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The Study of Air Fuel Ratio for Open Furnace MILD Combustion of Biogas on Bluff-body Burner

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Abstract—**Economical fuel cost is very critical in the heating industry. Lean combustion with high air fuel ratio (AFR) is normally practiced by the industry. Low air fuel ratio or rich combustion will result in unburned hydrocarbons (UHC). UHC is a waste and pollution to the environment. This paper discussed on the modelling of air fuel ratio for the moderate and intense low oxygen dilution (MILD) combustion of biogas on bluff-body burner. Biogas is a low calorific value (LCV) gas which was formulated by using 50% methane, 20% hydrogen and 30% carbon dioxide. AFR is the ratio of air and fuel injected to the combustion chamber. Nozzle outlet size for air and fuel plays important role to determine AFR. In this study, the air and fuel nozzle size ratio used is 23:1. The AFR will be evaluated based on the UHC produced by the combustion. Stoichiometric AFR occurred when zero UHC and zero excess oxygen flow through the EGR pipe. The result shows that when AFR is 4.0, zero UHC was detected in the EGR. UHC in EGR will be waste and create unwanted combustion at the wrong location.**

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

I. INTRODUCTION

Energy need with lower emission and higher efficiency becoming a global concern [1-3]. Intergovernmental Panel on Climate Change (IPCC) assessment report shows that global temperature from 1960 to 2005 has increased of 0.74^{o}C due to the greenhouse gases (GHG) effect [4,5]. The most GHG is CO_2 and combustion pollutions [6,7]. In order to reduce GHG effect, the combustion must use biogas and reduce the pollutions. One of the new combustion technology to reduce combustion pollution emission with higher thermal efficiency is moderate and intense low oxygen dilution (MILD) combustion [8,9] or flameless oxidation (FLOX) [10,11]. MILD combustion is getting more the attention from the scientific community [12] is part of dilution combustion technology [13]. MILD combustion emits low NOx and CO pollutant emissions and high thermal efficiency [6,14-20]. By using biogas [16] 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.

AFR for MILD combustion [21-24] and hydrogen fueled internal combustion engine [25-28] shows that the performance of combustion is very much impact by AFR used. The industrial heating prefers the lean combustion which is high AFR in order to reduce the fuel cost. Exhaust gas recirculation (EGR) was very important for MILD combustion. EGR was previously used for MILD combustion [21,24,29,30] and play to preheat the oxidiser and dilute the oxygen. Enclosing the combustion chamber in order to collect the flue gas and utilised it as EGR. EGR was flow downward to mix with incoming fresh air. The EGR ratio will be determined based on the dilution ratio required by the combustion. EGR ratio is the volume of flue gas use as EGR over total flue gas. MILD combustion can be achieved when the oxygen level is between 3~13%.

The purpose of this study is to check the AFR on LCV gas and the effect on unburned CH_4 and H_2 for the open furnace MILD combustion.

II. MODEL DEVELOPMENT

The open furnace was model (fig. 1(a)) using FLUENT 13.0 with the size of 2.0 m height and 0.6 m width. This model was the improved model from previous AFR study [21]. Air and fuel nozzle was design as a bluff body burner as fig. 1(b). Fuel nozzle in the middle with the size of 97 mm^2 and air nozzle size is 2261 mm^2. The air fuel nozzle size ratio for this model is 23:1. The method of meshing is tetrahedrons (patch conforming) with advanced sizing function of proximity and curvature and detail setting as in table 1. Mesh element refinement was used at air, fuel inlet, air fuel nozzle (fig. 2(b)) and EGR inlet and outlet. The mesh elements are 911,669 and nodes are 189,372 as shown in fig. 2(a).

The fuel inlet was located at the center and bottom of the burner. Fuel enters the burner through a central hole after merging through 4 small inlets with 6mm in diameter with total 113.1 mm^2 inlet area. If the velocity of the fuel injected is 100 m/s, the volume flow rate for the fuel is 1.13x10^{-2}m^3/s (1,130cm3/s).

Table 1: Mesh setting details

Sizing	Setting
Advance Size Function	On: Proximity and Curvature
Relevance Center	Fine
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Medium