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THE MODELLING OF THE EFFECT OF AIR FUEL RATIO ON UNBURNED HYDROCARBONS FOR MILD COMBUSTION

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ABSTRACT

Unburned hydrocarbons (UHC) are a waste and pollution to the environment. UHC will happen when rich combustion occurred. In the case of exhaust gas recirculation (EGR) utilized to diluted the oxidiser, UHC in the EGR can result in unwanted combustion at unwanted locations (i.e. in the EGR pipe). FLUENT was utilised to model the open furnace. The volume flow rate for air and fuel was the main parameter of the study. In order to consume all the fuel by the combustion, the air fuel ratio (AFR) must be higher than 5:1. Lean combustion (AFR more than 5:1) will eliminate the possibility of UHC in flue gas.

***Keywords*:** MILD combustion, unburned hydrocarbons, exhaust gas recirculation, air fuel ratio

INTRODUCTION

Global concern on combustion pollution emission makes moderate and intense low oxygen dilution (MILD) combustion [1,2] or flameless oxidation (FLOX) [3,4] more important. MILD combustion emits low NO_x and CO pollutant emissions and high thermal efficiency. CO_2 is one of greenhouse gases (GHG). By using biogas [5] or low calorific value (LCV) gas, CO_2 emitted by the combustion will be utilized by biomass, which is the source of biogas. In this study LCV gas used was produced by mixing the methane, hydrogen and carbon dioxide.

FUEL COMPOSITIONS

The fuel mole fraction for this work to produce LCV is 53.44% CH_4, 30.00% CO_2, 13.36% H_2, 1.30% N_2, 1.70% C_2H_6, 0.01% C_3H_8 and 0.01% C_4H_{10}. The air mole fraction is 21.008% O_2 and 78.992% N_2. The oxygen in the oxidizer will be diluted by EGR to the required level.

EXHAUST GAS RECIRCULATION

Exhaust gas recirculation (EGR) was the key for MILD combustion. EGR was previously used for MILD combustion [6] and play important role to preheat the oxidiser and dilute the oxygen. EGR can be achieved by enclosing the combustion chamber and collecting the flue gas. Then EGR was flowed downward to mix with fresh air. The EGR ratio will be determined based on the dilution ratio required by the combustion. MILD combustion can be achieved when the oxygen level is between 3~13%.

FUEL VOLUME FLOW RATE

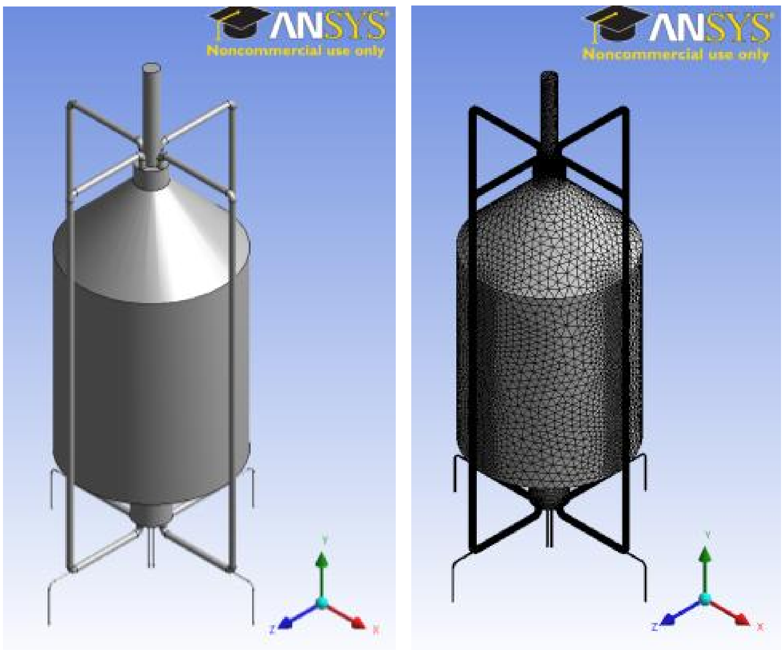
Fuel enters the burner through a central hole after merging through 4 inlets with 5mm in diameter with total 78.5 mm2 inlet area. If the velocity of the fuel injected is 10 m/s, the volume flow rate for the fuel is 7.85×10^{-4} m^3/s (7.8 cm^3/s).

AIR VOLUME FLOW RATE

Air injected through 4 inlets at the side of EGR with 5mm diameter each. If the air injected at 50 m/s, the air volume flow rate is 3.9×10^{-3} m^3/s (39 cm^3/s).

MODEL DEVELOPMENT

The open furnace was modelled (Figure 1(a)) using FLUENT 13.0 with the size of 1.8 m height and 0.6 m width and mesh (Figure 1(b)) with advanced sizing function of proximity and curvature. Element refinement was used at air, fuel inlet and EGR inlet and outlet. The air fuel nozzle size ratio for this model is 4:1.



(a) (b)

Figure 1. Open furnace with 4 EGR (a) geometry (b) 501,831 mesh element and 111,975 nodes

RESULTS AND DISCUSSION

The open furnace was modelled with the AFR reported in Table 1. The AFR of 1:1 will give the highest unburned CH_4 mole fraction. When AFR reaches 5.0, unburned CH_4 will become 0. This unburned CH_4 (Figure 2) in flue gas will flow through EGR and will burn at unwanted location when CH_4 mixed with O_2 at the fresh air supply (Figure3). Figure 4 is proper combustion with fuel consumed 100%.

Table 1. Air and fuel velocity compositions and mole fraction for unburned CH_4

Air (m/s)	Fuel (m/s)	AFR	UHC CH_4 mole fraction	UHC CH_4 mass fraction
50	50	1.0:1	0.1069	0.0615
100	50	2.0:1	0.0450	0.0258
90	40	2.3:1	0.0390	0.0215
75	30	2.5:1	0.0351	0.0201
100	40	2.5:1	0.0327	0.0185
60	20	3.0:1	0.0240	0.0119
100	30	3.3:1	0.0146	0.0082
55	15	3.7:1	0.0097	0.0056
60	15	4.0:1	0.0058	0.0033
65	15	4.3:1	0.0027	0.0015
70	15	4.7:1	0.0004	0.0002
100	20	5.0:1	0	0
80	16	5.0:1	0	0
50	10	5.0:1	0	0
70	13	5.4:1	0	0
90	15	6.0:1	0	0

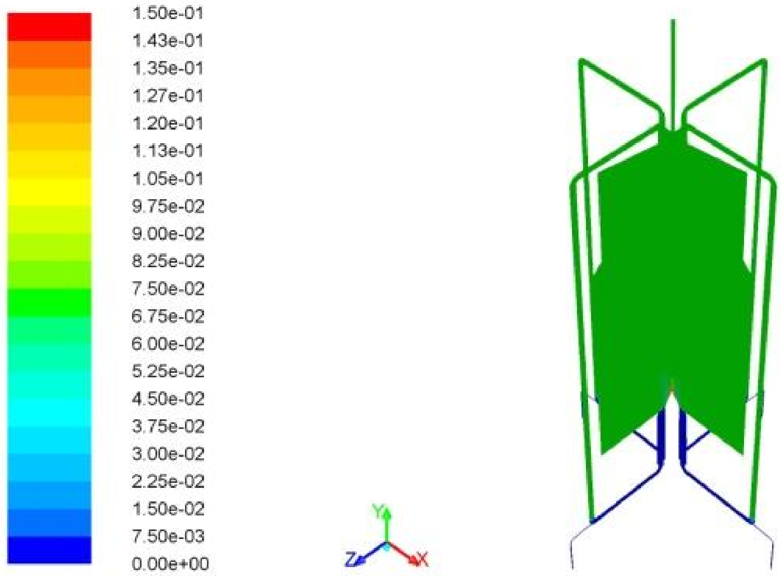


Figure 2. The CH_4 mole fraction between 0 to 0.15 with UHC in the EGR pipe

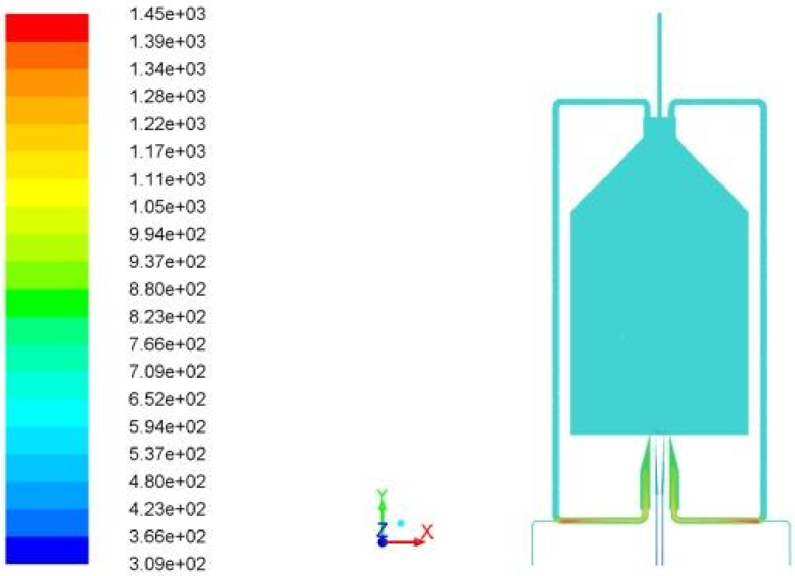


Figure 3. The combustion temperature with unwanted burning in EGR pipe due to unburned CH_4 in EGR (Figure 2)

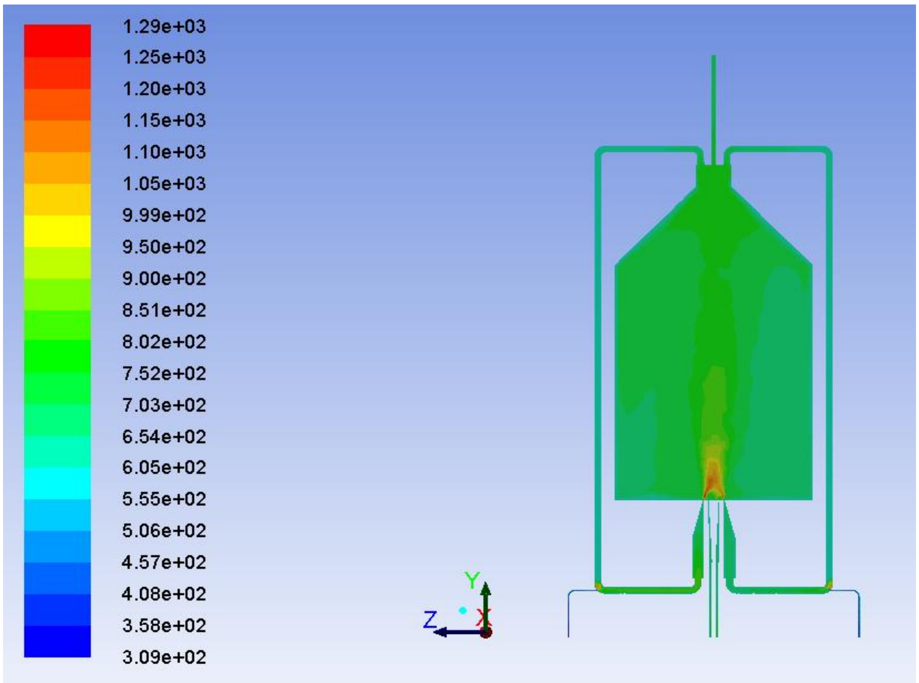


Figure 4. The maximum combustion temperature is 1290 K

CONCLUSION

The study of the effect of AFR to unburned CH_4 was successful. Both air and fuel play important role for the completed combustion. In order to consume all the fuel by the combustion, the AFR must be higher than 5:1. If AFR is lower than 5:1, unwanted unburned CH_4 will be produced.

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