Experimental Study of Injecting Water Vapor and Oil Compounds by Nebulizer on the Efficiency and Natural Gas Flame Pollution

Amin Jodat[1*], Mojtaba Najafian[2], Abolfazl Mohammadi[3]

[1] Mechanical Engineering Department, University of Bojnord, Bojnord 945 3155111, Iran.
[2] Mechanical Engineering, Applied Science University of North Khorasan, Bojnord, Iran.
[3] Chemical Engineering Department, University of Bojnord, Bojnord 945 3155111, Iran.

Abstract

In this study, by using nebulizer technology commonly used for the delivery of aerosolized drugs in pulmonary patients, the effect of injecting oil compounds and water vapor by nebulizer on the thermal efficiency and production of pollutants in gas emissions of natural gas diffusion flame is studied. The Nebulizer device creates micron incisions of injected liquid and, due to the reduced injection particle diameter, existing highly turbulent outflow and proper mixing of oil and water vapor compounds with gas and air inlet to the burner, effectiveness of the injection increases to enhance efficiency and reduce pollutants. In the experimental setup, the injection of 1 wt.% of oil compounds into the natural gas flame by a nebulizer improves thermal efficiency by 2.5%, decreases the temperature of the exhaust gases from the chimney by 12%, and also NO_x pollutants by 13%, and increases carbon monoxide pollutant by 6%. Also, the injection of 2 wt.% of water drops as well as 1 wt.% of oil compounds will increase thermal efficiency by more than 1%, reduce the temperature of chimney exhaust gases by 6 %, reduce pollutants by more than 42 % and carbon monoxide pollutant by 26%.

KEYWORDS

Experimental system, Natural gas flame, nebulizer, Thermal and radiation efficiency, pollutants.

[*] Corresponding Author: Email: Amin.Jodat@Yahoo.com

1. Introduction

An important characteristic of solid and liquid fossil fuel flames is the luminosity of the flame and high heat transfer rate compared to the blue flame of natural gas. Using natural gas rather liquid and solid fuels has reduced thermal efficiency and this has caused many problems for industrial producers. Researchers are looking for ways to improve the radiant heat transfer of a natural gas flame. Researchers have investigated different methods of the luminosity of natural gas fuel flame through gas fuel and coal combination, improvement of radiative heat transfer from fuel flame through carbon dioxide dilution, effect of injection of metal oxide particles on radiative thermal transfer, and gas-gasoline co-firing effect on luminosity and radiant heat transfer [1-4]. Using ultrasonic waves in the production of droplets with small particle diameters applied in combustion chambers has also been investigated by researchers [5]. Past studies show that although flame heat transfers and its improvement strategies are considered as one of the most important methods for increasing thermal efficiency today, no operational and cost-effective method has been proposed for improving flame radiation properties. In the present work, to achieve the applicable method in the industry, liquid fuel is injected in micron dimensions using a nebulizer to increase the efficiency and reduce pollutants.

2. Experimental setup and measurements

The experimental setup consists of a gas burner with the capacity of up to 100,000 kcal/h installed on a cast iron boiler. A nebulizer is used to inject oil compounds into the burner. Dimensions of nebulizer device made are $55cm \times 25cm \times 30cm$, the underside of which has two fully independent tanks and 10 adjustable ultrasonic piezoelectric tubes. The fluid existing in the tanks is diffused by ultrasonic waves as micron cuts and separated from the fluid surface. The flame thermal efficiency is measured by measuring the flow rate and the temperature difference of the inlet and outlet water to the boiler. A heat exchanger is used to keep the water temperature inlet to the boiler constant. The S-type thermocouple is used to measure the temperature with the accuracy of $\pm 2.5^{\circ} C$. The concentration of different gases in the chimney exhaust is measured using the TESTO350 model gas combustion analyzer. An analog flow meter with the precision of liters per minute is used to measure the flow rate of the heat exchanger. To perform the test, first in the non-nebulizer injection mode, the gas burner is installed on the cast iron boiler and, after reaching the boiler in the steady state, the test data are measured and recorded; then, the burner is switched off and after the system reaches its initial state, the above steps are repeated for different values of nebulizer injection. Also, to ensure the accuracy of the results obtained, the experiments are repeated twice and the developed uncertainty of the measurement of each parameter is calculated at 90% confidence level.

3. Results and Discussion

In Figure 1, the effect of the injection by nebulizer on the chimney outlet temperature is shown.

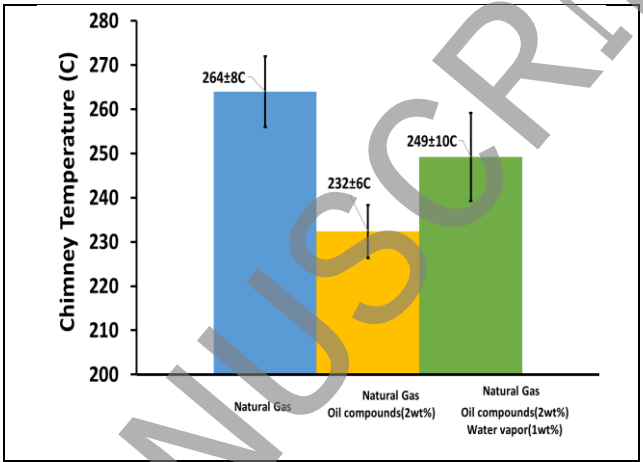

Fig. 1. Effect of nebulizer injection of various compounds on the chimney outlet temperature

Figure 2 shows the effect of nebulizer injections of various compounds on thermal efficiency. As demonstrated, the injection of oil compounds and oil compounds - water vapor will have a positive effect on increasing thermal efficiency.

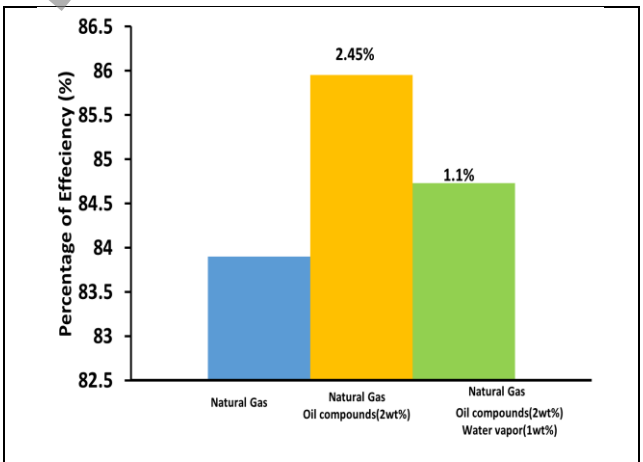

Fig. 2. Effect of nebulizer injection of various compounds on thermal efficiency

Figure 3 compares the color of the flame in the non-injection mode with the injection mode of the oil compounds. The change in flame color from blue to yellow indicates that the soot particles concentration has increased in the core of the flame by injecting oil compounds into the flame.

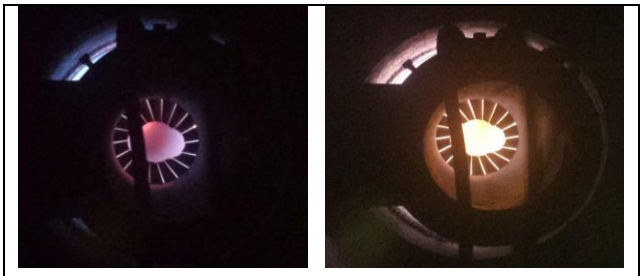

Fig. 3.Flame picture of before injection (left) and after injection (right)

Figure 4 shows the effect of the injection of various compounds by the nebulizer on NO_x emissions. It is found that, in general, the injection of oil compounds by the nebulizer device, will reduce NO_x emissions.

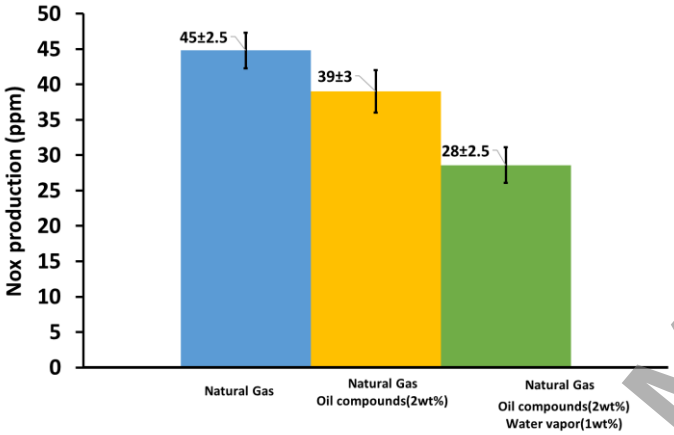

Fig. 4. Effect of nebulizer injection of various compounds on NOx emissions

Figure 5 shows the effect of injection of various compounds on *CO* emissions. It can be seen that injection of oil compounds will increase the carbon monoxide, the concentration in combustion products reaches 49 ppm, which is less than the standard carbon monoxide concentration for gas burners.

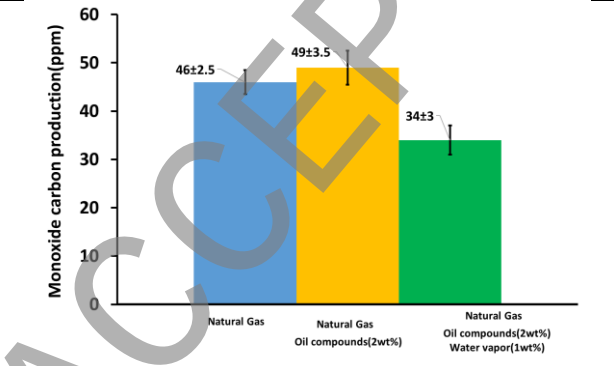

Fig. 5. Effect of nebulizer injection of various compounds on CO emissions

4. Conclusions

In The methods presented in many articles for increasing the luminosity and enhancing the radiant efficiency of natural gas flames have not been applicable in industries due to various problems such as implementation costs, hazards in some of these methods, increased pollutants, etc. The laboratory results of the present study showed that using nebulizer technology not only could increase the thermal and radiation efficiency of natural gas flames, but also significantly reduced the concentration of pollutants in combustion products due to the decrease in particle diameter, existing highly turbulent outflow, and proper mixing of hydrocarbon compounds with gas and inlet air into the burner. The laboratory results of this study showed that the method of injection of particles by nebulizer can be used as a practical method to increase the radiation efficiency of natural gas flame and reduce the chimney exhaust pollutants.

5. References

[1] S.W. Baek, J. Ju Kim, H.S. Kim, S.H. Kang, Effects of addition of solid particles on thermal characteristics in hydrogen-air flame, Combustion Science and Technology, 174(8) (2002) 99-116.

[2] C. Saji, C. Balaji, T. Sundararajan, Investigation of soot transport and radiative heat transfer in an ethylene jet diffusion flame, International Journal of Heat and Mass Transfer, 51(17-18) (2008) 4287-4299.

[3] A. Samanta, R. Ganguly, A. Datta, Effect of CO2 dilution on flame structure and soot and NO formations in CH4-air non premixed flames, Journal of Engineering for Gas Turbines and Power, 132(12) (2010) 124501.

[4] S.H. Pourhoseini, M. Moghiman, Experimental and numerical investigation into enhancing radiation characteristics of natural-gas flame by injection of micro kerosene droplets, Journal of Enhanced Heat Transfer, 21(6) (2014).

[5] S.C. Tsai, C.H. Cheng, N. Wang, Y.L. Song, C.T. Lee, C.S. Tsai, Silicon-based megahertz ultrasonic nozzles for production of monodisperse micrometer-sized droplets, IEEE transactions on ultrasonic, ferroelectrics, and frequency control, 56(9) (2009) 1968-1979.