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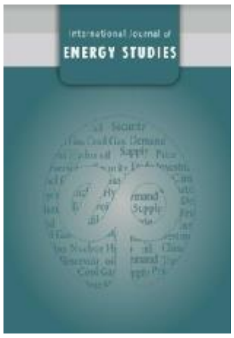

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Investigation of the effects of equivalence ratio on combustion characteristics in combustion of mixed gas CO_2-O_2 and biogas

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Highlights

- Increased equivalence ratio rised SO_2 emission
- Increased equivalence ratio moved the flame zone farther
- Increased equivalence ratio ascended emissions
- As equivalence ratio diminished, temperature is decreased

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ABSTRACT

This study concentrates on the numerical analysis of combustion of different oxidisers and numerical analysis of distributed combustion. The primaily aim of this study is to investigate the combustion properties of different equivalence ratio , which are temperature and emission values, with a burner. It was carried out with biogas and a mixture of gas, then temperature and emission values were examined at different points in the model burner in this study. This manuscript numerically investigates combustion and emission characteristics of various gas mixtures by particularly focusing on effects of equivalence ratio. Numerical studies have been carried out with 1.25, 1, 0.83 and 0.71 equivalance ratio, respectively. In the numerical study, gas of mixture 50% O_2 - 50% CO_2 was used for air on combustion biogas. It was observed that as the equivalence ratio increased, the temperature values in the combustion chamber decreased axially on the distributed combustion. This manuscript numerically investigates combustion and emission characteristics of various gas mixtures by particularly focusing on effects of equivalence ratio.

Keywords: *Biogas, Distributed, Oxy-Fuel, Combustion, Emission*

1. INTRODUCTION

Especially in the last 10 years, energy demand has been increasing rapidly all over the world. Renewable energy and environmental technology increases in parallel with this development. Today, although fossil fuels still maintain their importance as the first source of energy. They cause many health problems due to the increased greenhouse effect. Therefore, scientists try to discover new alternative energy sources such as solar energy, wind energy, hydrogen energy, biomass and others. Work on industrial symbiosis-themed clean energy production is increasing day by day.

Recently, organic wastes are considered as energy sources and are used as raw materials in biogas systems. Therefore, biogas energy has attracted great attention due to its environmentally friendly, clean energy, waste recycling and renewable energy features. Biogas provides good waste management strategies for human health and environmental protection. It consists mainly of methane and carbon dioxide, which contains traces of hydrogen, sulfur and nitrogen. The amount of these trace components varies depending on how gasification and production are performed. [1].

Distributed combustion is reduction of oxygen concentration in oxidizer. This reduction occurs through recirculating of hot combustion products Distributed combustion is the reduction of the oxygen concentration in the oxidizer by mixing it with other gases. This reduction takes place by circulating emissions from hot combustion, where the fuel flow rate or thermal load is kept constant. Pre-ignition recirculation of combustion emissions is one of the most important steps in the formation of distributed combustion. Therefore, combustion takes place with a lower reaction rate, and thus combustion products are spread evenly throughout the combustion chamber[2]. Oxy fuel combustion is the combustion process that takes place with pure oxygen instead of approximately 79% N_2 in the air. Flame temperature, using 100% O_2 to the air place leads to higher temperatures than traditional air-fuel combustion processes. Due to this high temperature obtained, the burner and combustion walls may overheat. To solve this problem, the modification of the burner and combustion material is required for higher temperature resistance. [3]. Therefore, since the oxy-fuel combustion technique is generally used in the glass and steel industries, biogas can be used under oxy-fuel conditions as an alternative to natural gas and other gases[4]. Oxy-fuel combustion results in approximately 75% lower flue gas flow rate resulting from using less flow than air in the combustion process. Oxy-fuel combustion technology stands out as a new combustion technique that has been working on for the last 10 years. In addition, this technology reduces the possible heat loss in the flue gas, it is suitable for sequestration. Flue gas resulting from oxy-fuel combustion mainly consists of CO_2, which means better combustion [5].

There are a lot of studies about biogas combustion. Şahin [6], For example, he did a numerical study of the distributed combustion of biogas. In this study, the combustion property of a non-pre-mixed methane flame was investigated numerically for a newly produced burner under conventional and distributed combustion conditions. It is concluded that NO_X and CO emissions are reduced emissions. He has purposed researching thermal field distributions and pollutant levels of various biogas flames under distributed combustion conditions. He has investigated numerically combustion characteristics of biogas flames by a commercial code on distributed combustion conditions in terms of fuel flexibility, diluent temperature, and diluent composition. Thanks to this work distributed combustion conditions have been achieved and determined that pollutant emission levels have been decreased to ultra-low levels as the oxygen concentration has been reduced in the oxidizer. Thanks to this work distributed combustion conditions have been achieved and determined that pollutant emission levels have been decreased to ultra-low levels as the oxygen concentration has been reduced in the oxidizer. Karyeyen [7] has purposed researching thermal field distributions under distributed combustion conditions. He has investigated numerically combustion characteristics on distributed combustion conditions in terms of fuel flexibility, diluent temperature, and diluent composition. Khalil and Gupta [8] have aimed to develop a high-density burner with ultra low NO and CO options and a very advanced mold factor. Test results, different fuel injection modes and tangentially air have been injected to swirl flammable gas outlet in all configurations. NO and CO emissions have been reduced for both pre-mixed and unpre-mixed combustion modes for the geometries studied. Arghode, Gupta and Bryden [9] have been investigated combustion characteristics of colorless distributed combustion for application to gas turbine combustors. Very high intensity distributed combustion has been shown for application to stationary gas turbine engines. Different configurations analyzed have catch out reverse cross-flow mode to be more favorable for desirable combustion characteristics. Arghode and Gupta [10] have investigated colorless distributed combustion (CDC) focused on gas turbine combustion applications because of its significant benefits for, much reduced NOx emissions and noise reduction, and significantly improved pattern factor. They have examined four different sample configurations to achieve colorless distributed combustion conditions that reveal no visible color of the flame. In a similar combustion chamber, Arghode et al. have been studied numerically and with the findings obtained, it has been determined that the recirculation rate in the combustion chamber can be achieved up to 0.7. In this study, in addition to these studies on oxy-fuel and distributed combustion, the effects of the equivalence ratio on combustion characteristics have been investigated [11].

2. CFD MODELING

CFD modellings have been performed using the existing burner in order to model combustion under different equivalence rate conditions in the present study. In figure 2a and 2b are showed the combustor and burner mesh structure employed in this work. The geometric shapes of the burner are used in a length of 100 cm and a diameter of 40 cm.

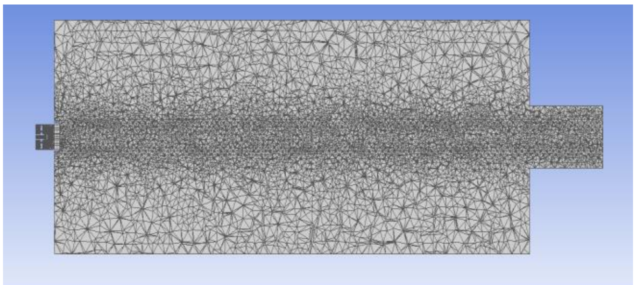

Figure 2a. Cross-Sectional View of the Mesh

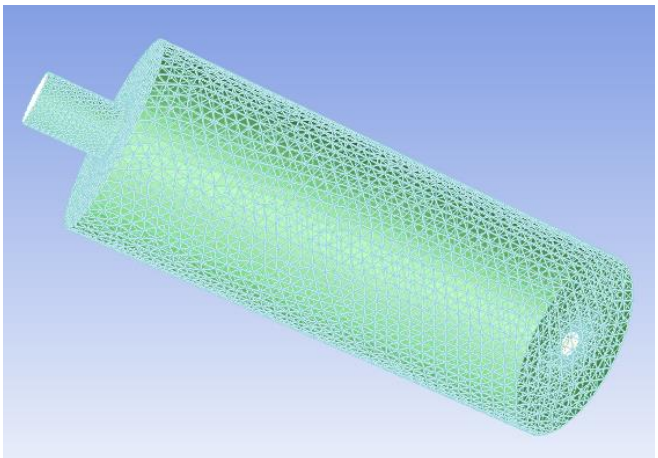

Figure 2b. General View of the Mesh

The combustion has been occurred numerically for four types of equivalence ratios which are 1.25, 1, 0.83 and 0.71. Biogas have been used as a fuel which content is %55 CH_4, %1,53 N_2, %0.3 O_2, %43.1 CO_2 and %0.07 H_2S. Temperature and percentage of H_2O, CO_2, CO and SO_2 gases values received and drawn graphics according to axial length.

3. VALIDATION

Predicted results entail validation through experimental studies. It is understandably seen in Figure 3, the axial temperature profiles are compatible with the experimental data. As a numerical model is realized, mesh independency is an essential application in order to minimize computational time. Therefore, the best mesh structure must be determined and as a result, it is widely known that it does not require more computation time. In the previous study conducted by Ilbas et al. for different mesh structures, mesh independence has been achieved[12]. It has been concluded that there is a small difference between the estimated axial temperature distributions and experimental temperature distributions. Thus, the mesh structure 613947 has been chosen as the best mesh structure for this study.

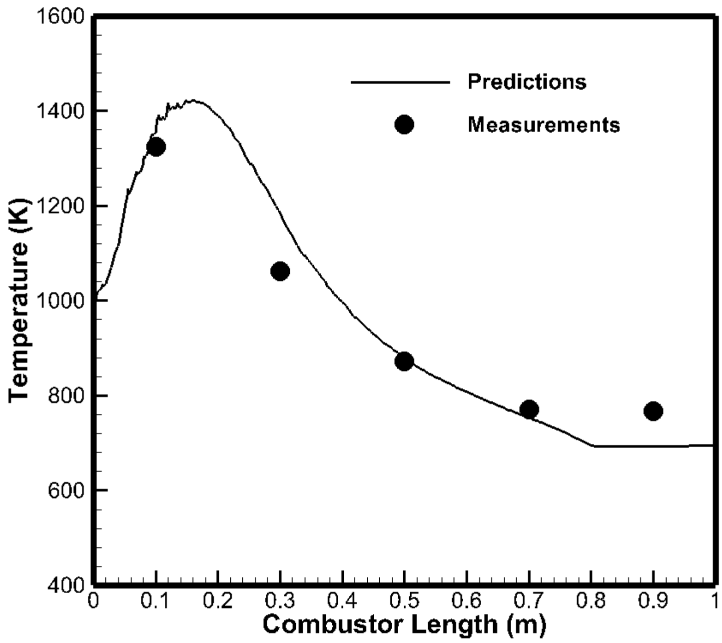

Figure 3. Model verification for predicted axial temperature profiles

4. RESULTS and DISCUSSION

The numerical axial temperature values presented in Figure 4. With the increase in the equivalence ratio, it is understood that the temperature values decreased axially from the center of the combustion flame zone to combustion chamber output. The maximum temperature value has been measured in the flame zone. Temperature values range from 780 K and 1480 K. In addition to these CO, SO_2,CO_2 and H_2O values change along axial length with the increase in the equivalence rate.

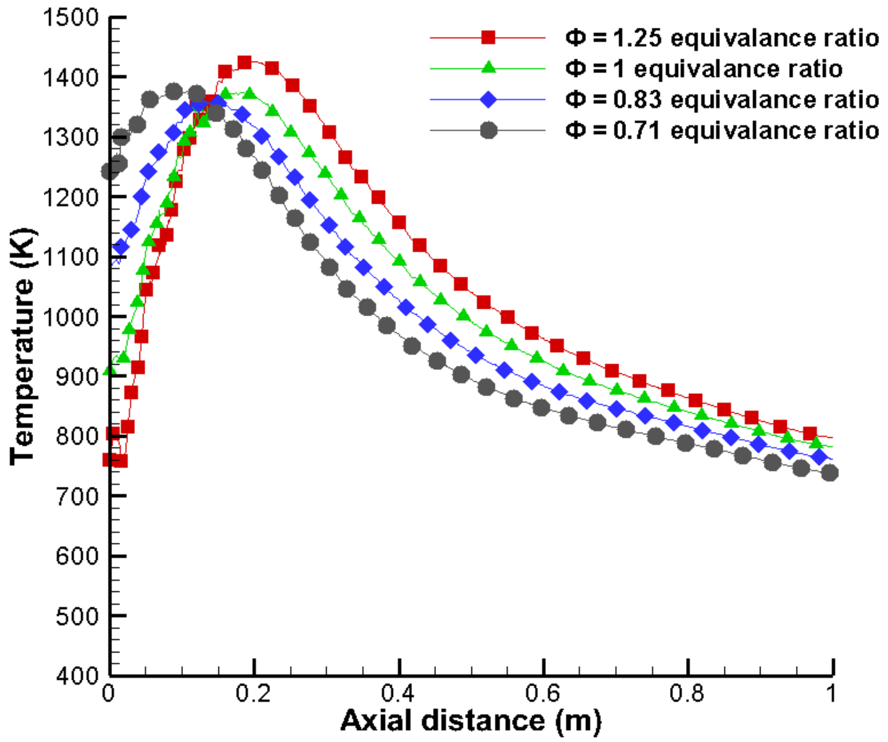

Figure 4. Axial Temperature Distributions For different of Equivalence Ratio

In Figure 4 the axial temperature distributions of different equivalence ratios are displayed. It is deduced that all temperature distributions raise in the flame zone initially and then, diminish gradually toward the combustor outlet because of convective and radiative heat transfers. They have keep almost temperature trend after 0.3 meter axially. It has been observed that the highest temperature value along the axial distance is 1.25 equivalence ratio. It has been determined that the lowest temperature value along the axial distance is 0.71 equivalence ratio. As the equivalence ratio increased, it has been observed that the combustion flame zone moved away from the burner.

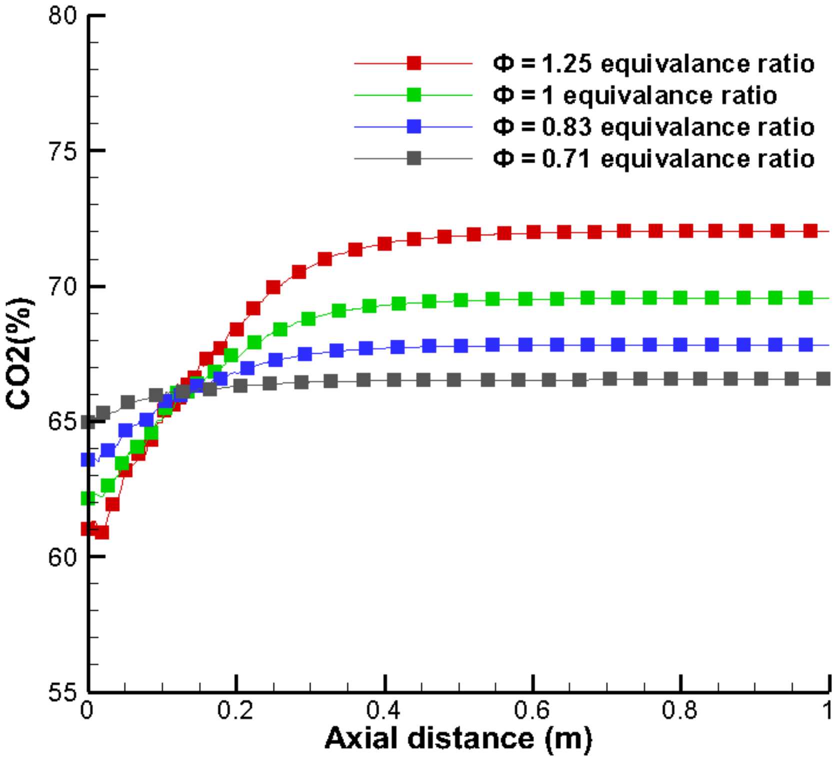

Figure 5. Axial CO_2 Distributions For Different of Equivalence Ratio

The predicted CO_2 distributions results of the different equivalence ratio are presented in Figure 5 as axial distributions inside the combustor. In Figure 5, distributed combustion has the highest CO_2 release when it compares to the other equivalence ratio. It has been identified that the highest value of CO_2 emission along the axial distance is 1.25 equivalence ratio. It is determined that the lowest CO_2 emission value along the axial distance is 0.71 equivalence ratio.

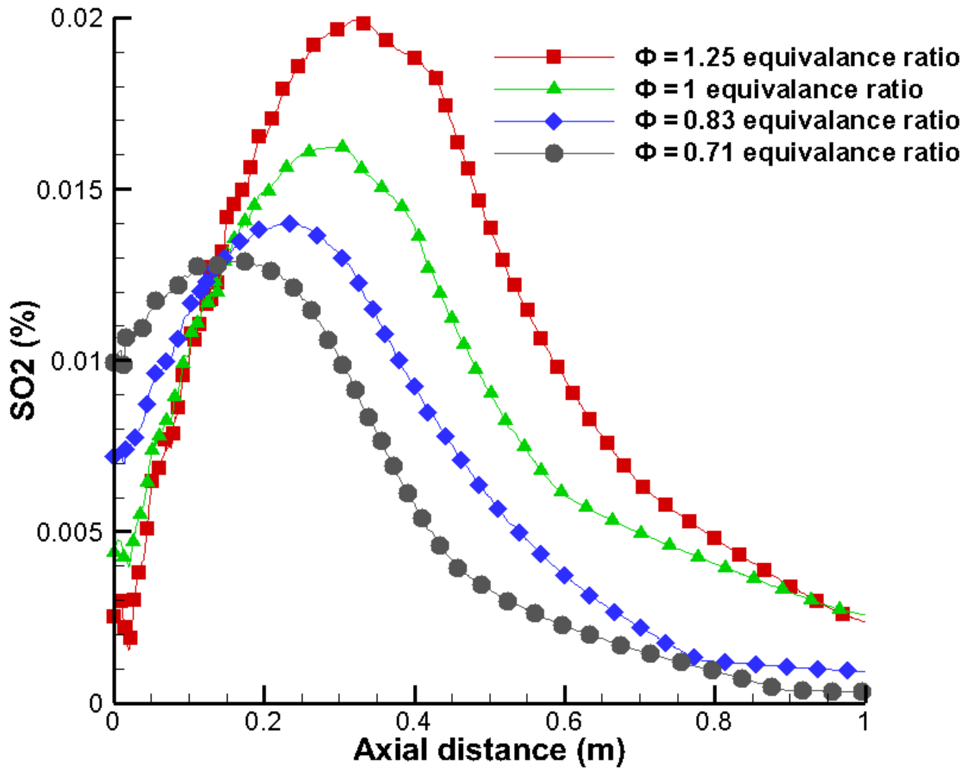

Figure 6. Axial SO_2 Distributions For Different of Equivalence Ratio

Figure 6 displays axially SO_2 distributions of different of equivalence ratio. SO_2 release distributions increase in the flame zone initially and then, decrease gradually toward the combustor outlet at axial 0.3 m. It has been determined that the highest value of SO_2 emission along the axial distance is 1.25 equivalence ratio. It is observed that the lowest value of SO_2 emission along the axial span is 0.71 equivalence ratio.

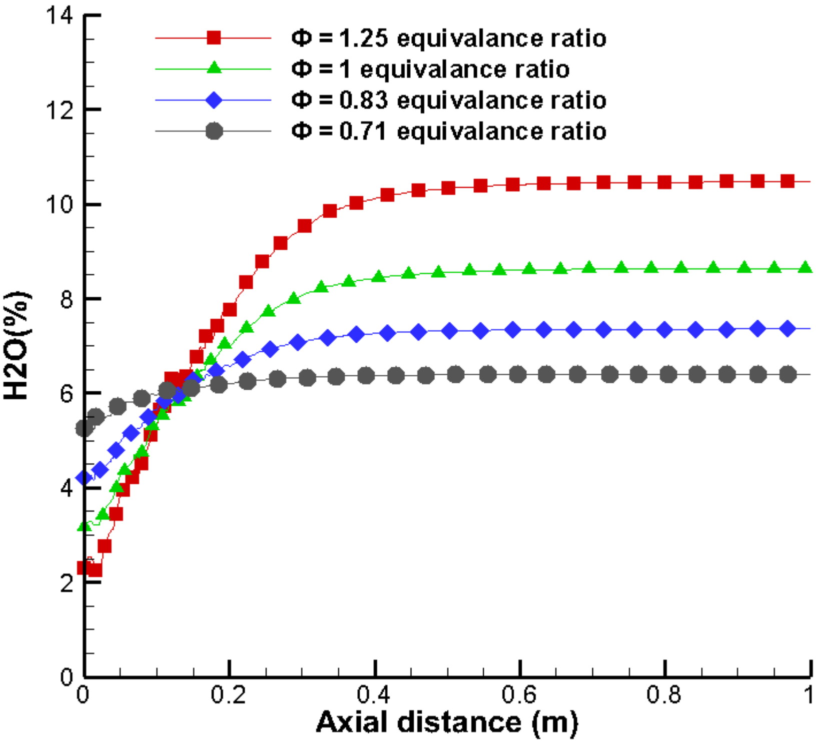

Figure 7. Axial H_2O Distributions For Different of Equivalence Ratio

Figure 7 displays axially H_2O distibutions for different of equivalence ratio. It has been determined that the highest H_2O value of emission along the axial distance is 1.25 equivalence ratio. H_2O emission distribution initially increases in the flame zone, but continues steadily towards the combustion output at axial 0.3 m. It is observed that the lowest value of H_2O emission along the axial interval is 0.71 equivalence ratio.

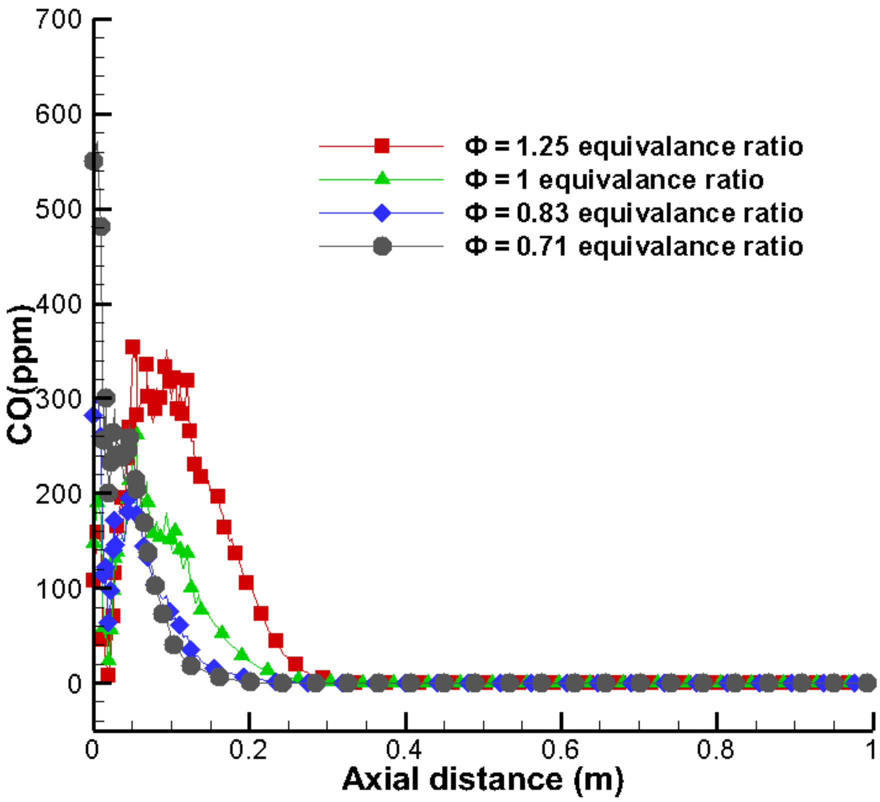

Figure 8. Axial CO Distributions For Different of Equivalence Ratio

Figure 8 exhibits axially CO distibutions for different of equivalence ratio. According to the Figure 8, it can be said that CO release distributions does not change along axial distance towards the combustion output at axial 0.3 m. In addition to this, gas of mixture 50% O_2 - 50% CO_2 combustion CO emission values are same after axial distance of 0.3 m. emission distribution initially increases in the flame zone, but continues steadily towards the combustion output at axial 0.3 m. After axial distance of 0.3 m, CO emission levels for gas of mixture 50% O_2 - 50% CO_2 combustion are nearly same up to the combustor outlet.

5. CONCLUSION

Once the results of numerical studies on the effect of different equivalence ratios are compared with each other, the temperature values decrease along the axial distance from the flame zone throughout the combustion chamber. It has been observed that as the equivalence ratio increased, the combustion chamber temperature level decreased. As the equivalence ratio increased, the flame zone moved from the burner to the exit of the combustion chamber. As for emission values, they values have change along of axial distance. It has been determined that 1.25 equivalence ratio is the highest H_2O, SO_2 and CO_2 emission values throughout the axial distance. It has been observed that H_2O, SO_2 and CO_2 emission values decreased throughout the combustion chamber as the equivalence ratio decreased.

When numerical analysis results of different equivalence ratio, distributed and gas of mixture 50% O_2 - 50% CO_2 combustion are compared with each other. As a result, when the equivalence ratio is 1.25, the highest value has been seen in the combustion flame zone. As the equivalence ratio increases, the temperature value decreases throughout the combustion chamber.

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Declaration of Ethical Standards

The author of the paper submitted declares that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

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