Performance Analysis of Diesel Engine on Variable Compression Ratio

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Abstract: A systematic study to determine the effect of varying the compression ratio on the performance of a diesel engine is carried out. In this paper the various performance parameters have been studied at various compression ratios and optimum value of compression ratio has been found. At this value the engine performs at its best efficiency and lowest fuel consumption. The entire study was carried out using a simulation software Diesel RK version 4.1.3.143. In order to find out the optimum compression ratio the simulation was carried out at the compression ratios ranging from 17:1- 21:1. The performance parameters considered for the simulation are Indicated mean effective pressure (IMEP), [1] Indicated Efficiency, Brake mean effective pressure (BMEP), Braking efficiency, Specific fuel consumption (SFC) and Exhaust gas temperature. The graphs for these parameters against the engine speed at different compression ratios are plotted. The results shows that engine works best at compression ratio 18.5 for the above stated parameters.

Keywords: *Diesel engine, Variable compression ratio, performance parameters.*

I. INTRODUCTION

With increasing demands for better engine performance and lesser exhaust emissions and improved fuel economy has led to much advancement in the automotive industry. One of those advancements is the concept of VCR. The concept of VCR proved in increasing the engine performance with limiting the exhaust emissions. This also proved in improving the fuel economy. The VCR technology works by varying the compression ratios. The compression ratio is defined as the ratio of the volume of the cylinder and the combustion chamber when the piston is at the bottom, and the volume of the combustion chamber when the piston is at the top. The higher the ratio, the more compressed the air is in the cylinder. When the air is compressed, you get complete combustion from the air-fuel mixture and more fuel being used and thus higher the efficiency. Conventional engines operate at a fixed compression ratio [2, 5]. Thus there might be a chance that the engine is running at a lower efficiency than when it is to be operated at any other compression ratio. So an engine with variable compression ratio is needed so that the compression ratio of the engine can be changed according to different load and speed conditions. Besides this the emissions may also be controlled with the variable compression ratio. This paper describes the effects of varying the compression ratio of a diesel engine on its performance.

II. LITERATURE REVIEW

With an increase in worldwide population, the demand of fossil fuel like petrol, diesel,and coal etc.have increased many times. There is challenge to save the fuels. So the scientists after extensive research came up with a concept of VCR (Variable compression ratio). The VCR engines improves the fuel economy with lesser car emissions especially those of CO_2. SAAB Automobiles in the year 2000 showed their VCR engine at Geneva motor show [6]. For varying the compression ratio, they lowered the cylinder head closer to crankshaft thus altering the clearance volume. Gomecys a Dutch company made his 4^{th} generation VCR engine. In this the crankshaft is integrated with the VCR engine and by replacing the normal crankshaft with Gomecys crankshaft the system can be upgraded. With the idea of having high power of turbo engine and low fuel consumption of non–turbo engine, Nissan made a concept of multi–link piston crank mechanism for providing with best suitable compression ratio. In this better fuel economy and higher power output can be achieved within the same engine. At SAE world congress 2013, FEV engineers described their two – stage VCR system which was based on the concept of variable length connecting rod with eccentric piston pin suspension. The small end of the connecting rod is equipped with an eccentric sleeve covering the wrist pin. By rotating the eccentric sleeve, the length of the connecting rod can be varied thus varying the compression ratio.

III. WORK DESCRIPTION

With the increasing cost and demand of energy resources such as diesel and gasoline there is continuous need for engines having high efficiency and lowest fuel consumption as these resources are on the verge of depletion. Therefore anengine with variable compression ratio is needed which provides best performance and also reduces the consumption of fuel. Besides this italso helps in cutting down the emissions. Thus further reducing the environmental damage and benefitting the manufacturers by satisfying the strict emission control norms. In this project a single cylinder Diesel engine has been taken into account for carrying out the simulation [3]. The simulation is done using the software Diesel RK version 4.1.3.143. The engine is operated at different compression ratios at different engine speeds and various parameters like Indicated mean effective pressure (IMEP), Indicated Efficiency, Brake mean effective pressure (BMEP), Braking efficiency, Specific fuel consumption (SFC) and Exhaust gas temperature were studied distinctly for every case. An optimum value of compression ratio has been found at which engine is running at best efficiency and lowest fuel consumption. The range of compression ratio considered for studying engine was 17:1 -21:1.

IV. ENGINE SPECIFICATION

The specifications of the engine are as follows :

Table 1. Specifications of the engine

S. No.	Features	Specification
1	Model	Kohler KD 500
2	Swept Vol.	505 cm^3
3	Strokes	4
4	Cylinders	1
5	Bore	87 mm
6	Stroke	85 mm
7	Power	8.4 kW
8	Torque	31 Nm (at 2000 rpm)
9	Rated speed	3600 rpm
10	Compression ratio	18:1-22:1

V. DESIGN AND CALCULATIONS

A. Calculations

Brake Power (BP):- The brake power of an engine is the actual power delivered by the crankshaft and is measured by the means of an electric dynamometer. It is an important factor for calculating the mechanical efficiency of an engine.

Mean Effective Pressure (MEP):- The mean effective pressure is the hypothetical pressure which is assumed to be acting on the piston during the power stroke.

Indicated Power (IP):- The indicated power of an engine is the actual power developed within the cylinder during the combustion process. It is always greater than the brake power. The sum of brake power and friction power gives the indicated power. The indicated power of a single cylinder engine is determined by using the following formulae [4],

$$IP = \frac{IMEP * L * A * N}{60}$$

Where,

IMEP = Indicated Mean Effective Pressure(N/m^2 *or* Pa)

L = Length of stroke (m)

A = Area of cylinder (m^2)

N = Number of working strokes per minute

Friction Power (FP):- The friction power is the power that is required to overcome the loss of power due to friction in an engine. Friction power increases in relation to engine speed and it is calculated by subtracting the brake power from the indicated power.

$$FP = IP - BP$$

Specific Fuel Consumption (SFC):- It is defined as the amount of fuel consumed per unit of power developed per hour.

Brake Specific Fuel Consumption (BSFC):- It is a measure of the fuel efficiency of an engine that burns fuel and develop power. It is obtained by using the formulae,

$$BSFC = \frac{M}{BP}$$

Where, M = Weight of fuel (Kg/hr)

Indicated Specific Fuel Consumption (ISFC):- It is the ratio of amount of fuel used by an engine to the indicated power of an engine. It is obtained by using the formulae, [9]

$$ISFC = \frac{M}{IP}$$

Where, M = Weight of fuel (Kg/hr)

Brake Thermal Efficiency (BTE):- It is used to evaluate how well an engine converts the heat energy produced from combustion of fuel to useful mechanical energy.

$$BTE = BP * \frac{3600}{M * CV}$$

Where, CV = Calorific Value of fuel (KJ/Kg)

Indicated Thermal Efficiency (ITE):- The ratio between the indicated power output of an engine and the rate of supply of energy in form of combustion of fuel.

$$ITE = IP * \frac{3600}{M * CV}$$

Where, CV = Calorific Value of fuel (KJ/Kg)

Mechanical Efficiency (ME):- It is a relationship between the power delivered and the power that would be available. It is used to evaluate the effectiveness of the engine in converting the energy produced by combustion of fuel into useful work.

$$ME = \frac{BP}{IP}$$

Exhaust Gas Temperature: - It is temperature at which the exhaust gas comes out from the exhaust system of the engine.

B. Procedure

To determine the optimum value of the compression ratio the specifications of the single cylinder diesel engine is entered into the simulation software Diesel RK. Bore, Stroke, Nominal speed, Compression ratio, No. of valves, No. of cylinders etc are entered into the software [7]. After inputting these values the software runs a simulation. After successful simulation, results for different parameters are obtained. By taking into account the results obtained graphs are plotted for different compression ratios which are as follows :

1. IMEP vs Engine Speed
2. Indicated Efficiency vs Engine Speed
3. BMEP vs Engine Speed
4. Braking Efficiency vs Engine Speed
5. Specific Fuel Consumption vs Engine Speed
6. Exhaust Gas Temperature vs Engine Speed

VI. RESULTS

After successful simulation results are obtained for different parameters such as Indicated mean effective pressure (IMEP), Indicated efficiency, Brake mean effective pressure (BMEP), Braking efficiency, Specific fuel consumption (SFC) and Exhaust Gas temperature. These results are then plotted into graphs against the engine speed. The graphs show variations of parameters with engine speed at different compression ratios. These graphs helps in determining at which compression ratio the engine works best for the different parameters. A value is then selected at which all these parameters are at their best. It is the optimum value of the compression ratio for the given specified engine.

As the speed increases the Indicated mean effective pressure (IMEP) also increases until it reaches a peak value as shown in Fig. 1.

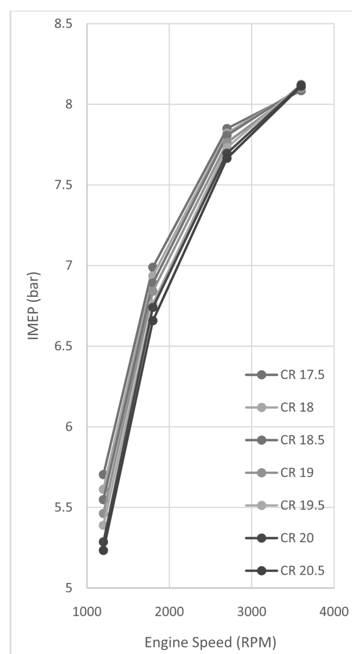

Fig. 1: IMEP vs Engine Speed

Fig. 2 Indicated efficiency shows almost a linear relationship with engine speed. It increases linearly with speed as shown in Fig. 2.

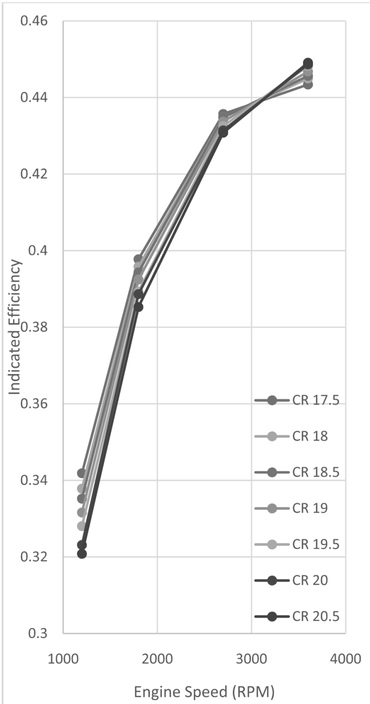

Fig. 2: Indicated Efficiency vs Engine Speed

The Brake mean effective pressure (BMEP) holds the same relationship as that of IMEP but decreases after attaining peak values as shown in Fig 3. It has lower values than IMEP.

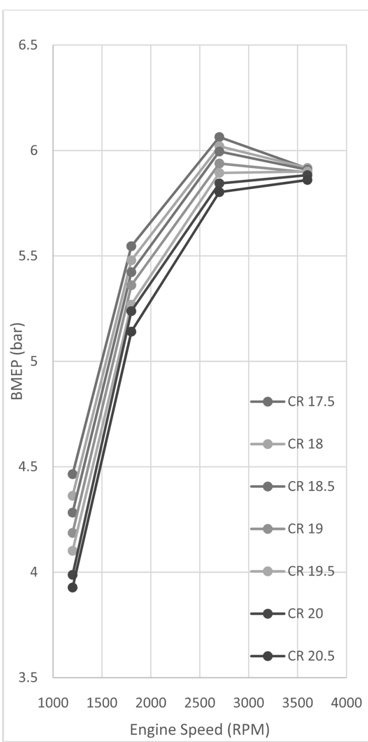

Fig. 3: BMEP vs Engine Speed

The Braking efficiency is low for lower speeds and increases till it reaches its peak value, then becomes almost constant for higher speeds as shown in Fig. 4.

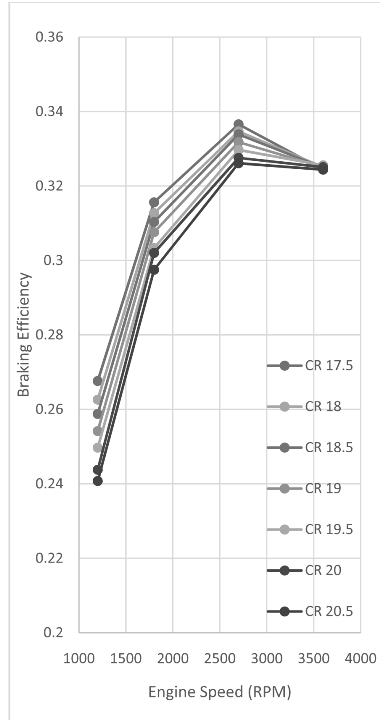

Fig. 4: Braking Efficiency vs Engine speed

As the speed increases the Specific Fuel Consumption (SFC) decreases as shown in Fig. 5. It is maximum at low speeds, decreases for medium speed range and increases for higher speeds.

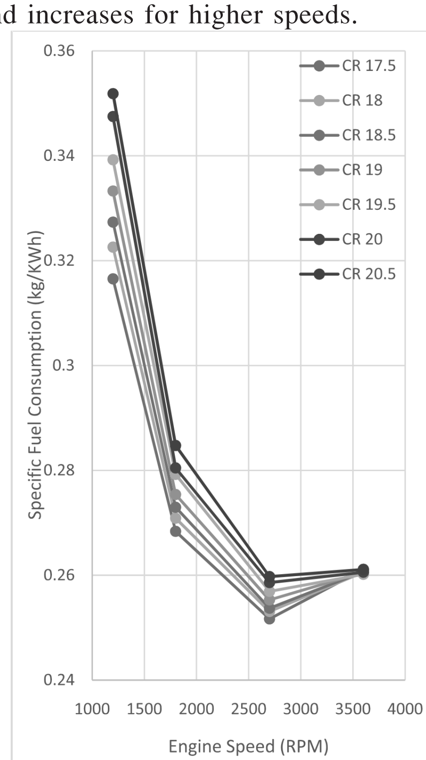

Fig. 5: Specific Fuel Consumption vs Engine Speed

The exhaust gas temperature increase as the speed increases as shown in Fig. 7. This gas temperature should not exceed a greater value as it may lead to catastrophic effects on the engine.

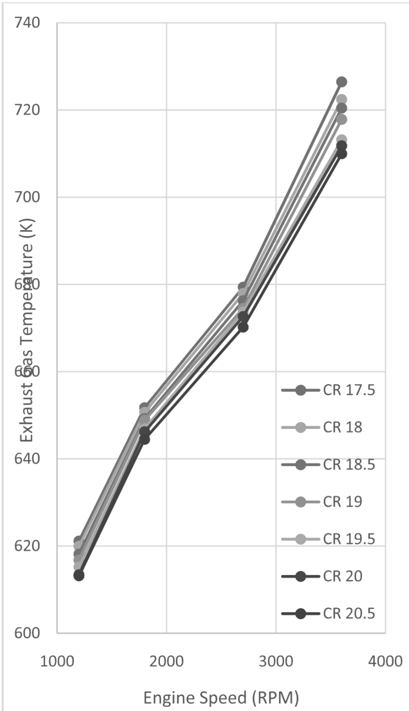

Fig. 6: Exhaust Gas Temperature vs Engine Speed

The particulate matters decreases very minutely as the speed increases and increases rapidly as the speed of engine reaches its peak value as shown in Fig. 7.

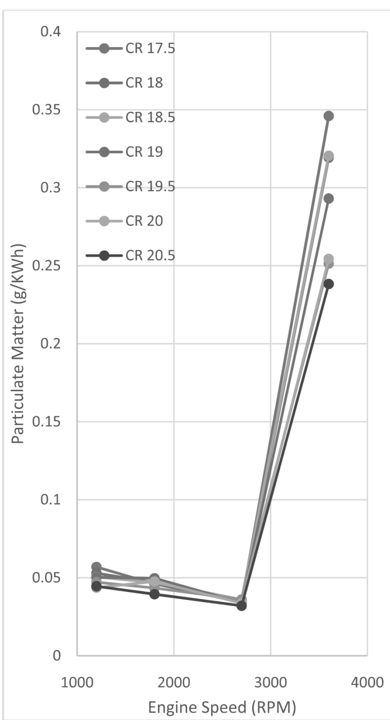

Fig. 7: Particulate Matters vs Engine Speed

The NO_X emissions keeps on decreases as the speed of engine increases. It is maximum for low speed and minimum at high speed as shown in Fig. 8.

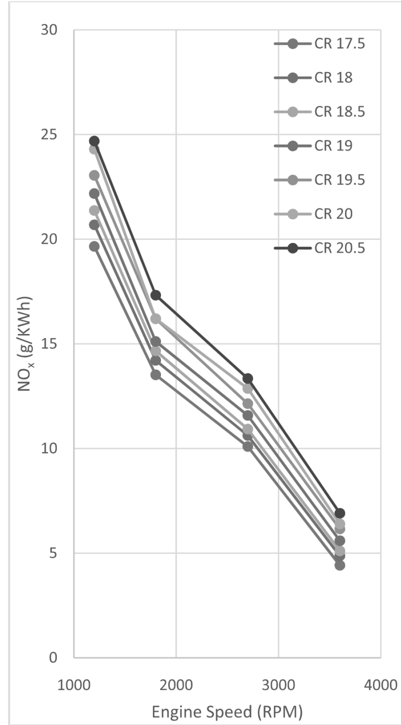

Fig. 8: NO_X vs Engine Speed

As the speed increases CO2 emissions decreases. It is maximum for lower speed values and becomes almost constant at higher speed bands as shown in Fig. 9.

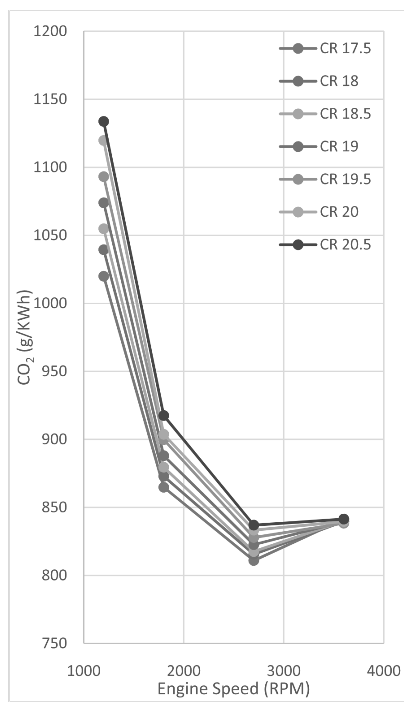

Fig. 9: CO_2 vs Engine Speed

VII. CONCLUSIONS

Considering the factor of BMEP, it shows steeper variations for compression ratios 17.5, 18, 19.5, 20 and 20.5. The compression ratios 18.5 and 19 are suitable. The exhaust gas temperature should not be at a higher side thus neglecting the compression ratios 17.5, 18. The compression ratios 18.5, 19, 19.5, 20 and 20.5 are suitable. Just as BMEP, IMEP also shows steeper variations for compression ratios 17.5, 18, 19.5, 20 and 20.5. The curve holds well enough at 18.5 and 19.The Indicated efficiency in the moderate speed band is higher for compression ratios 18.5 and 19. The Specific Fuel Consumption is minimum for compression ratio 17.5 and maximum for compression ratio 20.5.The Braking efficiency is higher in the moderate speed band for compression ratio 18.5. From the above conclusions the engine should work best at compression ratio 18.5. This is the optimum value of the compression ratio at which the engine performance can be maximised.

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