

Behavior of Thermochemistry Properties of Biofuels in an Internal Combustion Engine

1st Nadjat GHERAISSA

Department of Physics, Faculty
of Exact Sciences, University of
HL – El Oued

Department of Physics, Faculty
of Exact Sciences, University of
HL – Batna

El Oued, Algeria

nadjetph@gmail.com

2nd Fethi BOURAS

Department of Physics, Faculty
of Exact Sciences, University of
HL – El Oued

Dept. of Physics, Faculty of
Exact Sciences, University of
HL – Batna

f.bouras@hotmail.fr

3rd Fouad KHALDI

Department of Physics, Faculty
of Exact Sciences, University of
HL – Batna

Batna, Algeria

fouadkhaldi@gmail.com

4th Abdallah DOGGA

Department of Physics, Faculty
of Exact Sciences, University of
HL – El Oued

El Oued, Algeria

doggaabdallh7@gmail.com

Abstract— This work presents a numerical study of the behavior properties of biofuels combustion by comparison with the methane combustion, on the different stations of the cylindrical burner. Thereby, the combustion modeling is based on the mathematical approach to resolve the equations set of the chemical and thermal equations terms. Generally, the obtained results show that; the temperature behavior of biofuels is near to the methane combustion. In addition, the carbon monoxide produced by the combustion of biofuels equal to 0 in all stations of the combustion chamber.

Keywords— Biofuels, Combustion, Burner, Temperature, Carbon monoxide.

I. INTRODUCTION

Many factors are sharing to increasing attention in biofuels and their combustion properties. The crises of fossil fuel and problems of climate change

led to develop environmentally friendly sources. The biofuels considered as a preferable solution, such as palm oil or ethanol derived from corn and sugar cane [1-2]. The conversion of biomass into useful energy is done through various types of processes. The choice of the conversion process type based on the quantities and the properties of materials, and considering some criteria like cost, environment and energy capacity [3]. Han et al. are investigated the analysis of aviation fuels that based on biofuel and compared it with petroleum fuel. The analysis focused on the parameters of fuel production to identify the most factors affecting of the pollutants emission, showing the importance of biomass fuels share in the overall efficiency [4]. Bouras et al. performed a numerical simulation turbulent inert flow in ORACLES configuration, by implementing the LES-WALE eddy viscosity model, and proving its performances especially in terms of inert flows [5].

The present study investigates the numerical simulation of the non-premixed combustion in cylindrical chamber supplied by two biofuels/air. Also, we are focused on the evaluation finding for chemical and thermal characteristics of biofuels values. Then, we are compared these values with methane, which are confirmed in the previous work [5].

II. GOVERNING EQUATIONS

The governing equations for the motion of incompressible flow are recapitulated below [6-10]. The gaseous combustion equations are filtered in LES turbulent for Cartesian coordinates.

Continuity

$$\frac{\partial \bar{\rho}}{\partial t} + \frac{\partial}{\partial x_i} (\bar{\rho} \tilde{u}_i) = 0 \quad (Eq.1)$$

Momentum

$$\frac{\partial \bar{\rho} \tilde{u}_i}{\partial t} + \frac{\partial}{\partial x_i} (\bar{\rho} \tilde{u}_i \tilde{u}_j) = - \frac{\partial}{\partial x_i} [\bar{\rho} (\overline{u_i u_j} - \tilde{u}_i \tilde{u}_j)] - \frac{\partial \bar{p}}{\partial x_j} + \frac{\partial \bar{\tau}_{ij}}{\partial x_i} \quad (Eq.2)$$

Energy

$$\frac{\partial \bar{\rho} \tilde{h}}{\partial t} + \frac{\partial}{\partial x_i} (\bar{\rho} \tilde{u}_i \tilde{h}) = - \frac{\partial}{\partial x_i} [\bar{\rho} (\overline{u_i q} - \tilde{u}_i \tilde{h})] + \frac{\partial \bar{p}}{\partial t} + \frac{\partial \overline{u_j \tau_{ij}}}{\partial x_i} \quad (Eq.3)$$

Species

$$\frac{\partial \bar{\rho} \tilde{Y}_f}{\partial t} + \frac{\partial}{\partial x_i} (\bar{\rho} \tilde{u}_i \tilde{Y}_f) = - \frac{\partial}{\partial x_i} [\bar{\rho} (\overline{u_i Y_f} - \tilde{u}_i \tilde{Y}_f)] + \bar{\omega}_f \quad (Eq.4)$$

Thermodynamic state

$$\bar{p} = \bar{\rho} R_m \tilde{T} \quad (Eq.5)$$

III. THE DESCRIPTION OF CONFIGURATION

The configuration is schematized in Figure 1. Where, the burner is composed of coaxial jets from two round tubes of different diameters located concentrically [11].

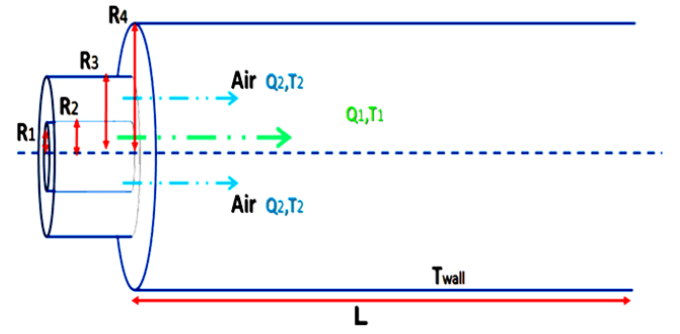


Fig. 1. Schematic of the burner

The cylindrical combustion chamber is of ray $R_4=0.06115\text{m}$ and length $L=1\text{m}$ supplied by two coaxial jets, the center circle has the jet fuel with inlet mass flow rate $Q_1=0.0072\text{kg/s}$ and temperature $T_1=300\text{K}$, also it has an internal ray $R_1=0.03157\text{m}$ and an external $R_2=0.03175\text{m}$. The annular jet of air has an inlet mass flow rate $Q_2=0.137\text{kg/s}$ and preheated at a temperature $T_2=750\text{K}$, it has an internal ray $R_3=0.04685\text{m}$. $T_{\text{wall}}=500\text{k}$ [11,6-8].

The fuels that used in this work are; methane, biofuel 1 (CH₄ 63%; H₂ 0.5%; CO₂ 34%; H₂S 1%; H₂O 1.5%), biofuel 2 (CH₄ 61%; H₂ 0.5%; CO₂ 36%; H₂S 0.5%; H₂O 2%). The details of air fuel ratio and mass flow rate are shown in Table1.

TABLE I. Fuels details

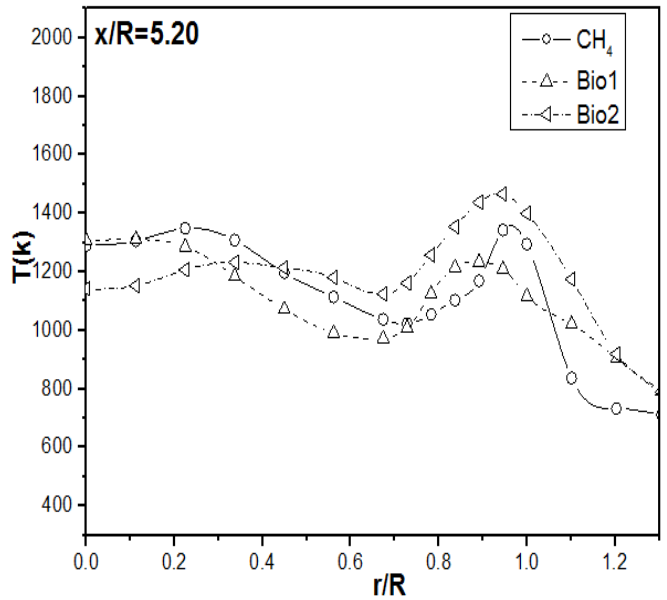
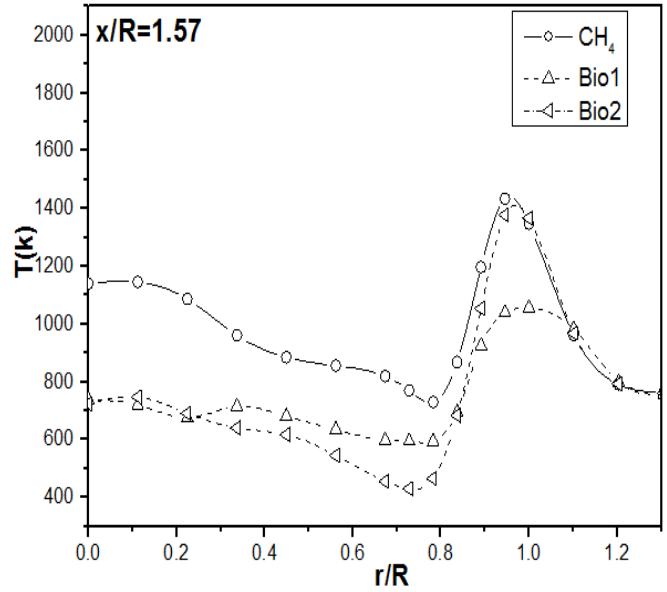
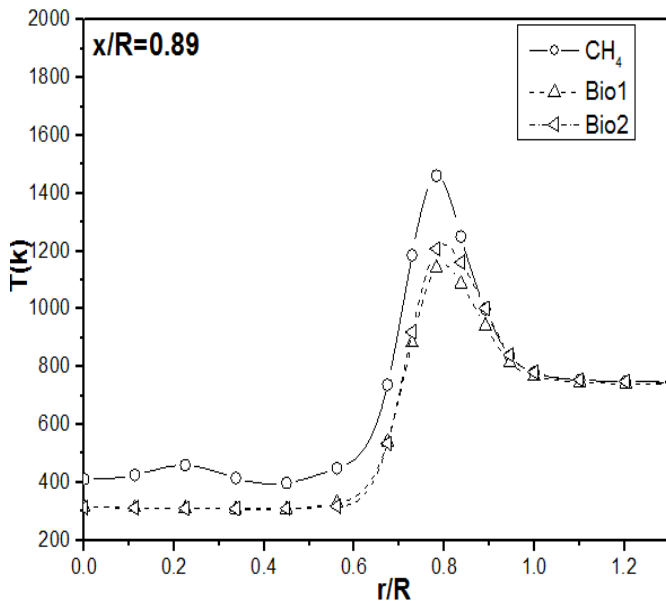
Fuels	Mass Flow [Kg/s]	AFR
Biofuel 1	0.0181	7.57
Biofuel 2	0.0192	7.13
Methane	0.0072	19.03

IV. RESULTS AND DISCUSSION

The simulated results of biofuels combustion were evaluated for cylindrical chamber. The finding of biofuels was compared with CH₄ values. The methane results were confirmed with experimental data in previous work [5,11].

A. Temperature

Fig. 2. Comparison of Temperature of CH₄ and Biofuels

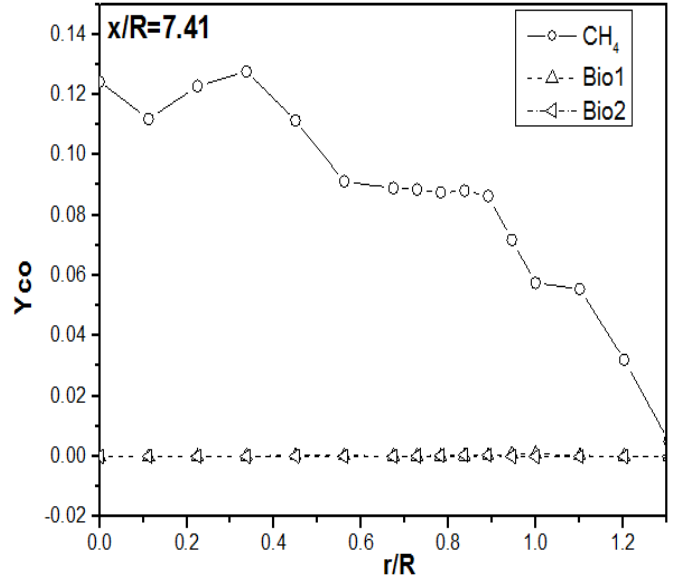
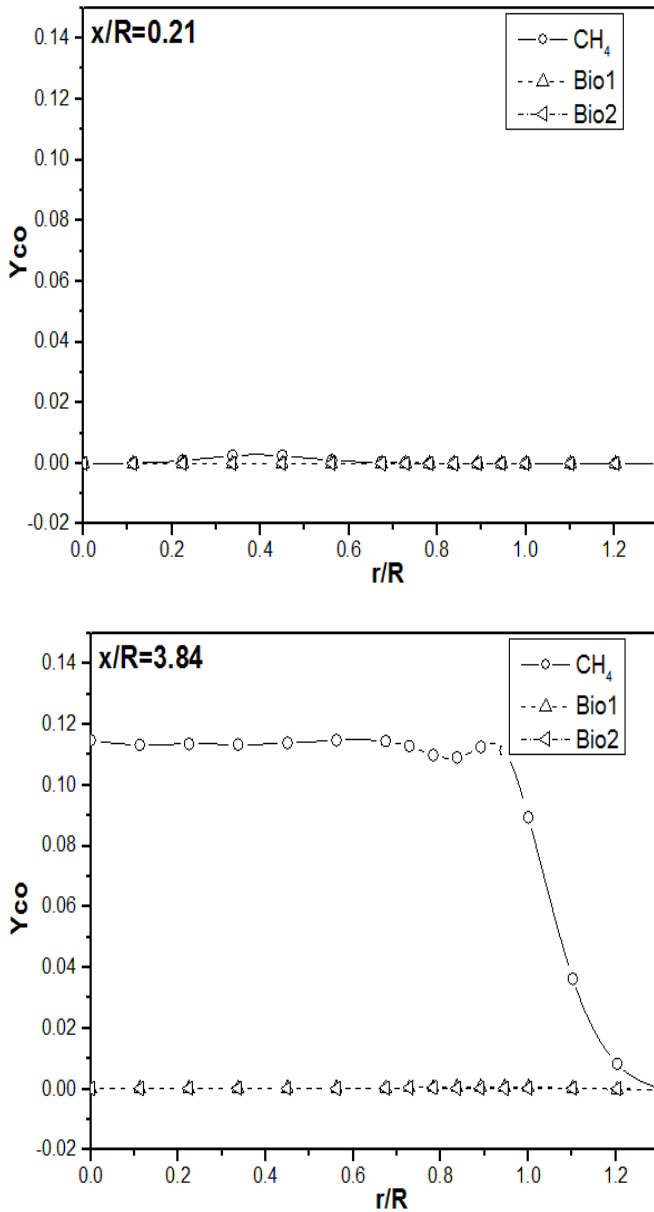


These Figure present comparison of temperature of CH₄ and biofuels: We can see that the profiles have the same tendency for all combustibles with the difference of 15%. In the flame zone the temperature profiles present a peak at 1500 K, and then decrease to equal the walls temperature 500 K. The high values of temperature are situated in the flame, because this zone is the same zone of chemical reactions, and these reactions are considered as exothermic reactions. The temperature values decrease when we get away to the flame zone. The difference in the temperature of the Biofuels and the

CH₄ can be interpreted by the difference in the adiabatic temperature that characteristic each flue.

B. Carbon monoxide

Fig. 3. Comparison of mass fraction of CO between CH₄ and Biofuels



These figures show a comparison between mass fraction of CO resulting from the combustion of CH₄ and biofuels. The results illustrate clearly that CO values of all biofuel is much lower amount than fuel of methane; where the difference between the two graphs is approximately 92%. At the inlet of the combustion chamber, the value of CO is considerable especially in the first station. For the second station, $x/R=3.84$, the graph is characterized by the $y_{co}=0.12$ for CH₄, but $y_{co} \approx 0$ for the Bio fuel. In the outlet of the burner, the values of the CO produced by the CH₄ present the reduction of approximately of 10% relatively to the inlet stations. However, the CO produced by the combustion of biofuel equal to 0 in all stations of the combustion chamber.

V. CONCLUSION

This work investigated non-premixed combustion in cylindrical chamber supplied by various biofuels. Which the study based on different stations in the combustion chamber to take the values. After that the biofuels results compared with methane values on the same stations. Overall, the temperature results are in acceptable agreement with the methane values. The flame seated on the shear layers for it is the mixture zone more rich. Also, the CO values are confirmed that biofuel is a clean fuel.

NOTATION

h — Enthalpy;
 L — Burner length;
 p — Pressure;
 q — Heat flux;
 Q — Inlet mass flow rate;
 R — Radius;
 R_m — Gas constant;
 T — Temperature;
 t — Time;
 u — Velocity component,
 x — Spatial components;
 Y — Mass fraction;
 ρ — Mass density;
 τ — Viscous stress tensor;
 ω — chemical reaction rate;
 i, j — Numbers of components;
 $\bar{\quad}$, $\tilde{\quad}$ — Filtered values;
AFR— Air Fuel Ratio;

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