SIMULATION ON SINGLE CYLINDER DIESEL ENGINE AND EFFECT OF COMPRESSION RATIO AND EGR ON ENGINE PERFORMANCE AND EMISSION

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Abstract: *In this research, the one dimensional (1D) CFD modelling of four-stroke direct injection diesel engine is developed by AVL Boost software. The performance of a diesel engine increases with increase in compression ratio. Variable compression technologies in IC engines are used to increase fuel efficiency under variable loads. Exhaust gas recirculation is a common way to control in-cylinder NOx production and is used in most modern high speed direct injection diesel engines. However the effect of EGR on performance, combustion and emissions production at different compression ratios are difficult to depict. In the present work an attempt was made to study the effects of exhaust gas recirculation on performance, combustion and emissions of a variable compression Diesel Engine. The test was conducted at different compression ratios with different loads and for different EGR rates.*

Keywords: SIMULATION, DIESEL ENGINE, MODEL, AVL BOOST, PERFORMANCE, SINGLE CYLINDER, EGR, VCR

1. Introduction

Diesel engines are characterized by low fuel consumption and very low CO emissions. However, the NOx emissions from diesel engines still remain high. Hence, in order to meet the environmental regulations, it is highly desirable to reduce the amount of NOx in the exhaust gas. The Diesel engines by small power have a wide range of application for the mechanization of the most activities in industry and agriculture. Owing to their low fuel consumption, they have become increasingly attractive for smaller lorries and passenger cars also. But higher NOx emissions from diesel engine remain a major problem in the pollution aspect. In order to reduce emission levels, some external engine features can be applied, such as EGR or after-treatment systems. EGR systems have been used to reduce emissions of nitrogen oxides (NOx) from diesel engines.

Cylinder charge dilution with exhaust gas can be classified into internal EGR and external EGR. With external EGR, exhaust gas is taken from the exhaust port and supplied into the inlet port. Internal EGR is achieved by increasing NVO (negative valve overlap) during exhaust stroke, which requires an improved cam that can rapidly switch cam profiles to achieve any variable valve timing, otherwise it's impossible to independently and effectively control EGR ratio. This greatly limits the application of internal EGR. As a result, external EGR has become widely used on today's automobile engines. External EGR has a relatively low cost. It only needs to use dedicated EGR control valve, which can control EGR rate effectively under all work conditions of engine [1–4].

When EGR is applied, engine intake consists of fresh air and recycled exhaust gas. EGR (%) usually represents the percentage of the recirculated exhaust gas. The percentage of exhaust gas recirculation is defined as the percentage of recirculated exhaust in total intake mixture [5]. Where m_i is the mass of total intake mixture and m_{EGR} is the mass of the EGR.

$$E(\%) = \frac{m_{EGR}}{m_i}.100 \qquad (1)$$

The principal source of NO formation is the oxidation of the nitrogen present in atmospheric air. The nitric oxide formation chain reactions are initiated by atomic oxygen, which forms from the dissociation of oxygen molecules at the high temperatures reached during the combustion process.

Shahadat.et.al [6] studied the combined effect of EGR and inlet air preheating on engine performance in diesel engine. They found that at medium load conditions, oxides of nitrogen (NOx), carbon monoxide (CO), engine noise, and brake specific fuel consumption decreased when inlet air preheating and EGR were applied together as compared to those during normal operations of the engine.

Arjun Krishnan et.al [7] studied the Prediction of NOx reduction with EGR using the flame temperature correlation technique. They developed a procedure to calculate the reduction in NOx levels due to EGR, given only engine base-data. This approach utilised the flame temperature correlation technique to obtain NOx predictions with sufficient accuracy – 6.5% at part loads.

Avinash kumar.et.al [8] studied the effect of EGR on exhaust gas temperature and exhaust opacity in compression ignition engines. They found that that the exhaust gas temperatures reduce drastically by employing EGR. Thermal efficiency and brake specific fuel consumption are not affected significantly by EGR. However particulate matter emission in the exhaust increases, as evident from smoke opacity observations.

AVL Boost is based on 1D gas dynamics which account for fluid flows and heat transfer. Each component in an AVL Boost model is discretized or separated in many smaller components. These components have very small volumes and the fluid's scalar properties in these volumes are assumed to be constant. The scalar properties of a fluid include pressure, temperature, density and internal energy. Each volume also have vector properties that can be transferred across it's boundaries. This properties include mass flux and fluid velocity.

2. Data Needed for Building an Engine Model

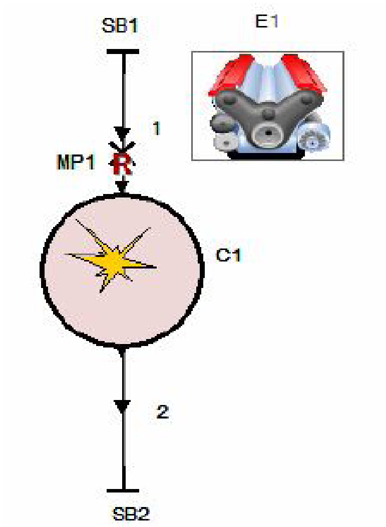

Fig. 1 *Model of Single Cylinder Diesel Engine: SB-system boundaries, MP-measuring points, C-cylinder.*

AVL Boost is a software tool that consists in a pre-processing program, used for initial data entry and technical characteristics of the engine to be designed as model. After forming the engine assembly with annexes systems, mathematical equations and algorithms of the model with the graphical user interface (GUI) will analyze and calculate the processes that are required during simulation [9, 10]. The model for the engine designed in AVL BOOST application is shown in figure 1.

A list of information that is needed to create a model in AVL BOOST is included in library. The main features of the diesel engine that have been used as initial data to define the cylinder parameters are presented in table 1. Cylinder (C1) of the model in AVL Boost is connected with element Engine (E1), and it defines the type of engine used, operating speeds on it, moments of inertia and break mean effective pressure (BMEP). Combustion method is Mixing Controlled Combustion model that predicts the rate of heat released (ROHR) and NOx emissions on the quantity of fuel in the cylinder and the turbulent kinetic energy introduced by the injection of fuel [8].

Table 1: Specification of the engine.

Engine Parameters	Value	Unit
Bore	76	[mm]
Stroke	65	[mm]
Displacement	295	[cc]
Power	4	[kw]
Speed	3000	[rpm]
Compression ratio	17:1	-
Valve lift	8,5	[mm]
Piston pin offset	10	[mm]

The pre-processing step of AVL Boost enable the user to model a 1-Dimensional engine test bench setup using the predefined elements provided in the software toolbox. The various elements are joined by the desired connectors to establish the complete engine model using pipelines

3. Result and Discussion

After definition of the engine parameters has been run a series of simulations, and then plot the results in Impress Chart were was analyzed.

The running simulation result is all of the engine performance data with the constant engine speed (rpm) by varying the compression ratios. This model was running at speed 2000 rpm.

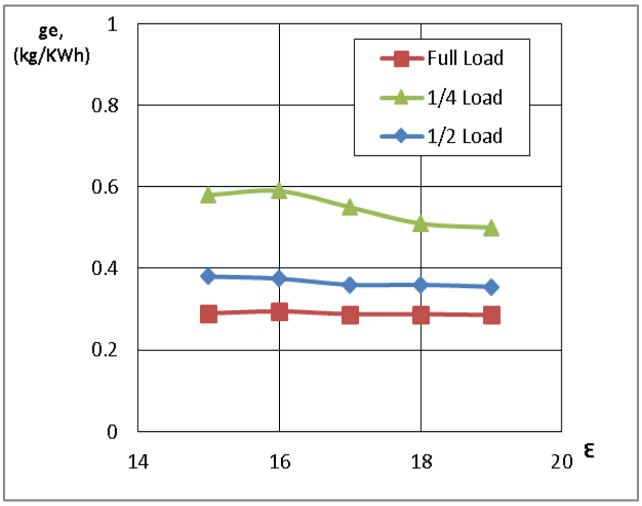

Fig. 2 *Influence of Compression ratio on Specific fuel consumption at different loads*

In Fig. 2 the specific fuel consumption at various loads and compression ratios are presented. With increase in compression ratio the specific fuel consumption decreases irrespective of the load except at compression ratio 16 due to less ignition delay and more combustion duration.

Figure 3 shows the effect NOx at different loads and compression ratios. With increase in load the NOx value also increased due to more heat release and caused for dissociation of gases.

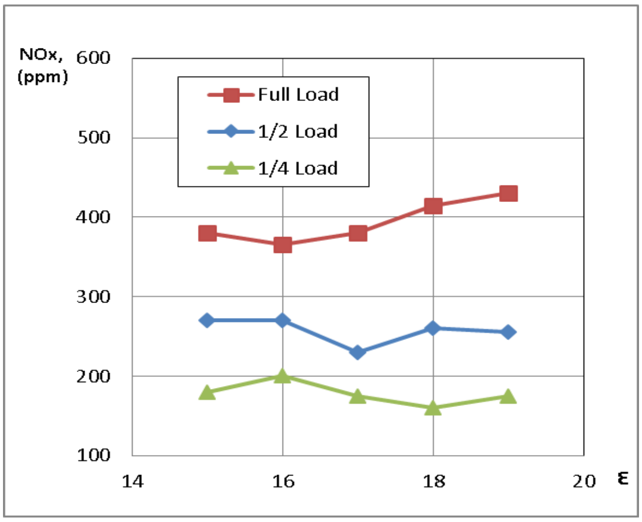

Fig. 3 *Influence of Compression ratio on NOx emission at different loads*

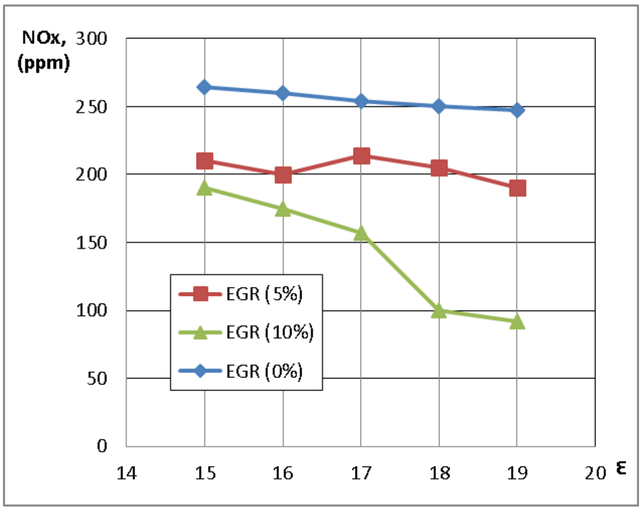

Fig. 4 *Influence of EGR on NOx emission at different compression ration*

Figure 4 shows the effect of exhaust gas recirculation (EGR) on NOx emissions. The model simulation result shows that with increase in percentage of EGR the NOx emissions are decreased. These are mainly due to the lower combustion chamber temperatures caused by EGR and because the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture.

3. Conclusion

This paper present the results of the engine cycle simulation of a single cylinder, direct injection diesel engine with different compression ratios, percentages of EGR and loads to estimate performance, combustion and emission characteristics of the engine. using AVL Boost software. It was found that with increase in compression ratio the specific fuel consumption decreases. The results obtained indicated that with increase in % EGR the NOx emissions was gradually decreases at different compression ratios due to less flame temperatures and low oxygen content in the combustion chamber. The high degree of recirculation is suitable for higher compression ratio because at compression ratio 19 and 10% EGR the percentage reduction of NOx was 36%.

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