In-flight gasification of livestock manure fuel by using three phase AC arc plasma sytem.

D. H, Lee[1], D. Figuera-Michal[1], N. K. Lee[1], H. J. Kim[1], S. Y. Yang[2] and J. H Seo[1]

[1] *Department of Applied Plasma & Quantum Beam Engineering, Jeonbuk National University, Jeonju, Korea*
[2] *Graduate School of Flexible & Printable Electronics, Jeonbuk National University, Jeonju, Korea*

Abstract: In this work, we tested in-flight gasification of livestock manure fuel powder by using a lab-scale three phase AC (Alternative Current) arc plasma torch system. For this pupose, sample powders were prepared by grinding livestock manure fuel pellet into the sizes of ~ 1mm and injected at feeding rate of 250 g/min into the central region of reactor by using 50 lpm air as a carrier gas. In the central region of reactor, three carbon electrodes are converging to generate the arc plasma, enabling in-flight gasification of the injected sample powder by keeping the reactor temperatures higher than 1000 ℃. For example, measurement results of off-gas concentration reveals that the sample powders were gasified with the contents of 27 %-CO, 17%-H_2 and 12%-CO_2 at the temperatures of ~ 1350 ℃.

Keywords: In-flight gasification, livestock manure fuel, three phase arc plasma

1. Introduction

Recently, plasma gasification processes have attracted much attention due to advantages in hydrogen content, tar content and cold gas efficiency compared with traditional gasifiers such as fluidized gasifiers[1]. For this purpose, various types of plasma torch have been employed including three phase AC (Alternative Current) arc plasma systems[1,2]. Compared with conventional DC (Direct Current) arc plasma torches, three phase AC arc plasma system can bring some advantages to the waste gasification process. First, air or steam can be used directly as a plasma forming gas when using carbon electrodes. Next, the carbon electrodes are convertible to useful chemicals, such as carbon monoxide, carbon dioxide or methane after erosion. In addition, the plasma forming gas can be injected into the central region where three electrodes are converging to generate the AC arc plasma. Since the AC arc plasma can heat the injected gases up to the temperatures of 1000 ~ 3000 ℃ depending on plasma power and gas flow rate[3], a cylindrical reactor coupled with a three phase AC arc plasma system can provide favorable thermal flow fields for waste gasification.

Based on this idea related to the structural adavantages of three phase AC arc plasma system, we test in-flight gasification of livestock manure fuel in this work by injecting fuel powder into the central region of the reactor. For this purpose, the plasma forming gas, air, is used as an oxidant for gasification as well as a carrier gas for fuel powders.

2. Experimental Set-up

Fig. 1 shows a lab-scale gasification test bed primarily consisting of an IGBT-inverter AC power supply which was connected to a three phase AC arc plasma torch, a cylindrical reactor with inner diameter of 150 mm and length of 500 mm, and an off-gas treatment system including heat exchanger, gas analyzer and scrubber. As illustrated in this figure, the three phase AC arc plasma torch was composed of three electrode units consisting of a graphite electrode with the diameter of 20 mm and a linear motion device to move it. Each electrode unit was inclined at 12.5 degree to the central axis to generate AC arc column inside the reactor

Table 1 presents CHNS analysis results of the waste sample, containing carbon, hydrogen and oxygen at the weight percentage of 29.97, 5.67 and 31.52, respectively. In addition, as shown in Fig. 2 for TGA data graph of the sample, most of carbon is predicted to be liberated at the temperatures higher than 650 ℃. The waste sample powders were prepared by grinding livestock manure fuel pellet into sizes of ~ 1 mm, and then, injected into the reator along the centreline for 5 minute at feeding rate of 250 g/min. Finally, Table 2 lists up the expereimental conditions for this in-flight gasification test.

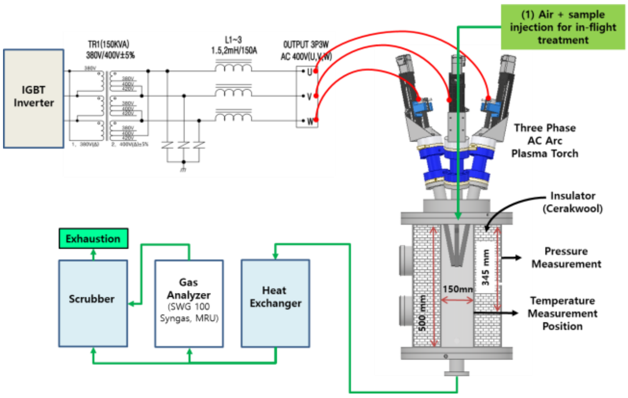

Fig. 1. A Schematic diagram of a lab-scale gasification test bed equipped with a three phase AC arc plasma sytem.

Table 1. CHNS Analysis results of the sample (Thermo Fisher Scientific, FlashSmart™ Elemental Analyzer).

Elements	C	H	O	N	S	Ash	Total
Content [wt/%]	29.97	5.67	31.52	3.95	0.54	28.35	100

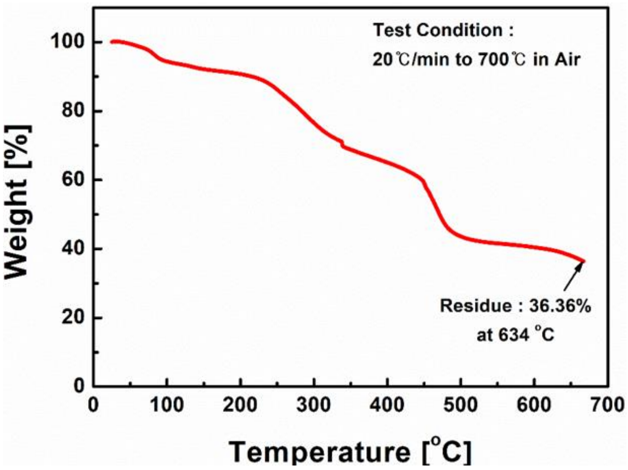

Fig. 2. Thermogravimetric Analysis (TGA) results of waste sample

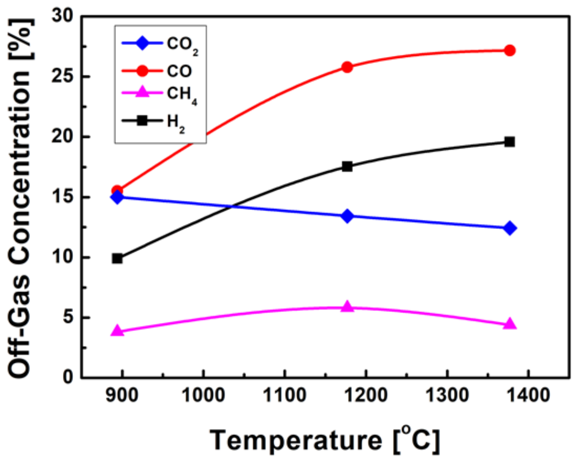

Fig. 3. Off-gas concentration variation according to the reactor temperatures.

Table 2. Experiemntal Conditions

Three Phase AC Arc Plasma	Frequency [Hz]	60
	Output Power [kW]	~25
Gasification Condition	Sample Feeding Rate [g/min]	~250
	Air Flow Rate [lpm]	0~50

3. Results and Discussion

Fig. 3 shows the off-gas concentrations according to the reactor temperatures. From this figure, it can be seen that as the temperature increases, the concentrations of CO and H_2 increase while the concentration of CO_2 decreases. The increases of CO and H_2 seem to be caused by steam gasification reaction ($C+H_2O \rightarrow CO+H_2$) at temeratures higher than 1000 ℃. In these temperatures, the solid carbon that was thermally decomposed from the waste sample can also be converted into CO from CO_2 through the Boudouward reaction, increasing CO and decreasing CO_2. These results of Fig. 3 indicate that the injected sample powder experienced chemical reactions for the synthesis gas as well as combustion during their flight of reator.

4. Conclusion

In this work, we experimented in-flight gasification of livestock manure fuel powder by using three phase arc plasma sytem. Due to the unique structure of three phase AC arc plasma torch, the fuel powders can be injected axially together with the plasma forming gas of air, then gasified with the contents of 27 %-CO, 17%-H2 and 12%-CO_2 at the temperatures higher than 1350 ℃. From these experimental results, it can be concluded that three phase AC plasma system can be used efficiently for quick and continuous gasification process by not only heating up the injected fuel powder in-flightly but also helping to keep high temperatures of gasifier.

5. References

[1] Y. G. Rueda, L. Helsen Biomass Conversion and Biorefinery. **10**, 857 (2020).
[2] L. Fulcheri, F. Fabry, S. Takali, and V. Rohani, Plasma Chemistry and Plasma Processing, **35**, 565 (2015)
[3] Y. Liu, M. Tanaka, T. Ikeba, S. Choi, and T. Watanabe, Journal of Chemical Engineering of Japan, **46**, 672 (2013)

6. Acknowledgements

This work was supported by grant (2021R1A2C201467) of the National Research Foundation (NRF) funded by The Ministry of Science and ICT (MSIT) and a grant (20229A10100120) of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) funded by The Ministry of Trade, Industry and Energy (MOTIE), Republic of Korea. This paper has been written with the support of Jeollannam-do (‘2020 R&D supporting program’ operated by Jeonnam Technopark).