indicated the better and smooth combustion. The variation of unburned hydrocarbon (HC) with air fuel ratio shown in Figure 15. The emissions are seen to be lower at compression ratio of 17 compared to other compression ratios due to efficient combustion at higher loads. (Figure 16). The variation of

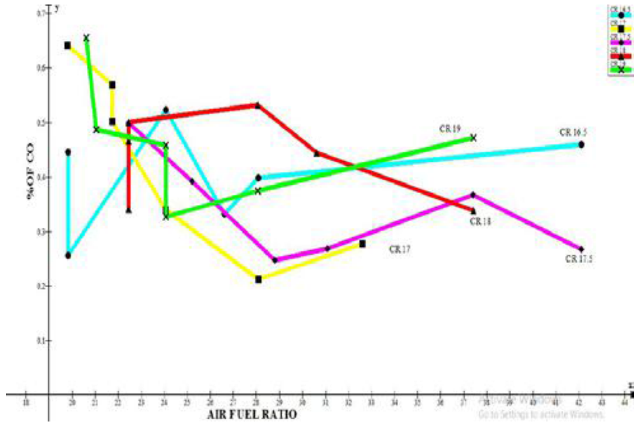

Figure 12: Effect of carbon monoxide with air fuel ratio.

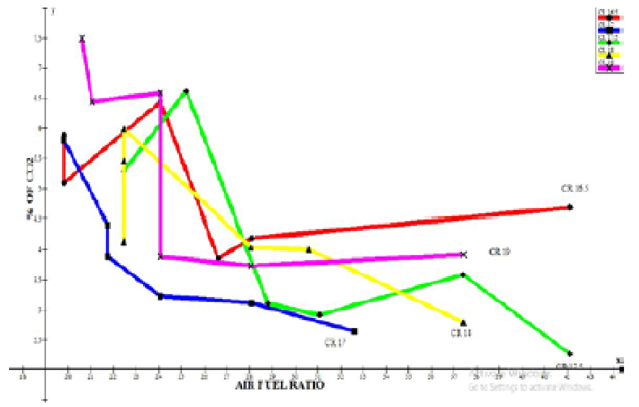

Figure 13: Effect of carbon dioxide with air fuel ratio.

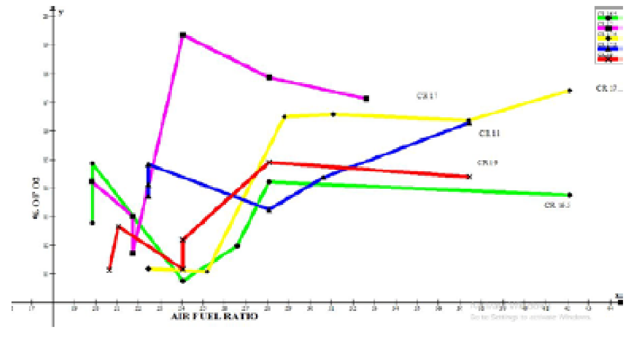

Figure 14: Effect of oxygen with air fuel ratio.

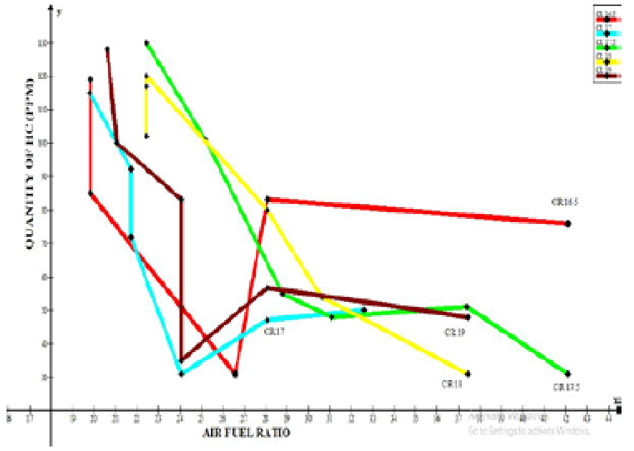

Figure 15: Effect of hydrocarbons with air fuel ratio.

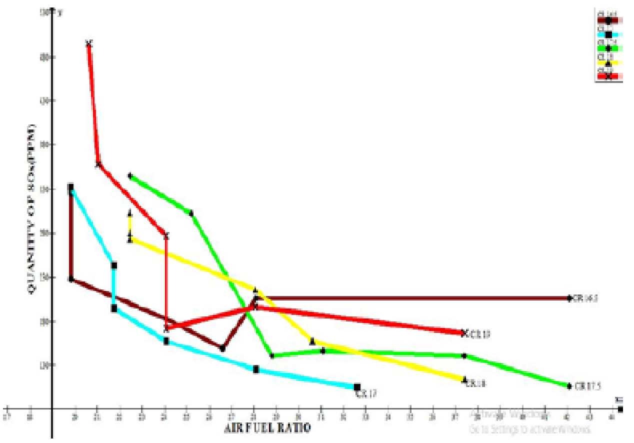

Figure 16: Effect of sulphur oxide with air fuel ratio.

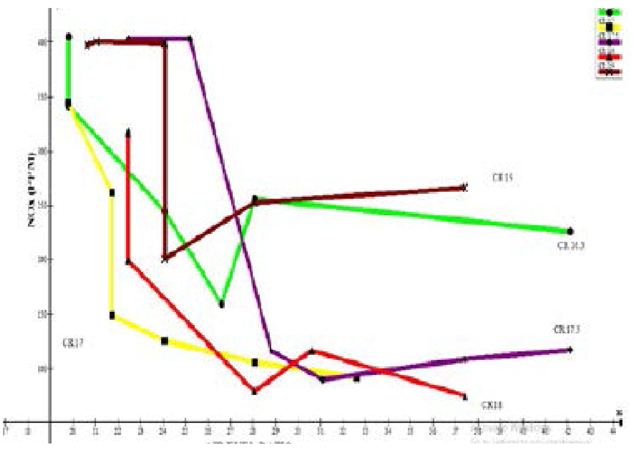

Figure 17: Effect of NOx with air fuel ratio.

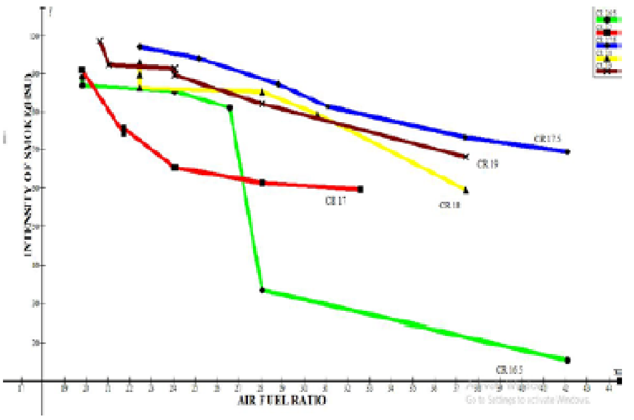

Figure 18: Effect of smoke with air-fuel ratio.

Sulphar Oxide (SOx) with air fuel ratio is shown in It is observed that SOx is similar trend for higher compression ratios at higher loads. But, SOx is lower for the compression ratio of 17 compared to other compression ratios due to efficient combustion. The variation of NOx emission with air fuel ratio is shown in Figure 17. It is observed that NOx is increasing with similar pattern for all the compression ratios due to increase of cylinder temperature. But, NOx is still lower for the compression ratios of 17 compared to other compression ratios due to proper combustion. The variation of intensity of smoke with the variation of air fuel ratio is shown in Figure 18. It is observed that smoke is decreasing for all the compression ratios at higher loads due to efficient combustion.

Conclusions

1. The Break thermal efficiency, Mechanical efficiency and efficiency ratios are higher for the compression ratio of 17 compared to other compression ratios due to efficient combustion.

2. Break Specific fuel consumption is lower and Break Power is almost similar with minor variations for the compression ratio of 17 compared to other compression ratios due to enhanced combustion.

3. Indicated mean effective pressure is higher for the compression ratio of 17 compared to other compression ratios due to efficient combustion.

4. The various emissions namely CO, CO_2, HC, SOx and O_2 decreasing for the compression ratio of 17 compared to other compression ratios due to efficient combustion.

5. The NOx emission increasing for all the compression ratios due to increase of cylinder temperature. However, still NOx is lower in the case of 17, compression ratio due to proper combustion.

6. The Smoke emission is also lower for all the compression ratios at higher loads due to enhanced combustion.

Acknowledgement

Authors express their sincere gratitude to their teacher Prof. P. V. Krishnan for his wonderful training and teachings.

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