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THE EFFECTS OF DUAL FUEL OPERATION ON EXHAUST EMISSIONS IN DIESEL ENGINES

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ABSTRACT

Generally fossil based fuels are used in internal combustion engines as an energy source. Excessive use of fossil based fuels diminishes present reserves and increases the air pollution in urban areas. This enhances the importance of the effective use of present reserves and/or to develop new alternative fuels, which are environment friendly. Use of alternative fuel is a way of emission control. In this study, reduction of exhaust emissions from diesel engines were investigated. For this purpose a single cylinder, direct injection diesel engine was modified to operate with dual fuel operation (30% LPG and 70% diesel fuel by weight). During the experiments engine speed was kept constant (1650 rpm) and load was changed. It was obtained that; NO_x and smoke emissions were reduced with dual fuel operation in the experiments.

Key Words: Diesel engine; Dual fuel engine; Liquefied petroleum gas (LPG), Exhaust emissions; Alternative fuel

DİZEL MOTORLARINDA ÇİFT YAKITLA ÇALIŞMANIN EGZOZ EMİSYONLARINA ETKİLERİ

ÖZET

İçten yanmalı motorlarda enerji kaynağı olarak genellikle fosil kökenli yakıtlar kullanılmaktadır. Fosil kökenli yakıtların mevcut rezervlerinin azalması ve şehirlerdeki hava kirliliğinin hızla artması, mevcut rezervlerinin azalması ve şehirlerdeki hava kirliliğinin hızla artması; mevcut rezervlerin verimli bir şekilde kullanılması ve/veya çevre dostu yeni alternatif yakıtların geliştirilmesinin önemini artırmaktadır. Alternatif yakıt kullanımı emisyon kontrolünde kullanılan yöntemlerden biridir. Bu çalışmada, çift yakıtla (Ağırlık olarak %30 LPG ve %70 dizel yakıtı) çalışmanın tek silindirli, direkt püskürtmeli bir dizel motorunda egzoz emisyonlarına etkileri araştırılmıştır. Deneyler sırasında motor hızı (1650 d/d) sabit tutulmuştur. Deney sonuçları çift yakıtlı çalışmada NO_x ve duman emisyonlarının azaldığını göstermiştir.

Anahtar Kelimeler: Dizel motoru; Çift yakıtlı motor; Sıvılaştırılmış petrol gazı (LPG); Egzoz emisyonları; Alternatif yakıt

1. INTRODUCTION

Nowadays, excessive use of fossil fuels in internal combustion engines, diminish the present reserves and increase air pollution in urban areas. Motor vehicles are a major source of urban air pollution. The U. S. Environmental Protection Agency (EPA) estimated that transportation sources were responsible for 63% of the CO, 38% of the NO_x, and 34% or higher of the HC's (national contribution of transportation emissions in the U.S.). In Europe, road transportation is blamed for roughly 50~70% of the NO_x, and around 50% of volatile organic compounds [1].

Diesel engine exhaust emissions have the potential to cause a range of health problems and they have considerable effect on the environment. Particulates absorb sunlight causing a decrease in visibility. Particle and gaseous components of diesel engine emissions contain many mutagens, carcinogens and toxic substances. So lung cancer has been spotlighted as a health risk in animal and human research [2]. Sulphur dioxide (SO_2) emissions are the other important diesel emission. They can generate hydrogen sulphide (H_2SO_3) or sulphuric acid (H_2SO_4) in humid places, and these can cause acid rain.

Engineers have proposed various solutions to reduce pollutant emissions from diesel engines. These engines, which use conventional diesel fuel and gaseous fuel, are referred to as dual fuel engines. The main aspiration from the usage of dual fuel combustion systems is mainly to reduce particulate emissions and nitrogen oxides [3]. Gaseous fuel is usually inducted with the intake air through the inlet manifold in dual fuel engines. They are mixed and compressed as in a conventional diesel engine. An amount of liquid fuel is injected near the end of the compression stroke, which initiates the combustion of the gas–air mixture. Diesel fuel auto-ignites and creates ignition sources for the surrounding gaseous fuel mixture [3-5]. LPG, as an alternative to diesel, is particularly attractive for motor vehicle use because it is stored in a liquid state and used in a gaseous form making it possible to obtain a high energy storage density along with clean and silent combustion [6].

Park [7] found that dual fuel engine conversions cost less than $1000 per ton of NO_x eliminated, which is less than the cost of some existing measures such as exotic alternative compression ignition fuels and catalyst exhaust after-treatment.

The use of exhaust gas recirculation (EGR) in a dual fuel engine is a promising method for improving part load operation and reducing the exhaust emissions of NO_x. However, when EGR is used, it may change the rate of combustion or the rate of pressure rise inside the combustion chamber, which is related to another dangerous pollutant, e.g. combustion noise and wear of piston rings due to relatively higher concentrations of SO_2 [8,9].

Ciniviz et al. [10] reported that in dual fuel operation NO_x and smoke emissions decreased 5%, 80% respectively. Also Barut [11] found that in dual fuel operation particulate emission decreased 60%.
According to the Papagiannakis et al. [3] under dual fuel operation using natural gas the level of NO concentration and soot emissions is lower compared to the one under normal diesel fuel operation.

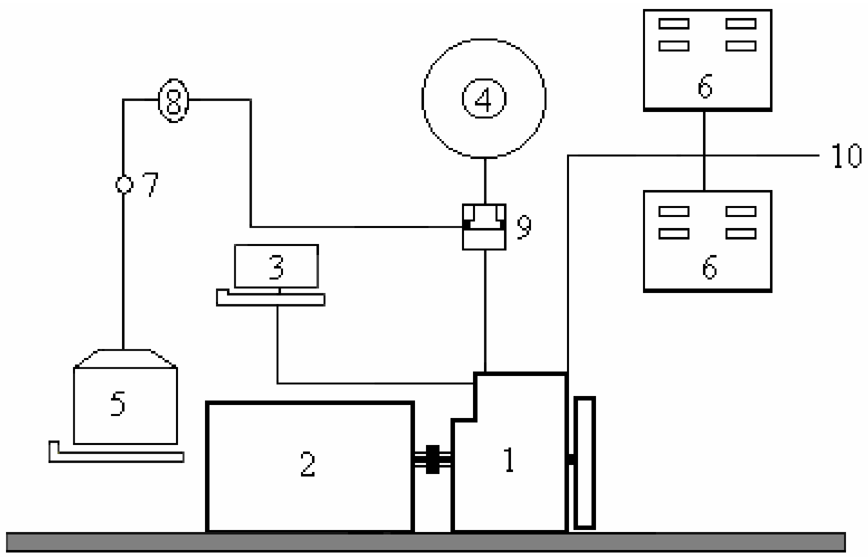
The present study is concerned with the reduction of diesel engine exhaust emissions. For this purpose, a single cylinder, direct injection diesel engine was modified to operate with dual fuel. During the experimental study the engine was run with 30% LPG and 70% diesel fuel (by weight) and changes in exhaust emission were observed.

2. TEST EQUIPMENTS AND METHODS

Experiments were performed in a single cylinder diesel engine. The specifications of the engine are shown in Table 1. The schematic view of the test equipments is shown in Fig. 1.

Table 1. Technical Specifications Of The Engine

Engine type	Direct injection, diesel
Cycle	Four stroke
Cylinder number	1
Injection pressure (bar)	175
Max. engine power	8 kW at 1800 rpm
Compression ratio	17:1
Stroke (mm)	100
Bore (mm)	98



1. Engine, 2. Dynamometer, 3. Diesel fuel tank and measurement system,
4. Air flow meter, 5. LPG tank and measurement system, 6. Exhaust gas analyser,
7. Pressure control valve, 8. Evaporator, 9. LPG mixer, 10. Exhaust outlet

Fig. 1. Schematic View Of The Test Equipments

Diesel fuel (46 cetane number) and LPG (50% butane and 50% propane) were used as engine fuel. A Leclasrege Electriou brand electrical type dynamometer was used for tests. Smoke emission was measured by a VLT 2600 S apocimeter and NO_x were measured by a Gaco SN type emission device. A mixer was used to admit the LPG into the cylinder. The cross-sectional drawing of the mixer is shown in Fig. 2. During the engine tests the average ambient temperature and atmospheric pressure were 22 ^oC and 752 mm-Hg, respectively. The tests were started after reaching the operating temperature (80^{o}C) of the engine.

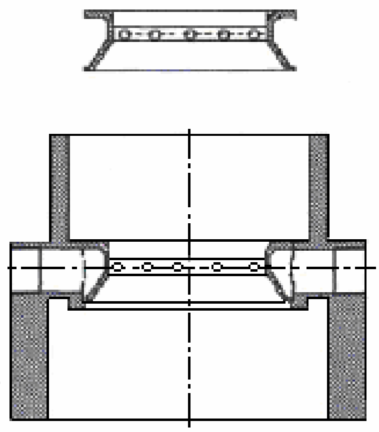


Fig. 2. The Cross-Sectional Drawing Of The Mixer

The engine was tested with two different fuels. Firstly, the engine was operated with diesel fuel only to determine the engine emission characteristics. The test engine was operated with dual fuel (30% LPG - 70% diesel fuel by weight) to determine the effects of dual fuel operation on emissions. During the tests, engine speed was kept constant at 1650 rpm. The fuel injection pump regulator was not employed during the tests.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The engine test results are shown in Fig. 3-6. The variation of the excess air ratio with engine load for both diesel fuel and dual fuel operation is shown in Fig. 3. Except for partial loads, the excess air ratio decreases approximately 10% for dual fuel operation.

Changes in NO_x emission according to the effective torque is shown in Fig. 4. At partial loads NO_x emission is almost the same for both diesel fuel and dual fuel operation. But at high engine loads NO_x emissions are approximately 25% lower than diesel fuel operation in dual fuel operation. In dual fuel operation with LPG was admitted to the cylinder in the gaseous phase, volumetric efficiency deteriorated, so less air was induced to the cylinder.

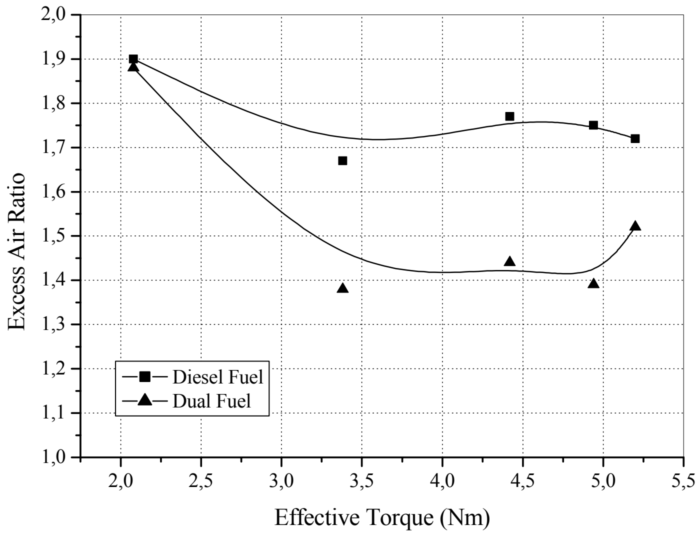


Fig. 3. Variations Of Excess Air Ratio With Effective Torque

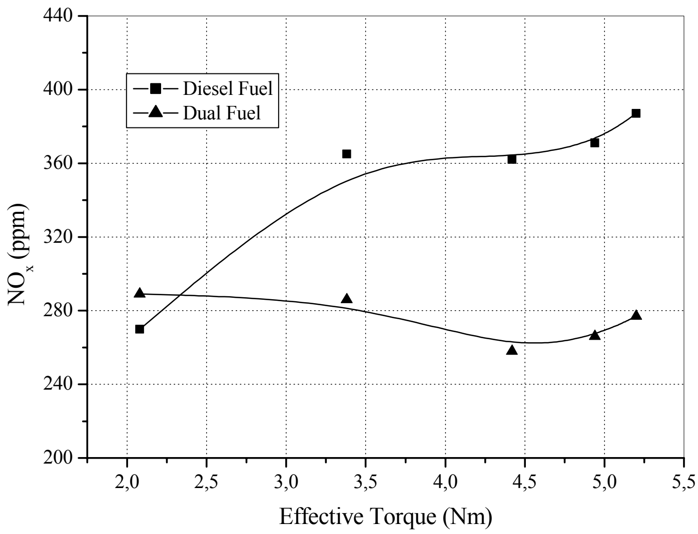


Fig. 4. Variations Of No_x Concentration With Effective Torque

Fig. 5 shows the smoke emission versus effective torque. For all engine loads smoke emission decreased drastically (approximately 40%) in dual fuel operation. In dual fuel operation presence of the premixed gas-air mixture gets a more homogenous charge than in diesel fuel operation. Also due to the amount of diesel fuel which is injected into the cylinder decreased 30% in dual fuel operation, less diesel fuel will be injected so smoke emission will be decreased.

Fig. 6 shows the variation of specific fuel consumption (SFC) with effective torque. At partial and high engine loads SFC decreased drastically (approximately 30%) in dual fuel operation.

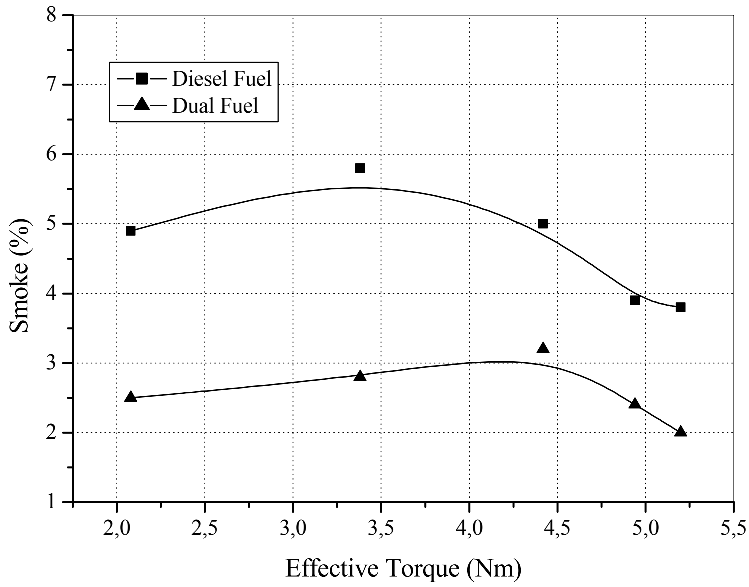


Fig. 5. Variations Of Smoke Emissions With Effective Torque

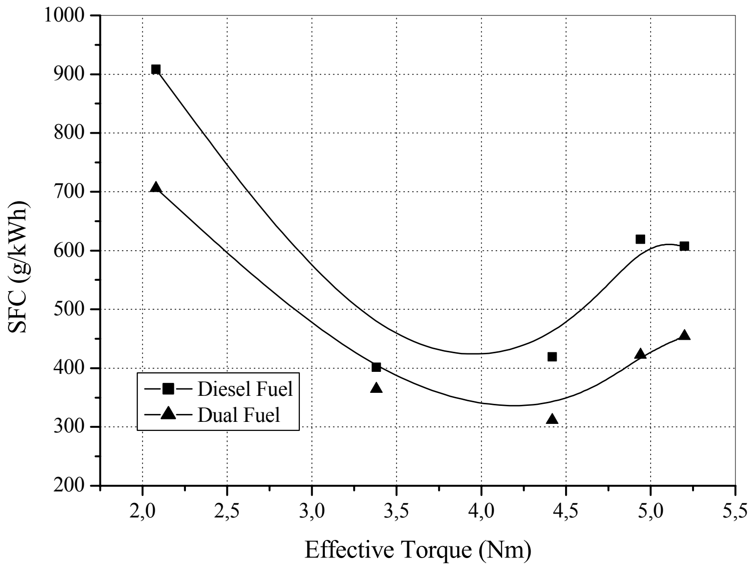


Fig. 6. Variations Of SFC With Effective Torque

4. CONCLUSIONS AND RECOMMENDATIONS

The experimental results showed that exhaust emissions (NO_x and smoke) were improved in dual fuel operation. This indicates that fuel property is one of the most important parameters, which affects the exhaust emissions. Diesel powered forklifts which work in warehouses can be converted to operate with dual fuel. So the air quality in the workplace will be better. LPG can be injected to the intake manifold to obtain the precise control of the amount of fuel, admitting to the cylinder. Also, by increasing the LPG proportion in dual fuel operation a further improve in exhaust emissions can be obtained. Dual fuel systems can be used in vehicles, and in public and cargo transportation. Thus motor vehicle sourced air pollution would decrease.

REFERENCES

1. Çakıroğlu, M., 1996, Motorlu Taşıt Trafiğinde Egzoz Emisyonlari, 1**. Ulusal Ulaşım Sempozyumu,** Istanbul, 565-573.
2. Kagawa, J., 2002, Health Effects of Diesel Exhaust Emissions- A Mixture of Air Pollutants of World Wide Concern, **Toxicology**, Volume: 181, pp. 349-352.
3. Papagiannakis, R. G. and Hountalas, D. T., 2002, Experimental Investigation Concerning the Effect of Natural Gas Percentage on Performance and Emissions of a DI Dual Fuel Diesel Engine, **Applied Thermal Engineering**, Volume: 23, pp. 354-364.
4. Hountalas, D. T., Papagiannakis, R. G., 2000, Development of Simulation Model for Direct Injection Dual Fuel Diesel-Natural Gas Engines**, SAE Paper**, 2000-01-0286.
5. Karim, G. A., 1980, A Review of Combustion Processes in the Dual Fuel Engine-The Gas Diesel Engine, **Progress in Energy Combustion Science**, Volume: 6, Issue: 3, pp. 278-280.
6. Sudhir, C. V., Suresh, K. Y., Desa, V. and Mohanan, P., 2003, Studies on Influence of Injection Timing and Diesel Replacement on LPG-Diesel Dual-Fuel Engine, **Technical Conference of the ASME Internal Combustion Engine Division Erie**, September 7-10, 2003, Pennsylvania, USA, pp. 161.
7. Park, T., 1999, Dual Fuel Conversion of a Direct Injection Diesel Engine, MSc. Thesis, Department of Mechanical and Aerospace Engineering, **Virginia University**, Morgantown, West Virginia.
8. Selim, M. Y. E., 2002, Effect of Exhaust Gas Recirculation on Some Combustion Characteristics of Dual Fuel Engine, **Energy Conversion and Management**, Volume: 44, Issue: 5, pp. 708-714.
9. Abd-Alla, G. H., 2001, Using Exhaust Gas Recirculation in Internal Combustion Engines: A Review, **Energy Conversion and Management**, Volume: 43, Issue: 8, pp. 1028-1035.
10. Ciniviz, M., Salman, M. S. and Çarman, K., 2001, Dizel Motorlarında Dizel Yakıtı + LPG Kullanımının Performans ve Emisyona Etkisi, **Selçuk-Teknik Online Dergisi**, ISSN 1302- 6178, Volume 2, Number 1, pp. 1-3.
11. Barut, E., 1997, Design and Implementation of a Distributive Gas Fuel Metering System for the Dual Fuel Operation of a Diesel Engine, MSc. Thesis, **Middle East Technical University**, pp. 114, 122.