Investigation of Heat Distribution in a Variable Compression Ratio Internal Combustion Engine

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ABSTRACT

In this work, an experimental investigation has been undertaken to analyze the effect of variation in compression ratios on heat distribution in a variable compression ratio engine. The compression ratio powerfully affects the operating method and provides an exceptional degree of control over engine performance. Variable Compression ratio (V.C.R) engine test rig is employed to see the effect of variation in compression ratios (C.R) on the performance parameters of the engine and also the distribution of warmth during the working of the variable compression ratio engine. The performance parameters like brake thermal efficiency, volumetric efficiency, brake power, and specific fuel consumption are measured at variable compression ratios. The compression ratio can be changed by an external mechanism provided in the variable compression ratio engine . Further, combustion phenomenon is additionally discovered through this work. The optimum compression ratio is determined by performing the tests on test rig engine at different compression ratios of 14.6, 15.4, 16.3, 17.6 and 18 at 3.5 KW electrical load. Results show the minimum heat losses at 17.6 and 18 compression ratios.

Keywords:, Variable compression ratio diesel engine, electrical dynamometer, performance parameters

I. INTRODUCTION

The transportation industry is growing day by day consequently the energy demand is also increasing. The researchers are finding out on substitute techniques to make sure a cleaner combustion as a result of depletion of petroleum power assets in the nearby future and environmental pollution problems. At the same time some of researchers investigates the use of alternative fuels, some researchers have been focused on new combustion modes. The usage of substitute fuels equivalent to ethanol, methanol, biodiesel etc. Has been taken awareness commonly till now. Nevertheless, confined thermal affectivity of spark ignition engines (SI) on account that of limited compression ratio because of knocking and problem to diminish particulate matter (PM) and nitrogen oxide (NOx) emissions. The compression ignition engines (CI) concurrently put into effect the researches to create replacement options to broaden engine effectivity and lessen exhaust emissions.

Low temperature combustion modes similar to homogeneous cost compression ignition (HCCI), in part premixed compression ignition (p.C.) [6, 7], reactivity controlled combustion ignition (RCCI) promising combustion modes providing better thermal effectivity and concurrently scale down PM and NOx emissions. Variable compression ratio (VCR) is a further promising technological know-how to run the engine at most appropriate point in phrases of effectivity and emission [1].

Many of the previous stories concerning the effects of the CR on HCCI engine are parametric researches investigating the have an effect on of CR on ignition delay, SOC, IMEP and so on. Nonetheless operation kind of the HCCI engine is a further valuable aspect that is limiting the use of the engine. Brake thermal fuel consumption and operation maps are also critical to manage the engine while switching between HCCI mode to traditional SI or DI mode [1].

Compression ignition engines offer superior fuel economic system. Nonetheless, in diesel engines utilizing mixing-managed combustion methods, reaching discounts in exhaust emissions stays a concern, since a turbulent diffusion flame surrounds the gas spray, producing nitrogen oxides (NOx) at the same time as soot forms inside the wealthy crucial response area of the gasoline spray, with soot concentrations increasing given that the spray is transported downstream . There isn't a flame sector among the tip of the gas injector and the uppermost circulation of the spray combustion in a turbulent diffusion flame, and the period of the neighborhood (from the injector to the flame, any other place termed lift-off length or here set-off length) performs a full-measurement operate inside the combustion and emission procedures as lots air is entrained and combined with the gasoline upstream of the set-off interval [3]. Controlling the set-off period in preserving with engine working circumstances is principal to optimize the air-entrainment into the fuel spray. Factors affecting the set-off period [2] as well as the data of the flame set-off had been tremendously studied. It has emerge as set up that reducing ambient density with low boosting and moreover the oxygen awareness with higher exhaust gasoline recirculation (EGR) makes it potential to extend the set-off size. However, at excessive load operations, it can be some distance required to expand consumption air with high boosting and less EGR, that shortens the set-off interval. A viable way to manipulate the setoff length is converting the gas reactivity, as the set-off size is strongly correlated with the ignition put off. When you consider that this, the low reactivity of fuel is an appealing feature to broaden the set-off length, and the authors have applied gas to compression ignition engines. This form of combustion system termed gas compression ignition (GCI) has attracted increasing attention as an opportunity to diesel engines due to the capacity of low emissions and high thermal efficiency [8]. This technique is fine to ignition control because the combustion phasing is carefully coupled to the injection timing. Nonetheless, engaging in ignition manage over a extensive variety of engine masses and rotation speeds is still hard as the ignition timing of the GCI strongly is dependent at the gas wide variety and the time after of injection, and an extra manner to govern the ignition timing, that's neutral of the injection timing, would be required. One manner to collect that is to make use of two fuels that have precise reactivities as applied in reactivity managed compression ignition (RCCI) engines [2], but this method requires two fuel tanks which makes it difficult to enforce in engine programs used for transportation.

Depleting petroleum reserves, developing petroleum prices, danger to the atmosphere from exhaust emissions and world warming desires an huge global curiosity in developing substitute on petroleum fuels for engines [3]. It has determined that the vegetable oils are promising fuels given that their houses are corresponding to that of diesel and are made out of crops with minimal strive [5]. Vegetable oils are simply available in rural regions, are renewable, have a moderately excessive cetane variety will also be utilized in diesel engines with convenient changes and may also be with ease mixed with diesel throughout the neat and esterified (Biodiesel) forms. Jatropha oil, Karanja oil, Coconut oil, Sunflower oil, rapeseed oil and neem oil are some of the vegetable oils which might be used as fuels in internal combustion engines [4]. The biodiesel from the above mentioned vegetation, behave in a different method in diesel engines in phrases of overall performance, emission and combustion. As on date, some of experiences works had been carried out on biodiesel combustion, total efficiency and emissions [5e9]. Several vegetable oil esters referred to as biodiesel is attempted as replacement to diesel gasoline [10e16]. The engine witnessed bigger performance with reduction in smoke, hydrocarbon and CO (carbon monoxide) emissions and expand in NOx (nitrogen oxides) emission for the entire above recounted situations.[7].

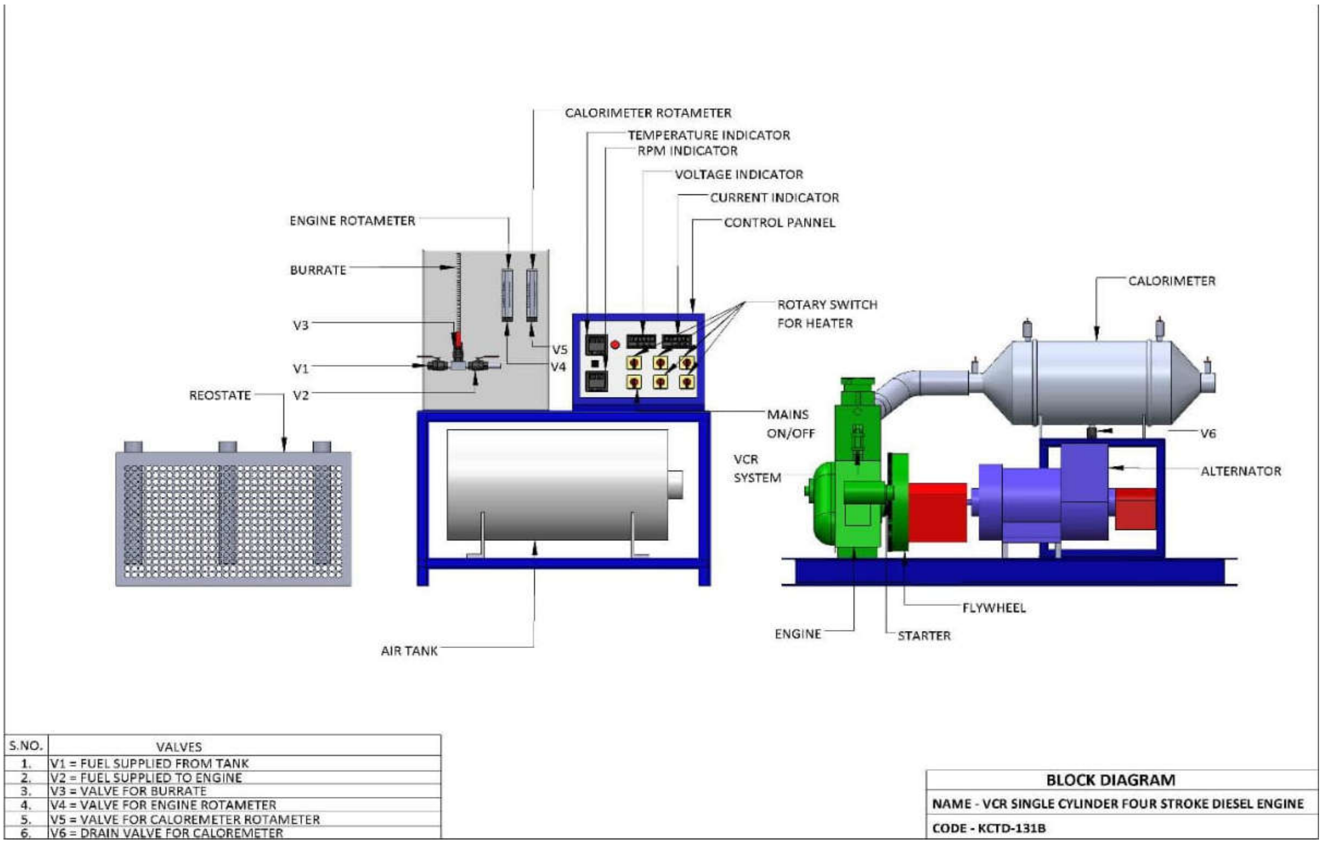
II. Materials and methods

In this experimental work, the variable compression ratio engine was run with diesel at different compression ratios to evaluate the performance with heat losses like losses through cooling water, heat loss through exhaust gas and unaccounted heat. The results were compared between the heat supplied, compression ratios, heat loss to engine cooling water, heat unaccounted as well as for different combinations of compression ratio and load.

III. Experimental set-up

Commercial diesel fuel used in India has been taken for base line reading for this work. The test engine used is variable compression ratio multi fuel engine coupled with eddy current dynamometer. The performance of the engine was analyzed by using panel board arrangement attached with test engine rig. The present work was carried out to investigate the heat during exhaust, engine cooling and unaccounted heat at different points in VCR engine. Table 1 shows the specification of the experimental engine setup. An electric dynamometer was used to apply load on the engine. Tests were carried out at a load of 3.5 KW for different compression ratio, the fuel flow rate and the various effects of unaccounted heat were analyzed. Control Panel board arrangement system equipped with the digital indicators is used to collect, store and analyze the data sensed by various installed sensors during the experiment.

Test Engine Specifications	
Features	**Specification**
Type	Four Stroke, Water cooled Diesel
Bore X Stroke(mm)	87.5 X 110
No. of Cylinders	One
Combustion Principle	Compression Ignition
Rated Speed (RPM)	1500
Rated Output in kW(hp)	5.2 (7)
Torque at Full Load in kN-m(kg-m)	0.033 (3.342)
Crank Shaft Center Height(mm)	203
Specific Fuel Consumption (SFC) (gm/hp-hr)	185 + 5%
Type of Fuel Injection	Direct Injection
Crank Radius	55 mm
Connecting Rod Length	300 mm
Cylinder Diameter	80 mm
Stroke Length	110 mm
Compression Ratio	Variable from 17.6 : 1
Loading	Eddy Current Dynamometer



S.NO.	VALVES
1.	V1 = FUEL SUPPLIED FROM TANK
2.	V2 = FUEL SUPPLIED TO ENGINE
3.	V3 = VALVE FOR BURRATE
4.	V4 = VALVE FOR ENGINE ROTAMETER
5.	V5 = VALVE FOR CALOREMETER ROTAMETER
6.	V6 = DRAIN VALVE FOR CALOREMETER

BLOCK DIAGRAM
NAME - VCR SINGLE CYLINDER FOUR STROKE DIESEL ENGINE
CODE - KCTD-131B

Figure 1.1 – Block diagram of Variable Compression Engine

IV. TEST PROCEDURE

The variable compression ratio engine available in the laboratory is started by using automatic starter motor crank start. When the engine reaches the operating condition, load is applied. The test is conducted at variable speed. Experiment was carried out on a test engine running on diesel, with compression ratios of 14.6, 15.4, 16.3, 17.6 and 18 in order to analyze the effect of Compression ratio on heat losses and performance parameters, specially on unaccounted heat. All the experiments were carried out at constant injection pressure of 200 bar and constant load of 3.5 KW by varying the compression ratio from 14.6 to 18.0. After completion of each experiment the engine was run on diesel in order to flush out fuel in fuel line.

Figure 1.2 – Experimental setup and test rig of Variable Compression Engine

V. ERROR ANALYSIS

Errors and uncertainties in the experiments can arise from instrument selection, condition, calibration, environment, observation, reading and test planning. Errors will creep into all experiments regardless of the care which is exerted. Uncertainty analysis is needed to prove the accuracy of the experiments. In any experiment, the final result is calculated from the primary measurements. The error in the final result is equal to the maximum error in any parameter used to calculate the result(Holman) Percentage uncertainties of various parameters like total fuel consumption, brake power, brake specific fuel consumption and brake thermal efficiency was calculated using the percentage uncertainties of various instruments used in the experiment. For the typical values of errors of various parameters given in Table 4, using the principle of propagation of errors, the total percentage uncertainty of an experimental trial can be computed

Uncertainty in measurements and calculated results		
Item Uncertainty Maximum uncertainty [%]	Uncertainty	Maximum uncertainty [%]
Speed	±10 rpm	±1
Torque	±0.2 s	±1.4
Time	±1	±1.8
BSFC	-	±2
BTE	-	±2

VI. RESULT AND DISCUSSION

6.1 Effect of compression ratio

Distribution of Heat at 3.5 KW load with Variable Compression Ratios						
Compression Ratio		**14.6**	**15.4**	**16.3**	**17.6**	**18**
Heat Balance Sheet	Heat Supplied By Fuel (%)	100	100	100	100	100
	Heat Equivalent to Brake Power (%)	21.19	20.17	21.14	22.40	22.48
	Heat loss to Exhaust Gases (%)	39.06	28.64	28.65	25.38	28.82
	Heat Loss to Engine cooling water (%)	20.71	24.38	23.30	27.41	26.19
	Heat Unaccounted (%)	19.01	25.93	25.91	25.68	22.40

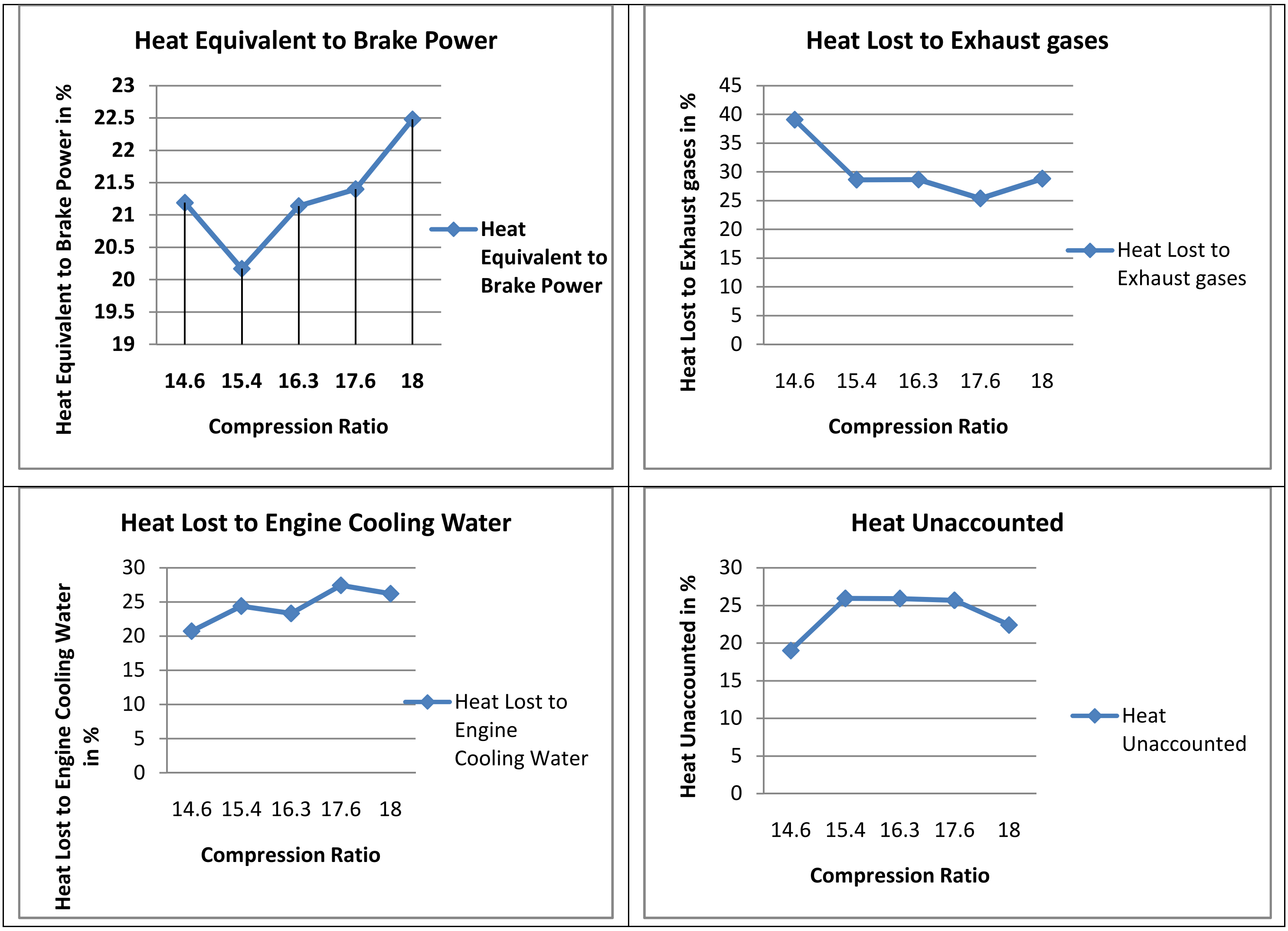


Figure 1.3 – Representation of heat losses observed during testing

6.1.1 Effect of compression ratio on heat distribution

The torque values of different compression ratio are predicted. It is observed that at constant load the heat losses are decreased as the compression ratio increases. The reason behind that is due to the increased effective and proper combustion. Compression ratio of 17.6 and 18.0 are more prominent as compared to the other compression ratios. The unaccounted heat losses values for compression ratios 14.6, 15.4, 16.3, 17.6 and 18.0 were in range of 18.0–20%, 24–26%, 24-27%, 23-26% and 21–23%. Thus, increasing the compression ratio had more benefits with unaccounted heat, due to their effectiveness of low volatility and higher viscosity in fuel during compression.

6.2 Effect of compression ratio on performance parameters

Compression Ratio	**14.6**	**15.4**	**16.3**	**17.6**	**18.0**
Load(KW)	3.5	3.5	3.5	3.5	3.5
Brake Thermal Efficiency (%)	21.19	20.16	21.34	21.40	22.48
Specific fuel Consumption (gm/Kw-hr)	425.45	411.02	382.13	356.15	345.17

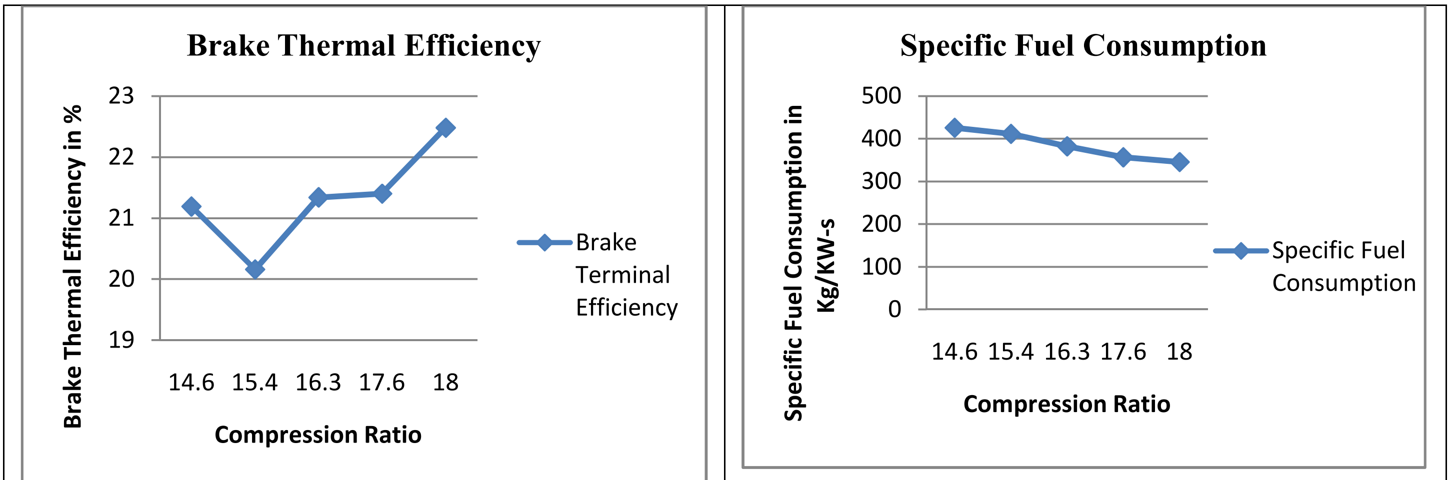


Figure 1.3 – Representation of thermal efficiencies and SFC observed during testing

6.2.1 Brake thermal efficiency (BTE)

The brake thermal efficiency (BTE) as a function of compression ratio and different compression ratios are shown in Table. BTE of the compression ratio 18 decrease unaccounted heat by 18.6% as compression ratio increased from 14.6 to 18. Compression ratio of 18 performance improvement at unaccounted heat and improves brake thermal efficiency higher compression ratio is due to the complete combustion because of effective combustion. The compression ratio of 18 was found to be the best for all cases of unaccounted heat and combustion. On increase in the compression from 14.6 to 18, increases the BTE.

6. 2.2 Effect of compression ratio on specific fuel consumption

The better specific fuel consumption was obtained at a compression ratio of 17.6 and lower compression ratios than 17.6 resulted in high specific fuel consumptions. The specific fuel consumption at a compression ratio of 17.6 and 18 was almost the minimum difference fuel consumption. The specific fuel consumption reduced with increase of compression ratio which could be due to better combustion and lesser heat losses where slight reduction of specific fuel consumption was observed at higher compression ratio. So, at the lower sides of the compression ratios, the specific fuel consumption is high due to incomplete combustion of the fuel. It is obvious from the figure that SFC of the engine gradually decreases with the increase in load. SFC for compression ratio 18:1 is comparatively lower than other compression ratios of 14.6, 15.4:1, 16.3:1, 17.6:1.

Conclusions

The present experimental work describes the effect of unaccounted heat and different engine compression ratios on the performance of a variable compression diesel engine. A direct injection naturally- aspirated diesel engine was used to analyze the effect of unaccounted heat at exhaust. The results showed that the engine performance improved considerably after the compression ratio was set at higher value that is 15.4. This improvement was particularly noticeable with compression ratio of 17.6 and 18.

- On increasing compression ratio from 14.6 to 17.6, the heat lost to exhaust gases and heat lost to engine cooling water by the engine is decreased on an average by 20.12%. The corresponding value for further increase of compression ratio from 17.6 to 18, the heat losses by engine is increases on an average 8.9%.
- At 85% load condition (3.5KW), on increasing the compression ratio from 14.6 to 17.6 there is a reduced in fuel consumption is observed from 356.15 gm/KW/h to 345.17 gm/KW/h. In fact, the lower volatility and higher viscosity of the produced diesel assisted in reaching the optimum condition for the combustion. Fuel consumption is little higher at compression ratio 17.6 than 18. Better fuel economy is obtained at the compression ratio 18 and 17.6.
- The compression ratio of 18 also brings about higher air temperature and pressure at the time of the injection. The maximum brake thermal efficiency is obtained at a compression ratio of 18; the least brake thermal efficiency is obtained at a compression ratio 15.4. Hence, with respect to brake thermal efficiency, 18 can be treated as optimum power output. This can be attributed to the better combustion and better intermixing of the fuel and air at this compression ratio.The higher temperature and pressure improve the overall engine performance in general and the brake power in particular.

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