Utilizing membrane technology to optimized diesel engine performance through oxygen-enriched air combustion

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Abstract

Internal combustion engines are designed to convert the chemical energy in the fuel into mechanical power. Fuel is burned or oxidized within an internal combustion engine, as opposed to an exterior combustion engine. The pre-combustion combination of air and fuel, as well as the post-combustion product, are working fluids. The mechanical components of the engine are directly connected to the working fluids, resulting in the engine's output. In recent years, there has been a lot of worry about the internal combustion engine causing too much pollution in the atmosphere, which is bad for human health and bad for the ecosystem. Because of this, it is necessary to consider ways to reduce emissions without compromising power or fuel efficiency. Compliance with strict environmental regulations is the primary hurdle to its long-term viability. The idea of oxygen enrichment using membrane technology attempts to obtain good performance qualities and low emissions while also increasing the amount of oxygen in the air. Oxygen enrichment allows for more fuel to be burnt. The resultant boost in power is a welcome side effect, but it isn't pursued for that reason alone. Due to its ability to shorten the ignition delay under any and all operating circumstances, oxygen enrichment of combustion air offers a way to ignite fuel with little premixing.

Keywords: *Oxygen Enrichment, Membrane Technology, Oxygen Enriched Combustion.*

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1. Introduction

The combustion process in a normal internal combustion engine requires air, which is all that's used in them nowadays. Heat energy created by combustion is lost owing to the unwanted combusting of gases in air, which is a mixture. As a consequence, the efficiency of that specific internal combustion engine is diminished. Diesel engines are more cost-effective than gasoline engines because of the cheap cost of diesel fuel. High-power and high-torque diesel engines are extensively used in a variety of industries. Diesel engines, on the other hand, have naturally greater emissions of particulate matter and nitride oxide. For diesel engines, one of the most promising combustion methods is the use of oxygen-enriched combustion (P.Baskar et al,2016). Particulate matter, carbon monoxide, oxides of nitrogen, and other hazardous substances are all released into the air by diesel engines. Fuel economy, pollution reduction, and improved engine performance may all be achieved by fine-tuning the intake air system to better suit the engine's needs (Bingyuan Han et al,2011). The incomplete combustion of diesel fuel is the source of all harmful exhaust emissions. Complete combustion of the fuel is required to prevent pollution and heat loss, and it may be achieved by providing more combustion oxygen. Manufacturers of diesel engines confront significant hurdles in obtaining adequate combustion of diesel fuel in order to enhance performance characteristics of diesel engines. Oxygen content in combustion air has been a variable that has been underutilized in the quest to increase performance and reduce exhaust emissions. Evaluation of combustion characteristics was carried out by comparing the use of oxygen enhanced air to various levels of oxygen enrichment. Adding more oxygen to the combustion process enhances stability, lowers CO and HC, and raises NOx emissions. However, the growth in NOx maintains a lower level in the first stages (K.rajkumar et al,2010). To increase diesel engine combustion characteristics, oxygen enrichment and a diesel particulate trap that does not alter the engine architecture play a significant role. To analyze combustion parameters, the use of oxygen enhanced air was compared with various levels of oxygen enrichment. The combustion process and overall engine thermodynamics will be affected by the usage of oxygen-enriched combustion air (Li Shengqin et al,2010). Oxygen Enriched Combustion (OEC) has been shown to improve the performance of diesel engines in

a number of experiments. With higher oxygen concentration and injection pressure, the engine's power production and thermal efficiency improve significantly, but NOx emissions rise proportionately (P.Baskar et al,2013). Oxygen enrichment may be accomplished in a variety of ways, including using zeolite or other additions. Many studies on diesel engine oxygen-enriched air have used a simulated oxygen enrichment by mixing the air stream with pure oxygen stored in the cylinder. However, more recent studies have used actual oxygen-enriched air. A separate oxygen cylinder was used in this study to raise the oxygen content of the intake air, and a tiny mixing chamber was installed before to the inlet manifold to facilitate this. However, supplying oxygen held in a tank is not an efficient or cost-effective solution; instead, a polysulfone hollow fiber membrane was tested on a combination of oxygen and nitrogen to determine the impact of feed pressure and feed flow rate on oxygen enrichment. (M.I.suhaina et al,2014).

2. Experimental Methods

2.1 Experimental Process Flow

For this investigation, we employ the experimental setup shown in the image. Membrane technology in the air box adds oxygen during the intake, which is detected by an O2 analyzer, to ensure proper mixing. To regulate the flow of oxygen from the membrane at a volume fraction of 21% to 27%, a flow control valve is utilized.

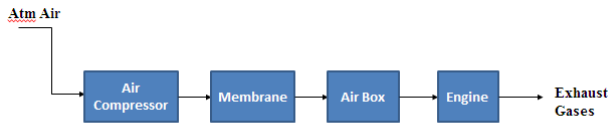

Fig 1 Process flow for experimentation

2.2 Engine Specification

It was decided to do the experiment on a vertical diesel engine with a single cylinder, four stroke, compression ignition, direction injection, and the following specifications (table 1)..

Table 1 : Engine Specification as follows

Product	Engine test setup 1 cylinder, 4 stroke, Diesel (Computerized)
Product code	224
Engine	Make Kirloskar, Model TV1, Type 1 cylinder, 4 stroke Diesel, water cooled, power 5.2 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5
Dynamometer	Type eddy current, water cooled, with loading unit
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Make-Cuadra, Model AX-409.

Between the air box and the engine's intake manifold, an Oxygen analyzer is used to monitor air quality. Saj Test Plant Pvt. Ltd. (model-AG10) eddy current dynamometer is connected to the test engine. Mass balance, theoretical constant for calorific value, a thermocouple, a TDC marker, and a rpm indicator were used to monitor the flow rate of the fuel and the temperature of exhaust gas and input air respectively. Fuel chamber pressure is measured using a data gathering system and an electric transducer from PCB Piezotronics, Inc.HSM111A22 and M108A02, a PCB Piezotronics, Inc M-Series USB powered by NI USB-6210

2.3 Experimental procedure

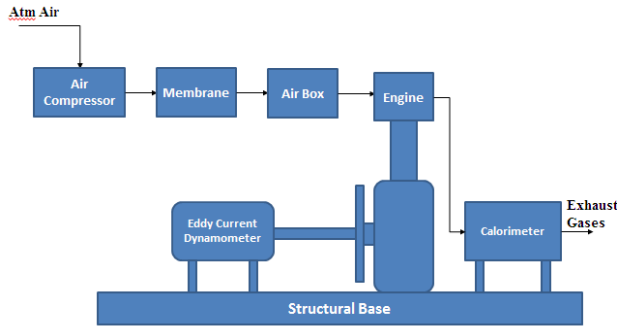

Fig 2 Experimental Setup

The aforementioned instruments are used to measure the engine parameters, such as air flow rate and fuel flow rate. The engine's performance and combustion parameters were studied in relation to oxygen concentration over the course of the tests. To put it another way: (Manish Deshmukh and colleagues 2021). At a steady 1500 RPM, the engine was subjected to a variety of loadings, ranging from no load to the rated capacity of the engine. Running the engine for around 10 minutes at 1500 rpm at 50% load until the exhaust gas temperature hit 250 °C confirmed that the operating parameters were consistent and repeatable.

Upon achieving these conditions, the test engine was brought to the appropriate test condition and then allowed to remain there for at least two minutes prior to collecting the test data. The input air had an oxygen content of 21 percent (ambient air), 23 percent, 25 percent, and 27 percent (by volume). The original fuel injection time and pressure were maintained while oxygen was added to the air intake..

Results & Discussion

The major purpose of this study is to evaluate the engine performance characteristics impacted by the application of oxygen enrichment. The performance metrics are presented at four operational performance points.

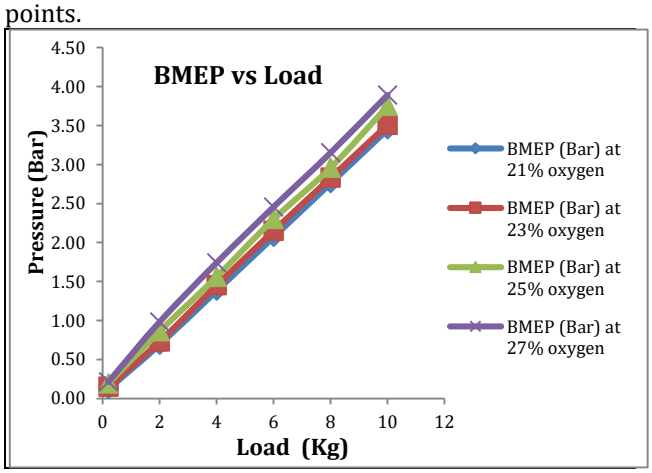

Fig 3 BMEP VS Load

Fig.3 depicts In 23 to 27 percent oxygen-enriched air compared to ambient air, a maximum increase in peak cylinder pressures of 1 to 4 percent may be attained by braking the mean effective pressure created after combustion in the cylinder. These results suggest that net engine power may be increased by a fair amount.

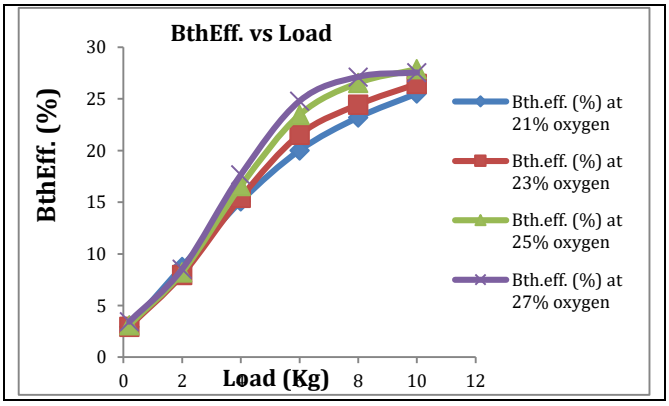

Fig 4 Bth. Eff. VS Load

As can be seen in Figure 3, the brake thermal efficiency, which can be defined as the ratio of the observed brake power to the product of the fuel flow rate and its calorific value, was computed and plotted against the various loads. The compression ratio and the thermodynamic parameters of the working mixture both have an impact on the thermal efficiency of the brakes, when seen from an idealized point of view. Although the compression ratio remained the same throughout the course of this research, the thermodynamic parameters of the mixture were significantly altered as a result of the introduction of oxygen. An rise in the concentration of oxygen results in an increase in the ratio of specific heats of the mixture, which, in effect, results in an increase in the potential to transform the thermal energy of the mixture into work energy. There is around a 4 to 8 percent improvement in brake thermal efficiency across all levels of oxygen enrichment according to the study that has been done. This rise occurs at the usual air composition, which is about 21 percent of oxygen content.

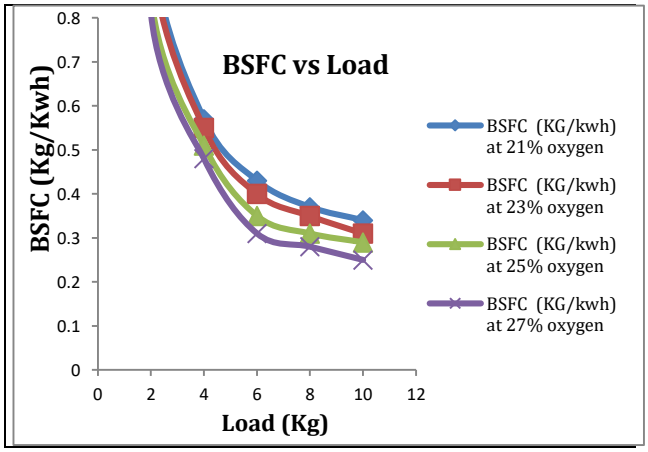

Fig 4 BSFC VS Load

The brake specific fuel consumption is the ratio of rate of fuel consumption to break power generated, an essential metric that reveals how excellent the engine Performance is. Stoichiometric air–fuel ratio drops as the oxygen content in air rises. This implies that less air is needed for full combustion of diesel fuel. When air mass flow is constant, as in these studies, the increased oxygen was utilised to burn fuel and enhances combustion. There is roughly 5 to 8 percent reduction in specific fuel usage with rise in oxygen content from 21 to 27.

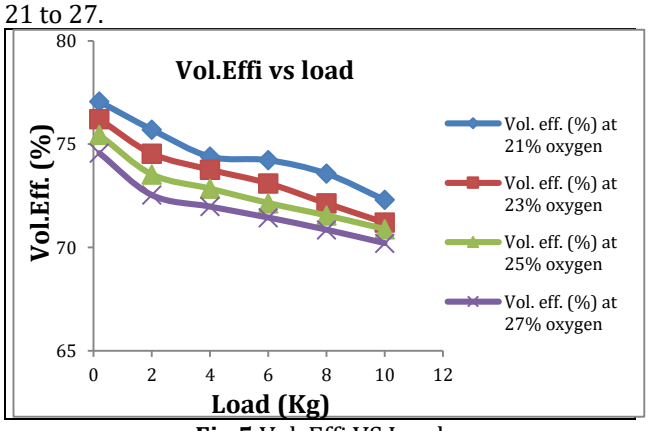

Fig 5 Vol. Effi VS Load

There is around a 4 to 6 percent loss in volumetric efficiency across all levels of oxygen enrichment, according to the findings of the experimentation. This decrease in volumetric efficiency was seen at varied oxygen contents in the air, which ranged from 21 to 27 percent.

Conclusions

The primary impact of oxygen enrichment on the performance of the engine has been characterized, and it has been seen that there is an improvement in brake thermal efficiency as well as a reduction in brake specific fuel consumption..

1. Increasing the amount of oxygen in the intake air causes a rise in cylinder pressure and a rise in peak heat output, according to study. For the varying amounts of oxygen enriched engine combustion air, the power output and combustion performance were taken into account..
2. As far as membrane technology is concerned, there are several polymer fibers available for oxygen enrichment, and experiments and simulations were conducted to assess the separation performance of for example, a polysulfone hollow fiber membrane for oxygen enrichment system..
3. It is possible to adjust percentage of Oxygen from the ambient air by employing Membrane technology, therefore it will be revolution to vehicle if it's become implemented.

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