

Research Article

Combustion and Emission Investigation of Diesel Fuel and Kerosene Blends

Bilal A. Akash

American University of Ras Al Khaimah, United Arab Emirates

Abstract: This study presents experimental investigation of combustion of diesel fuel, kerosene and their blends. The objective of this study is to determine the combustion performance and gas emission of diesel fuel, kerosene and various mixtures of diesel fuel and kerosene in a horizontally positioned cylindrical furnace. Heat was removed from the system by the use of water around a jacket of the combustion unit. The combustion unit is capable of burning most types of liquid and gaseous hydrocarbon fuels. Results on combustion performance and gas emissions are presented for a wide range of air-fuel equivalence ratios. The results of exhaust gas analyses of carbon monoxide, carbon dioxide and oxygen are presented. Combustion efficiency and the effect of blending of fuels on its performance are also presented. In general, some improvements in exhaust gas emission and combustion efficiency were obtained upon using mixtures of fuels. The best results were obtained when a fuel blend of 75% kerosene and 25% diesel was prepared and burned in the unit.

Keywords: Combustion, diesel fuel, fuel blends, kerosene

INTRODUCTION

Combustion of fuel blends can improve the combustion process itself and in other instances it may allow for combustion of some available fuels that cannot be burned separately (Asfar and Hamed, 1998; Shyam *et al.*, 1987; Cookson *et al.*, 1987; Chicurel, 1993). Blending of fuels is not restricted on combustion. Other studies are reported for pyrolysis and liquefaction of fuel blends, which showed remarkable improvements (Kim *et al.*, 1999; Akash *et al.*, 1994, 1992).

De Souza *et al.* (2009) have conducted a study on biodiesel (ethyl ester from waste vegetable oil) in a water-cooled tube furnace comparing it to diesel. It was found that biodiesel burns much better than diesel fuel with higher heat transfer in most part of the furnace tube. It was concluded that some fuels can have higher heat transfer rates than diesel, which results in higher furnace performance. In another study Saario *et al.* (2005) have studied combustion behavior of heavy fuel oil in a cylindrical furnace. It was reported that how turbulence plays important in achieving good combustion results. Galan *et al.* (2009) studied the reaction kinetics of triacetin without adding any catalyst. The results were promising to find a solution to generated by-products of glycerine from biodiesel industry. Abu-Qudais (2002) reported the effect of heat transfer and emissions on the combustion of shale oil in a water-cooled furnace. Such combustion unit has the capability of allowing other types of non-petroleum fuels to be investigated such as shale oil, vegetable oil etc. (Akash, 2012; Akash and Jaber, 2003; Schwab

et al., 1987; Dagaut and Cathonnet, 2006; Akash and Mohsen, 1999; Akash, 2006). It was found that heat transfer was improved when shale oil was used as compared to diesel fuel (Akash, 2012). Also, there was some improvement with the exhaust emissions. Any improvement in combustion efficiency means financial savings for the national economy. In literature, there is a lack of information about combustion characteristics and gas emissions on many fuel blends. Therefore, the main objective of this study is to investigate the effect of combustion characteristics and emission of diesel, kerosene and various diesel-kerosene blends in a horizontally positioned cylindrical furnace. Combustion efficiency and the effect of blending of fuels on its performance will also be considered. In general, the study will determine whether there is any improvements in exhaust gas emission and combustion efficiency would be obtained by using blends of two fuels. The findings of this study will help researchers and industry benefit from its results in the various applications of furnaces and combustion chambers.

MATERIALS AND METHODS

Diesel fuel and kerosene: Many developing countries around the world produce one grade of diesel fuel (gas oil) for use. It is used in compression ignition internal combustion engines. The same fuel is used as a heating fuel oil in residential heating and industrial furnaces. As an example kerosene is used in domestic application for cooking and space heating (Akash and Mohsen, 1999). The diesel fuel and kerosene samples used in this study were commercially available in the local market.

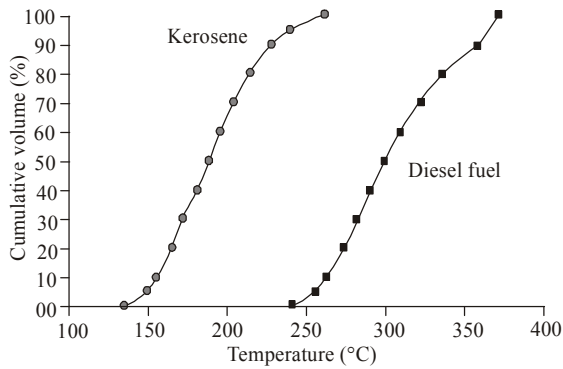


Fig. 1: Boiling range distribution curves of kerosene and diesel fuels used in this study

Figure 1 shows comparison of boiling range distributions of kerosene and diesel fuels used in this study.

Experimental apparatus: The main apparatus of the reported experimental work is the combustion unit. A schematic diagram of the unit is shown in Fig. 2. It consists of a horizontally positioned cylindrical furnace that is capable of burning most types of liquid and gaseous hydrocarbon fuels. The combustion unit

demonstrates the handling and combustion of typical furnace equipment operated at atmospheric pressure. A combination liquid gas burner fires into a stainless steel water-cooled chamber provided with observation windows. Heat was removed from the system by the use of a water jacket around the combustion unit. The combustion unit is made of steel horizontal combustion chamber which is 90 cm in length and 45 cm inner diameter. The unit is cooled by a water jacket of stainless steel that surrounds it with a diameter of 55 cm. The inlet of the combustor is equipped with a refractory wall in the form of a diffuser of 19° conical angle and 30 cm length. The refractory wall was well insulated with glass wool. Pressure atomizing injector of the spill type at the inlet section of the diffuser was used as fuel atomizer. The air supply system consists of an air blower, an air intake duct and an orifice meter. More details are provided elsewhere (Akash, 2006).

A total of 6 observation windows were positioned to show the burning flame. Two small windows were placed on each side with a diameter of 5 cm each, while front and rear ends were provided with larger diameters of 14.5 cm, as shown in photographs of Fig. 3 through 5.

Various mixtures of diesel fuel and kerosene were made. Figure 3 shows photographs of front and rear

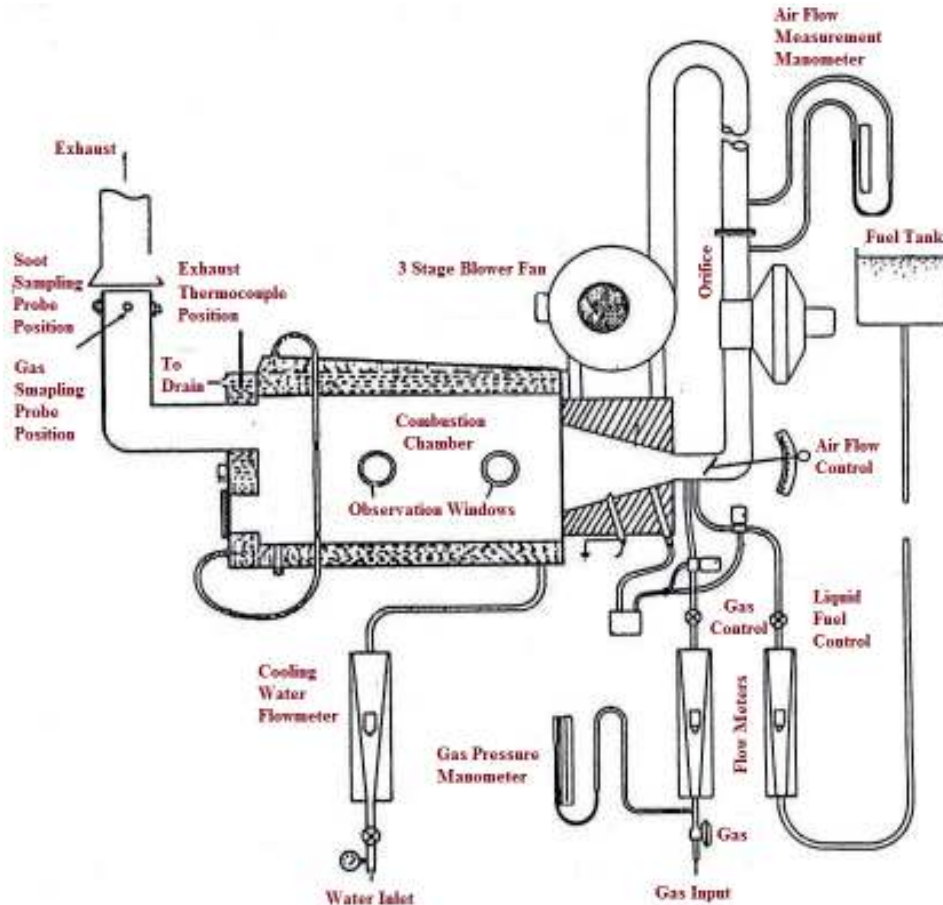


Fig. 2: Schematic diagram of the experimental setup



Fig. 3: Front and rear views of the combustion unit

views of the combustion unit with major manual controls and components of the unit with observation window showing burning flame. Gas analysis was achieved by using a paramagnetic oxygen analyzer (0-25% range), infrared carbon monoxide (0-0.1 and 0-1% range) and carbon dioxide (0-15% range) analyzer.

RESULTS AND DISCUSSION

The amount of the steady-state heat transfer rate to the water jacket can be calculated from the following equation:

$$q = m_w C_p (T_{wo} - T_{wi}) \quad (1)$$

The thermal efficiency is expressed as the amount of heat transfer rate to water jacket to the amount of heat generated in the furnace due to combustion of fuel as give in Eq. (2):

$$\eta = \frac{q}{m_f \text{LHV}} \quad (2)$$

Figure 4 shows the variation of thermal efficiency with mass air-fuel equivalence ratio. As shown by the figure all fuels have about the same trend in having maximum efficiency values around the stoichiometric limit. Also, the figure shows that high combustion

efficiency is obtained when a blend of 75% kerosene with 25% diesel is burned. This finding is consistent with those obtained by Asfar and Hamed (1998) and De Souza *et al.* (2009). Thermal efficiency values as high as 68% were obtained from burning such mixture due to the high volatility of the fuel. On the other hand the worst case was when a mixture of 25% kerosene with 75% diesel was used. The results are also in agreement with Saario *et al.* (2005) who have studied combustion behavior of heavy fuel oil in a cylindrical furnace.

Exhaust gas emissions versus equivalence ratio are presented in Fig. 5. The figure shows the concentrations of the major gases that were produced during the combustion process; they are carbon dioxide, carbon monoxide and oxygen. It is interesting to see that combustion of fuels can be obtained at various equivalence ratios, but in few cases such as combustion of diesel alone, it was easier for the fuel to be burned as lean mixture with air. The reason it was due to production of soot in exhaust gases when diesel was burned at high equivalence ratio. On the other hand kerosene preferred to be burned at stoichiometric limit and near the rich mixture limit and that was due to the nature of volatility of the fuel. This is also consistent with previous studies (Saario *et al.*, 2005; Asfar and Hamed, 1998; De Souza *et al.*, 2009; Abu-Qudais, 2002).

However when kerosene was mixed with diesel especially with 75% kerosene and 25% diesel blend we were capable of combusting the fuel blend in the entire range of equivalence ratio. Also, gas emission is not affected by type of fuel for the entire range of equivalence ratio and that is due the fact that C/H ratio for kerosene and diesel is almost constant. Therefore, the chemical reaction mechanisms cause the production of exhaust gases to be similar for all fuel blends at a given equivalence ratio.

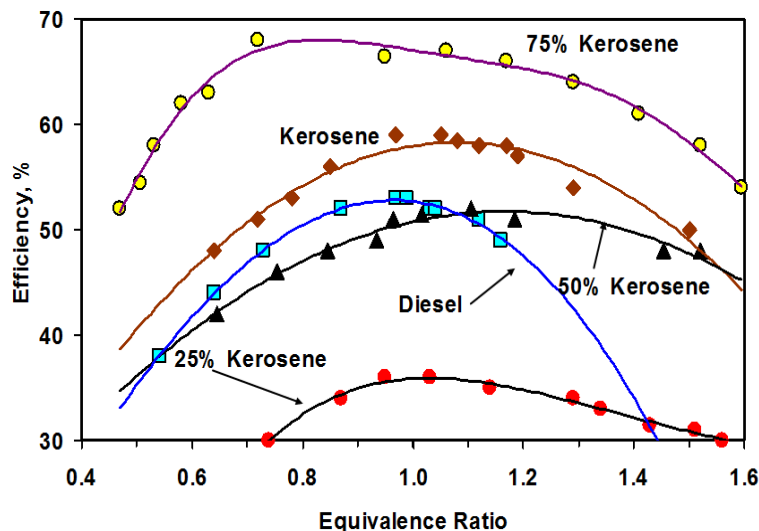


Fig. 4: Thermal efficiency vs. equivalence AF ratio

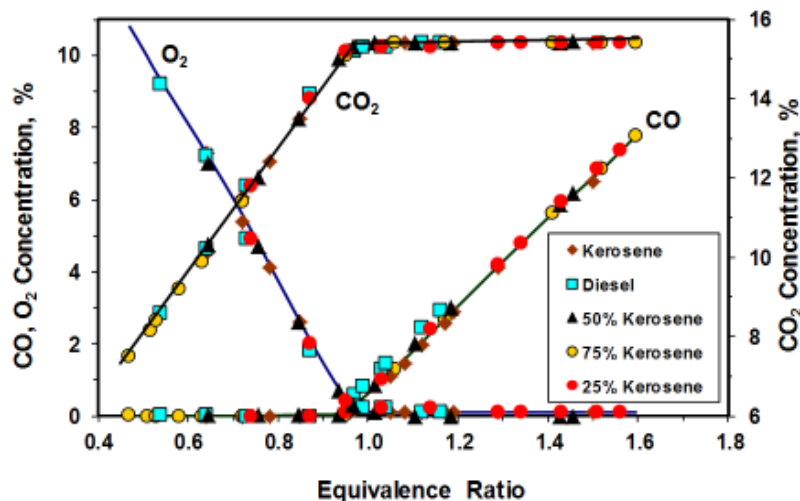


Fig. 5: Carbon monoxide, carbon dioxide and oxygen concentrations vs. equivalence ratio

CONCLUSION

It was shown experimentally, that blending two fuels together prior to combustion can improve the combustion process by improving the combustion efficiency. Test results showed that addition of 25% of diesel to kerosene resulted in a remarkable improvement in the combustion process allowing better combustion efficiency than burning of diesel or kerosene separately. This is due to the volatility of kerosene which generates heat early causing complete combustion of diesel, especially at lean mixtures of fuel. The main advantage of such improvement may allow us to save in fuel consumption.

Further studies are needed in order to blend more than two fuels. Especially, addition of alcohols should be considered. Also, non-petroleum products can be blended with petroleum products such as blending used oils, liquefied coal, or biofuels with diesel and kerosene.

NOMENCLATURE

C_p : Constant-pressure specific heat kJ/kg-K
 LHV : Lower heating value of fuel kJ/kg
 m_f : Fuel mass flow rate kg/sec
 m_w : Cooling water mass flow rate kg/sec
 Q : Heat transfer rate kW
 T_{wi} : Inlet water temperature °C
 T_{wo} : Exit water temperature °C
 η : Thermal efficiency

REFERENCES

Abu-Qudais, M., 2002. Performance and emissions characteristics of a cylindrical water-cooled furnace using non-petroleum fuel. *Energ. Convers. Manage.*, 43: 683-691.

Akash, B., 2006. Combustion of diesel and kerosene in water jacketed horizontal cylinder combustion unit. *Proceeding of the 2nd International Conference on Thermal Engineering Theory and Applications*. Al-Ain, United Arab Emirates.

Akash, B., 2012. Thermochemical liquefaction of coal. *Int. J. Therm. Environ. Eng.*, 5: 51-60.

Akash, B. and J. Jaber, 2003. Characterization of shale oil as compared to crude oil and some refined petroleum products. *Energ. Source.*, 25: 1171-1182.

Akash, B. and M. Mohsen, 1999. Energy analysis of Jordan's urban residential sector. *Energy*, 24: 823-831.

Akash, B.A., C.B. Muchmore and S.B. Lalvani, 1994. Coliquefaction of coal and newsprint-derived lignin. *Fuel Process. Technol.*, 37: 203-210.

Akash, B., C. Muchmore, J. Koropchak, J. Kim and S. Lalvani, 1992. Investigations of simultaneous coal and lignin liquefaction: Kinetic studies. *Energ. Fuel.*, 6: 629-634.

Asfar, K. and H. Hamed, 1998. Combustion of fuel blends. *Energ. Convers. Manage.*, 39: 1081-1093.

Chicurel, R., 1993. Dual-fuel system to improve variable octane mixture to an engine. *Energy*, 18: 611-614.

Cookson, D., B. Smith and I. Shaw, 1987. Determination of hydrocarbon compound class abundances in kerosene and diesel fuels: Chromatographic and nuclear magnetic resonance methods. *Fuel*, 66: 758-765.

Dagaut, P. and M. Cathonnet, 2006. The ignition, oxidation and combustion of kerosene: A review of experimental and kinetic modeling. *Prog. Energ. Combust.*, 32: 48-92.

- De Souza, G.R., A.M. dos Santos, S.L. Ferreira, K.C. Ribeiro Martins and D.L. Módolo, 2009. Evaluation of the performance of biodiesel from waste vegetable oil in a flame tube furnace. *Appl. Therm. Eng.*, 29: 2562-2566.
- Galan, M., J. Bonet, R. Sire, J. Reneaume and A.E. Pleşu, 2009. From residual to useful oil: Revalorization of glycerine from the biodiesel synthesis. *Bioresource Technol.*, 100: 3775-3778.
- Kim, J., S. Lalvani, C. Muchmore and B. Akash, 1999. Coliquefaction of coal and black liquor to environmentally acceptable liquid fuels. *Energ. Source.*, 21: 839-847.
- Saario, A., A. Rebola, P.J. Coelho, M. Costa and A. Oksanen, 2005. Heavy fuel oil combustion in a cylindrical laboratory furnace: Measurements and modeling. *Fuel*, 84: 359-369.
- Schwab, A.W., M.O. Bagby and B. Freedman, 1987. Preparation and properties of diesel fuels from vegetable oils. *Fuel*, 66: 1372-1378.
- Shyam, M., S.R. Verma and B.S. Pathnak, 1987. Physio-chemical properties of plant oils and blends in diesel and kerosene oils. *Energy*, 12: 589-598.