EFFECT OF EXHAUST TEMPERATURE ON THE PERFORMANCE OF A DIESEL ENGINE WITH EGR

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ABSTRACT

The aim of this project is to determine the effect of the exhaust temperature on the performance of the diesel engine with exhaust gas recirculation (EGR) with respect to engine speed, throttle, biodiesel fuel and diesel fuel. Experiments have been performed for diesel fuel and bio-diesel fuel with 50% of throttle position for with and without EGR system. Engine brake torque, brake power and the exhaust temperature have been investigated for both fuels. All data were collected using data acquisition system which operates with Dewesoft software. The data were then exported to the Microsoft excel in order to construct graphs for performance analysis for each type of fuel and the engine conditions. From the analysis, it was found that the existence of EGR valve were reducing the exhaust temperature. Other than that, the torque produced by the engine with EGR valve were also lower than the engine without EGR valve. This shows that the exhaust temperature has an effect on the engine performance and allows the reduction of NO_x formation.

ABSTRAK

Tujuan projek ini adalah untuk menentukan pengaruh suhu ekzos pada prestasi enjin diesel dengan resikulasi gas buang (EGR) bergantung kepada kelajuan enjin, gas, bahan api biodiesel dan diesel. Eksperimen telah dilaksanakan dengan menggunakan bahan api diesel dan biodiesel dengan 50% bukaan pendikit yang menggunakan sistem EGR dan tanpa sistem EGR. Daya kilas, kuasa enjin, dan suhu ekzos telah diselidik bagi kedua-dua jenis bahan api. Semua data dikumpul dengan menggunakan sistem data pengambilalihan yang beroperasi dengan perisian Dewesoft. Data tersebut kemudian dieksport ke Microsoft Excel untuk tujuan pemplotan graf bagi menganalisis prestasi untuk setiap jenis bahan api dan keadaan enjin. Dari hasil analisis tersebut, didapati bahawa dengan penggunaan injap EGR, ia telah mengurangkan suhu ekzos dan daya kilas enjin berbanding dengan tanpa injap EGR. Hal ini menunjukkan bahawa suhu ekzos mempengaruhi prestasi enjin dan membolehkan pengurangan pembentukan NOx.

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LIST OF SYMBOLS

Π	pi
τ	Torque
W_b	Brake power
V_d	Displacement volume
N	Engine speed
$\dot{m}_f$	Fuel flow rate
B	Cylinder bore
S	Piston stroke
n	Number of cylinder
N-m	Newton meter

LIST OF ABBREVIATIONS

EGR	Exhaust Gas Recirculation
TDC	Top Dead Center
BDC	Bottom Dead Center
Bmep	Brake mean effective pressure
RPM	Revolution per minute
Bsfc	Brake specific fuel consumption
SAE	Society of Automotive Engineers

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Heat is a form of energy which can be transferred from a medium to another medium when it is connected to each other. Heat or thermal energy exists when chemical reaction occurs resulting into a process known as combustion process. Thus inventors throughout the century have invented a few machines which operate based on thermal energy. Internal combustion engines are one of the inventions which use thermal energy application. The internal combustion engine is an engine that works based on the air-fuel mixture combustion process in the combustion chamber. Due to high thermal conversion, gases inside the chamber expand. These expanded gases produces high amount of force that is used on moveable parts application which are parts inside the engine, such as pistons and crankshaft. By the linear movement of the piston and the rotation movement of the crankshaft, it produces mechanical energy.

The internal combustion engine uses a few types of fuel as the main source to produce thermal energy. One of them is diesel, which is used as the main fuel in diesel engine. Most of the heavy duty vehicles are using diesel engines, because these engines can provide high power-to-weight ratios or high torque and higher thermal efficiency (K. Rajan and K.R. Senthil Kumar, 2009). The diesel engine uses the heat of compression to ignite and to burn the air-fuel mixture, which is injected into the combustion chamber during the end of compression stroke.

Unfortunately, after the combustion the diesel engine produces a waste product. These waste products are various mixtures of Nitrogen Oxide compounds with varying characteristics. It affects the ozone layer and is also harmful to humans. Many inventors and engineers have done various researches and experiments in order to reduce the amount of Oxides of Nitrogen produced by the engine while operating. As the results from the researches and the experiments, the Exhaust Gas Recirculation (EGR) system was developed. This EGR system can reduce the amount of Oxides of Nitrogen (NOx) which is produced by the engine.

The EGR system reduces the amount of NOx by recirculating small amounts of exhaust gases into the intake manifold. By mixing the exhaust gases with the air-fuel mixture, it reduces the peak combustion temperature and pressure (G.H.Abd-Alla, 2001). NOx formed when the combustion temperature exceeds about 1371°C. Therefore, when the peak combustion temperature and pressure is reduced, amount of NOx produced is also reduced

1.2 PROBLEM STATEMENT

Performance of a diesel engine is affected by various parameters. One of the parameters is the intake air temperature. When cool air enters the combustion chamber, performance of the engine will be increased. This is because cool air has more density which contributes to a perfect combustion process. However, this also increases the exhaust emission. To overcome this problem, engineers came up with the Exhaust Gas Recirculation system, which is a process of recirculating small amounts of exhaust gas into the combustion chamber to reduce the quantity of Nox but this process will result in reduction of combustion temperature and this will affect the performance of the engine.

1.3 PROJECT OBJECTIVE

The main objectives of this project are:

i. To setup a diesel engine for experiment
ii. To test the engine while operating in 50% throttle.
iii. To compare the performance and the exhaust temperature of the diesel engine with and without EGR using diesel and biodiesel fuel.

1.4 PROJECT SCOPE

The scopes of this project are:

i. Install the four cylinder diesel engine
ii. Installation of instruments on a diesel engine
iii. Engine performance testing with EGR and without EGR

CHAPTER 2

LITERATURE REVIEW

2.1 DIESEL ENGINE HISTORY AND PROCESS

The diesel internal combustion engine was invented by a German engineer named Rudolf Diesel. Rudolf Diesel has filed the patent of the method and design for the diesel engine on February 27th 1892 at the patent office in Germany. After Rudolf Diesel filed the patent, the inventor attempted to construct the most efficient engine. In year 1893, Rudolf Diesel successfully came out with the first diesel engine model with an efficiency of approximately 26%. After a few more years, Rudolf Diesel accomplished a great achievement by producing a diesel engine that operates at 75% efficiency. In the 1920's this diesel engine was then redesigned into a smaller and compact model. The development of the diesel engine is continued and it was redesigned by many other inventors (Robert Bosch, 2004).

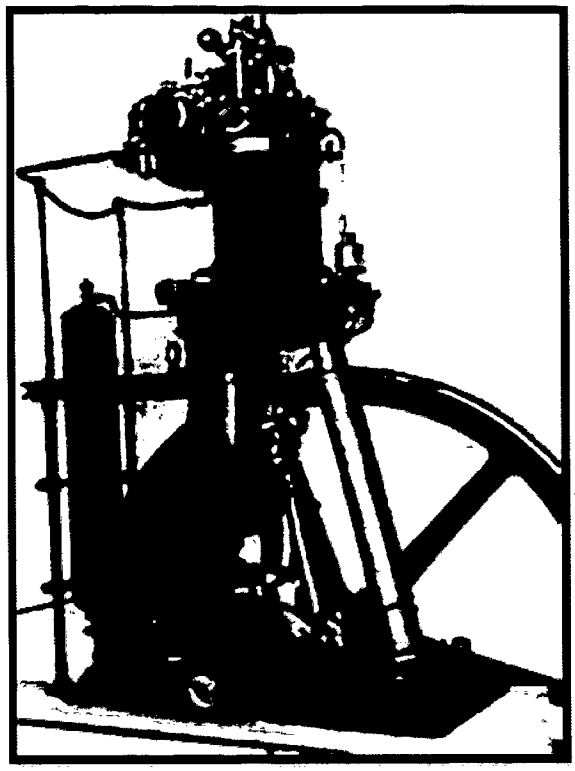


Figure 2.1: Internal combustion engine

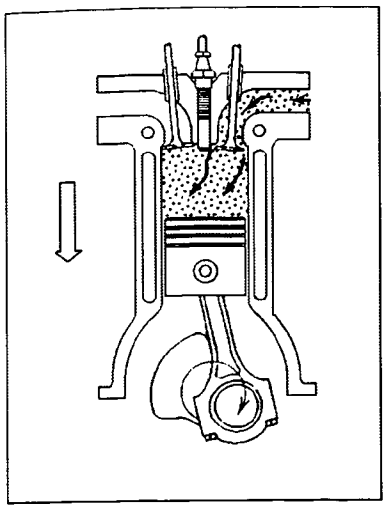
Source: Bryant, L., The Development of the Diesel Engine

Diesel internal combustion engine is a heat engine which converts the chemical energy into mechanical energy. From the energy produced, the mechanical parts in the engine will move, such as the piston and the crankshaft. Movement of the mechanical parts will produce kinetic energy which drives the vehicle.

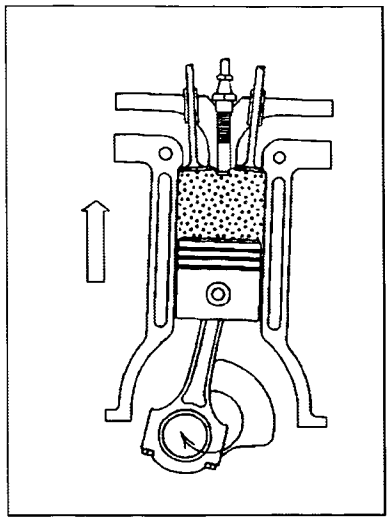
2.1.1 Working procedure of diesel engine

Working procedure of a diesel engine is the same as a gasoline engine, but there are a few differences in parts compared to gasoline engine. The diesel engine differs from gasoline engine primarily in the way the combustion process occurs. Fuel ignites on its own for diesel engines where else for gasoline engines, fuel is ignited by the spark

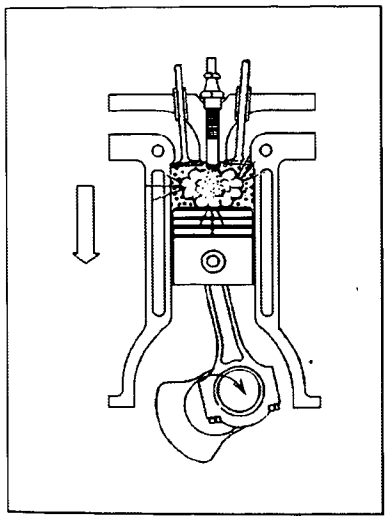
created from the spark plug. There are two types of diesel engine, which are the 2 stroke and 4 stroke engine. There are 4 strokes in a 4 stroke diesel engine; the first stroke will be the intake stroke. In this stroke, the intake valve will open according to the camshaft lobe and permits the air flow into the combustion chamber while the piston will move downwards to develop suction force, so that the air can flow into the combustion chamber. Once the piston reaches to BDC position, the intake stroke ends and the compression stroke will start. In this stroke, the piston will move upward and will compress the air to 30 – 55 bar in the combustion chamber. When the piston starts to move upward, both valve is closed as to prevent air leakage from the combustion chamber. Due to compression, the air will be highly charged with thermal energy. This stroke will be over, when the piston reaches TDC position. When the air is fully compressed, the combustion stroke will start. In this stroke, fuel is injected at just the right moment and ignited. The heat produced by compressed air ignites the fuel in the diesel engine. The energy developed from the combustion will force the piston back down to BDC position again. When this stroke occurs, both valves are closed. Once the piston reached BDC position, the piston will move back to TDC position again, this movement of the piston is marked as the exhaust stroke. When this stroke occurs, the intake valve is closed where else the exhaust valve is opened. When the piston moves to TDC position, it will force the exhaust gas to move out from the combustion chamber. After the exhaust stroke is over, the cycle will continue with intake stroke again as shown in Figure 2.2



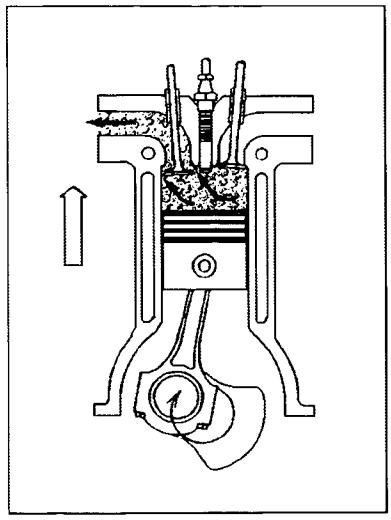
a) Intake stroke



b) Compression stroke



c) Power stroke



d) Exhaust stroke

Figure 2.2 a-d: Operating cycle of a four-stroke diesel engine

Source: Robert Bosch, Basic principles of the diesel engine

2.2 GLOW PLUG

Glow plug is a device that is used in a vehicle that does not require a spark plug to ignite the fuel. This device will be supplied with electricity as to be heated up. This produced heat will increase the air temperature in the combustion chamber and this helps the engine to start easily when the engine is cold.

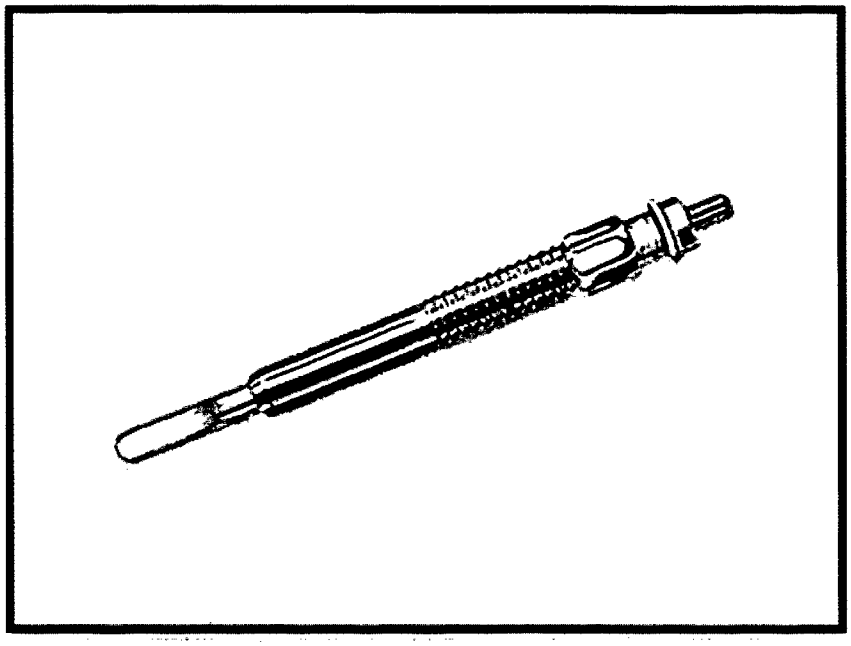


Figure 2.3: Glow plug

Source: NGK Spark plug. CO. LTD.

2.2.1 Type of glow plug

There are two main types of glow plug, which is the Metal glow plug and the Ceramic glow plug. For Metal glow plug, the heating coil is made of metal, where else Ceramic glow plug, the heating coil is made of compositions of ceramic and metal.

2.2.2 Function of glow plug

Typically, a glow plug comprises of a heating coil in a metal tube closed at one end and it's filled with electrically insulating ceramic powder. The closed end of the glow plug is fixed through a hole in the cylinder head into the combustion chamber of a diesel engine. When the glow plug is supplied with the electric power, it produces heat that the surface temperature reaches above 1000°C within few seconds. Once the fuel is injected into the combustion chamber, the air-fuel mixture ignites.

2.2.3 Design of a glow plug

The design of a glow plug consists of a few components which are the heating coil, insulating filter, central electrode, and electrical connection. Figure 2.4 shows the design of a glow plug.

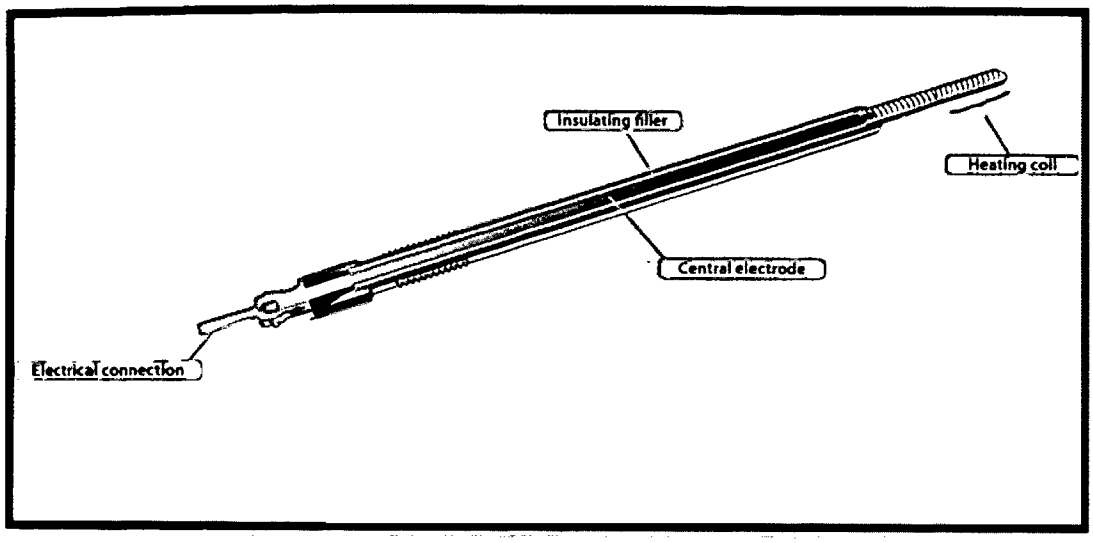


Figure 2.4: Glow plug design and mechanism

Source: NGK Spark plug. CO. LTD.

2.2.4 Heating coil

Heating coil is made of metal. When current is supplied to the coil, it starts to glow and spread the heat to its surroundings. Different heating coil diameters are used to change the glowing time of the glow plug. Figure 2.5 shows the heating coil is glowing when the current is supplied.

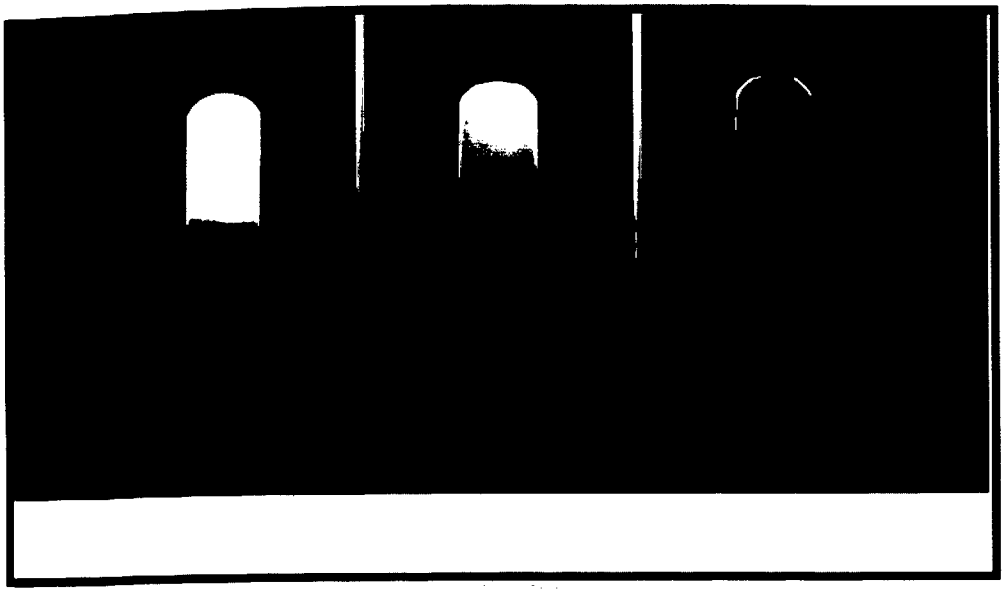


Figure 2.5: Heating coil when glowing

Source: NGK Spark plug. CO. LTD.

2.2.5 Insulating filter

Insulating filter is used to protect the heating coil from vibration and high impact. It also provides an optimal transmission of produced heat. This insulating filter is made from the special magnesium oxide powder. This powder is used due to its ability to conduct heat and insulate electricity.

2.2.6 Central electrode

The central electrode is functioned to convey the current from the battery to the heating coil.

2.2.7 Electrical connection

The electrical connection used to connect the glow plug to the battery supply.

2.3 INJECTION SYSTEM

Basically, a diesel engine has three types of injection systems which depend on the structure of the combustion chamber in a diesel engine. The design of the combustion chamber determines the quality of the combustion. The combustion chamber designs create turbulence effects which improves the mixing and distribution of the air-fuel mixture inside the combustion chamber.

- Direct injection
- Pre- chamber system
- Swirl chamber method

2.3.1 Direct injection

For direct injection system, the process uses multi-holes nozzle. The fuel injector is fixed through a hole into the combustion chamber. This injector will inject the fuel at high pressure, so that the fuel will be atomized and easily burnt. The special design of the intake port in the cylinder head creates an air vortex whereas the design of the combustion chamber creates the air flow pattern. Figure 2.6 shows the direct injection system.

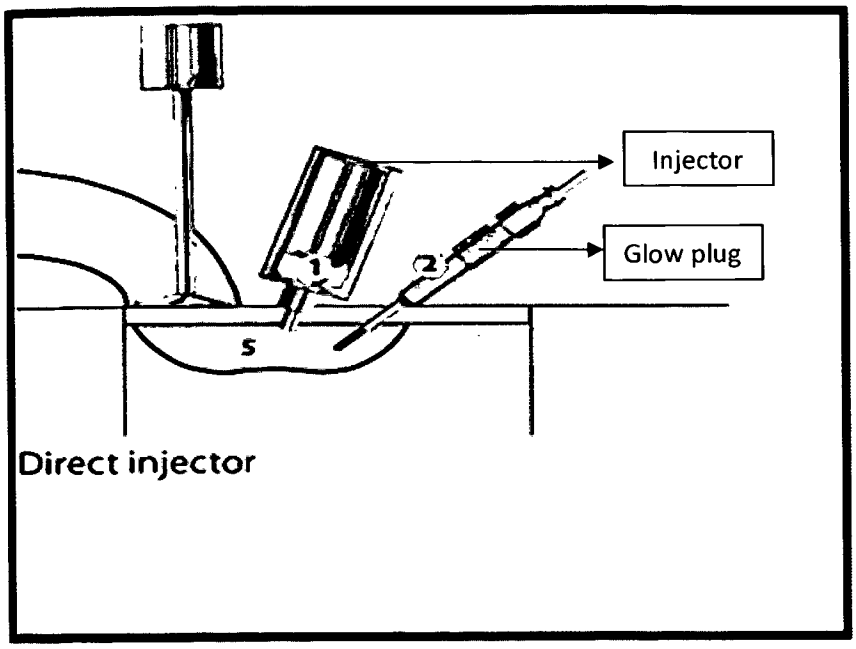


Figure 2.6: Mechanism for direct injection system

Source: NGK Spark plug. CO. LTD.

2.3.2 Pre-chamber system

For the Pre-chamber system, there are two parts of combustion chamber. One is the pre-chamber and another is the main combustion chamber. These two chambers are connected by several drilled holes. During the compression stroke, a part of the compressed air will be pressed into the pre-chamber. The fuel will be injected directly into the pre-chamber when the piston reaches to TDC position and the injected fuel combusts partially in the chamber. The high temperature caused by the combustion will increase the pressure and the content is blown through the drilled holes into the main combustion chamber where the actual combustion will happen. Figure 2.7 shows pre-chamber system.