THREE-DIMENSIONAL MODELLING OF AMMONIA/METHANE/AIR TURBULENT FLAMES IN A GENERATED PERFORATED BURNER AND FURNACE

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Abstract

This study concentrates on CFD modelling and entrainment effects to achieve distributed regime for ammonia fuel in a perforated burner. Entrainment without decreasing oxygen concentration in air was provided from the flame holder wall of the newly generated perforated burner at 10% and 20% entrainment rates in order to achieve ultra-low pollutant emissions levels. The results showed that the temperature distributions were achieved more uniform and the flame zones became more thinner for all cases studied. This provided more invisible or colorless flame appearance, and as a result of this, more uniform thermal field was achieved without substantial decrease in combustion performance. In terms of evaluation of distributed regime achievement on NOX emission levels, one can say that ultra-low emission levels were achieved with entrainment effects without decrease in oxygen concentration in air.

Keywords: Ammonia, combustion, burner, emission, entrainment

1 INTRODUCTION

With the rapid development of standards of life, the need for energy is increasing. In line with this increasing demand, there are some important problems that fuel, a significant source of energy production, can bring about. And at the very beginning of these problems are the emission values that have greatly jeopardized the future of our world and have recently been the focus of the focus. Many new combustion patterns have been developed, studied and continued to be done to aim to reduce emissions. Şahin [1], developed a perforated burner and studied combustion performance, entrainment effects and emission values on different synthesis gases. In this study, a perforated burner was designed and investigated for root oven gas, biogas and January gas at 10% to 20% to 30% drift rates respectively. As a result, a more homogeneous combustion has been achieved with increased entrainment rates, without a reduction in combustion performance, and it has been stated that the NOx and CO2 emission levels are dropped to ultra-low points outside the root oven gas. Ilbas et al. [2] using a burner that was non-premixed, they observed the effect of the oxidizer on NO emission and temperature when the ammonia was burned. Karyeyen ve Ilbas [3] studied for the turbulent flames of hydrogen-assisted synthesis gas mixtures for a new type of burner developed. The study examined the temperature and emission values of the low calorific synthesis gases derived from charcoal, in the improved burner. As a result, the temperature of the synthesis gases increased by the addition of hydrogen, and the NOX level was initially low owing to a low flame temperature, and it was stated that it increased by the addition of hydrogen. Furthermore, it has been emphasized that the addition of hydrogen on conversion from co2 emission to CO emission is significantly effective. In another study, Chen et al. [4] has implemented a new incineration system to a 300 MW down-fired boiler with a swirl burner. In the study, experiments were tried for 180-250-300 MW forces and a new NOX burn technology was applied to reduce emissions. With this system developed, they indicated a reduction in NOX level without increasing the amount of carbon in the ash. Jang et all. [5] has studied the effect of pulsed oscillating combustion on temperature and emissions in an industrial burner system. Measurements were taken at 3.32m axial distances within an oven with thermal capacity of 3 MW and radial directions at 0.15m intervals. As a result, NO generation in the oscillating flame has been reported to be reduced

by a maximum of 32% and heating performance improved by 9.8% in oscillating combustion. Yu et all. [6] has studied on thermal yield emissions for pre-mixed porous environment type burners. Three types of burners have been examined in the study; metal fiber (MF), ceramic (CM) and stainless-steel wing (SM). As a result of the investigations, MF has the lowest CO emission, SF lowest NOx emission and finally MF has the highest thermal efficiency. It has also been emphasized that the most suitable burner for condensed boiler is metal fiber (MF) burner according to certain standards. Increasingly, more and more study is being emerged in line with the needs of both emission improvement and to improve the quality of combustion.

Finally, the aim of this study is both to achieve uniform results without any changes in combustion performance, and reduction in emissions, with burners and entrainment structures developed in this study. The study conducted examinations for methane and ammonia. The results are obtained with the help of CFD simulations.

2 MATERIALS AND METHOD

In this study, 4 holes have been made that will have entrainment effect on the burner, as shown in figure 1, to improve the combustion quality and improve emission values.

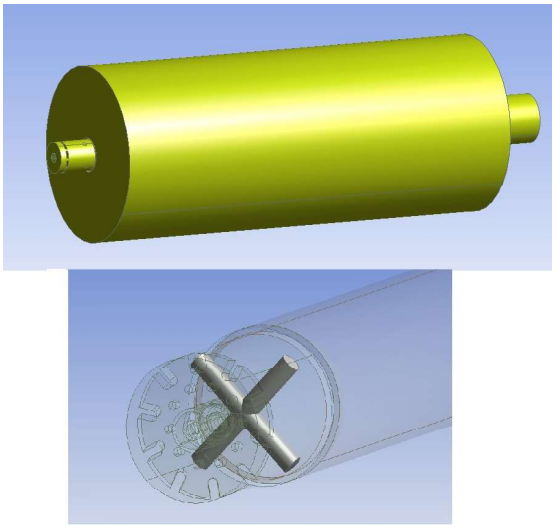


Figure 1. Schematic representation of the combustion chamber and burner structure

The emissions levels with entrainment applied from these created holes are predicted to be improved. Also, the burner dimension designed are 1 m long and 0.4 m in diameter.

The Ansys Fluent software has been used to simulate the study performed. Figure 2 shows the network structure applied to the structure that is designed. The tetrahedron mesh structure is applied to all areas of the design structure. It consists of 1509830 elements in total. For this network structure created, the highest Skewness value was 0.96478 and the lowest Orthogonal quality value was 0,058.

In this study, inspections were conducted for two cases, ammonia gas (100 NH3%) and methane gas (100 CH4%). The specified gases are followed by 10% and 20% entrainment effect respectively. Under these conditions, changes in temperature, speed and NOX emission values have been studied. The different axial positions of the combustion chamber were determined when performing the checks and the characteristics of the specified axial positions at 0.05m intervals of the radial distance were analyzed.

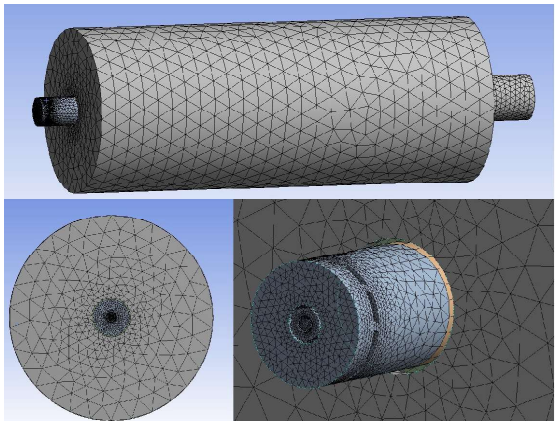


Figure 2. The mesh structure of the design model

In addition, the system modeling was applied the non-premixed combustion model, the standard k-u turbulence model, and the P-1 radiation model. Together, assumptions are accepted that the flow is stable, there is no surface radiation, there is gas radiation, there is no energy flow, and there is no slip boundary condition on the combustion chamber wall. The inlet temperatures for simulation are set to 300K. The presto method is applied for pressure parsing and the second-row wind top diagram is selected. Convergence criteria are set to $10-4$.

3 RESULTS AND DİSCUSSİON

This section shares the temperature, speed and NOX emission values at different radial distances in the prescribed axial lengths of the study. For axial lengths, 10cm, 30cm, 50cm,

70cm and 90cm are determined respectively. Radially, the values for each length point are taken into account in the 0.5cm ranges.

3.1 Temperature and velocity

Figure 3 shows contours of temperature variations based on different entrainment effect. In these figures, it can be said that at 20% entrainment effect, ammonia gas makes the flame thinner. In addition, the flame is almost lost in methane gas. Also, the increase in entrainment levels makes combustion more homogeneous. As can be seen from the figures, it is clear that at 20% entrainment effect, it is reduced distinction between temperatures. In addition, at 20% entrainment effect, higher temperatures were achieved compared to 10% entrainment effect for both ammonia and methane gas.

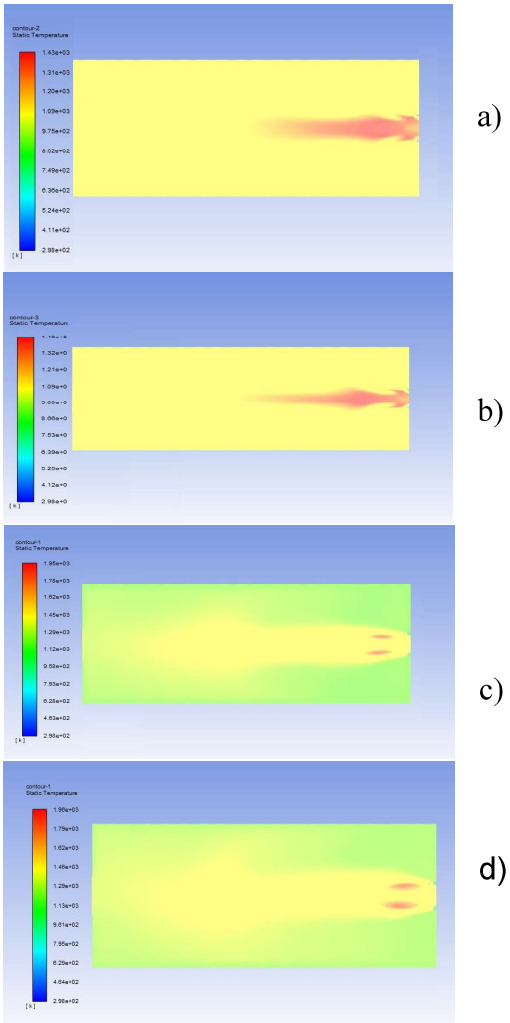


Figure 3. a) temperature contours for ammonia combustion at 10% entrainment effect b) temperature contours for ammonia combustion at 20% entrainment effect c) temperature contours for methane at 10% entrainment effect d) temperature contours for methane at 20% entrainment effect

Figure 4 shows contours of velocity profiles resulting from combustion at 10% and 20% entrainment effect of ammonia gas and methane gas. In this context, both gases show that velocity profiles are get thinner at radial distance. There is also an increase in the velocity at the burner output with a 20% entrainment effect. This confirms that entrainment effect has an effect on the flow being faster. Finally, methane gas may indicate higher velocity at the burner outlet compared to ammonia gas.

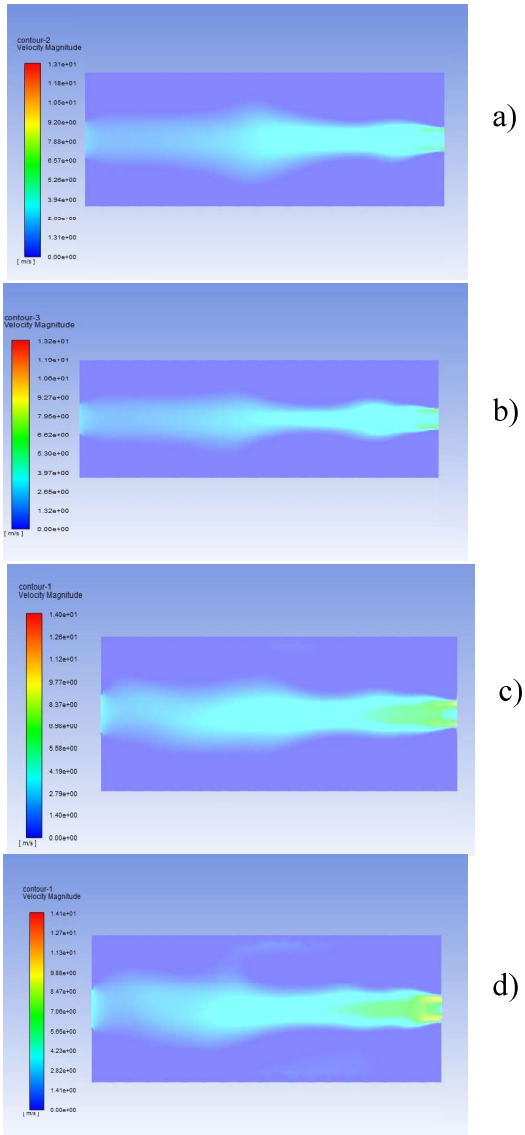
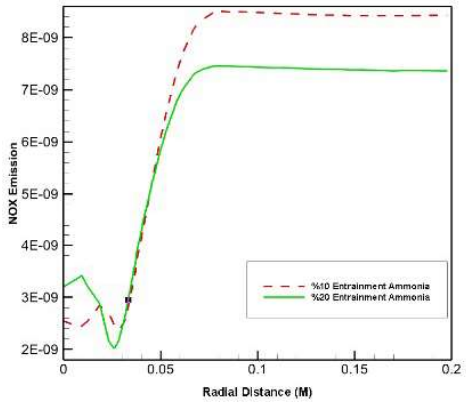


Figure 4. A) Velocity contours for ammonia combustion at 10% entrainment effect b) Velocity contours for ammonia combustion at 20% entrainment effect c) Velocity contours for methane combustion at 10% entrainment effect d) Velocity contours for

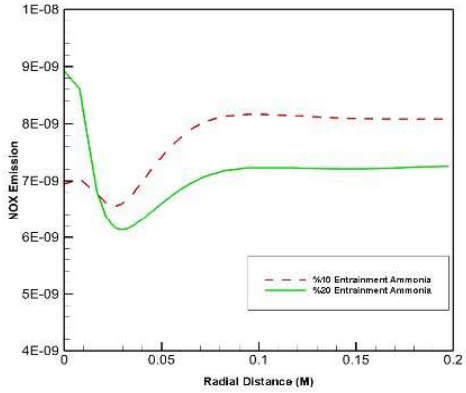
methane combustion at 20% entrainment effect

3.2 NOX Emission

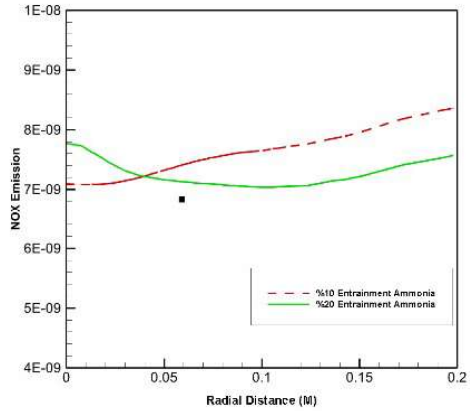
Figure 5 shows the graphs generated in the NOX emission values of the specified length ammonia gas. For a more habitable environment, reducing emission values is very important. At this point, as can be seen in the graph, there has been a reduction in NOX values without changing the oxygen concentration in the air by increasing the entrainment effect. With the used burner system, the NOX emission level are intended to be reduced to a minimum amount.



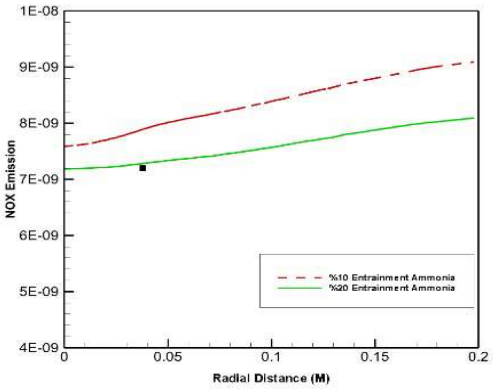
10 cm



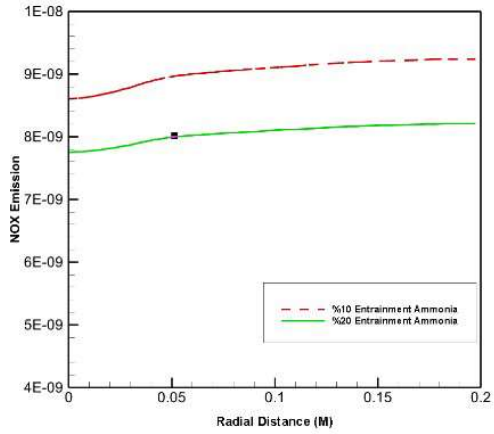
30 cm



50 cm



70 cm



90 cm

Figure 5. NOX emission variations of ammonia gas for radial distances at different axial distances

Unlike ammonia gas, methane gas is estimated to have a very small increase in NOX emissions due to an increase from 10% to 20%. These increases are estimated to have caused a slight increase in the number of NOX formations by the increase the combustion temperature of methane gas in consequence of increase of entrainment effect.

CONCLUSION

In this article, the studied of a designed burner with the CFD software of methane and ammonia gases have been studied on combustion temperature, speed and NOX emission. This burner is designed to achieve homogeneous combustion and low emissions without changing the combustion performance by having a 10% and 20% entrainment effect effect on the combustion chamber. At this point, the temperature and speed profiles for ammonia gas and methane gas were first examined. There has been a more uniform temperature distribution in terms of temperature. In ammonia gas, the flame has been seen with increase the entrainment effect, the flame is further thinned. In methane gas, the flame is almost invisible, along with the

entrainment effect. In addition, there has been a decrease in radial distance with the increase in entrainment effect in terms of speed profiles. As a result of the checks carried out, the effect of the entrainment effect on the flow rate during combustion is also very clear.

In terms of emission values, the NOX levels that may be the result of combustion have been analyzed. As a result of the study, with the increase in the entrainment effect, the reduction in NOX values in the ammonia gas are clearly seen. It is likely that it is very valuable to achieve these levels of reduction without any change in the air oxygen concentration. However, unlike ammonia gas, there have been very little increases in the NOX levels that have emerged along with the increase in the entrainment effect in methane gas. It can be stated that the burner structure, designed for these results, has positive results at both an improvement in emissions values and a uniform combustion.

ACKNOWLEDGEMENTS

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