CHAPTER

4

FLAME SPECTROSCOPY OF DUAL-FUEL BIODIESEL AND NATURAL GAS COMBUSTION

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4.1 INTRODUCTION

The gas turbine combined cycle (GTCC) power plants had outperformed coal power plants in the United States (US) since the year 2018 in terms of electricity production (United States Energy Information Administration [EIA], 2019a; 2019b). As of January 2019, the GTCC (Figure 4.1) generated 21 GW more electricity than the coal power plant in the US (EIA, 2019a; 2019b). This notable change in power generation plants is largely because coal has exceptionally high chances of polluting our living environment from its mining to consumption (Reddy, 2014).

As such, there has been a rising interest in fuelling the land-based electric generation gas turbine with liquid biofuels since the previous decade (Chiong et al., 2018). While the use of biofuels is currently slow-moving, it is expected to speed up in the near future as carbon taxes are imposed in more and more countries (Blakey et al., 2011). Biofuels, although renewable and sustainable, generally exhibit inferior physicochemical properties to conventional fossil-based energy sources

(Hoekman et al., 2012). This generally leads to less satisfactory combustion performances such as lower reactivity, poorer emissions performances, and aggravated flame instability.

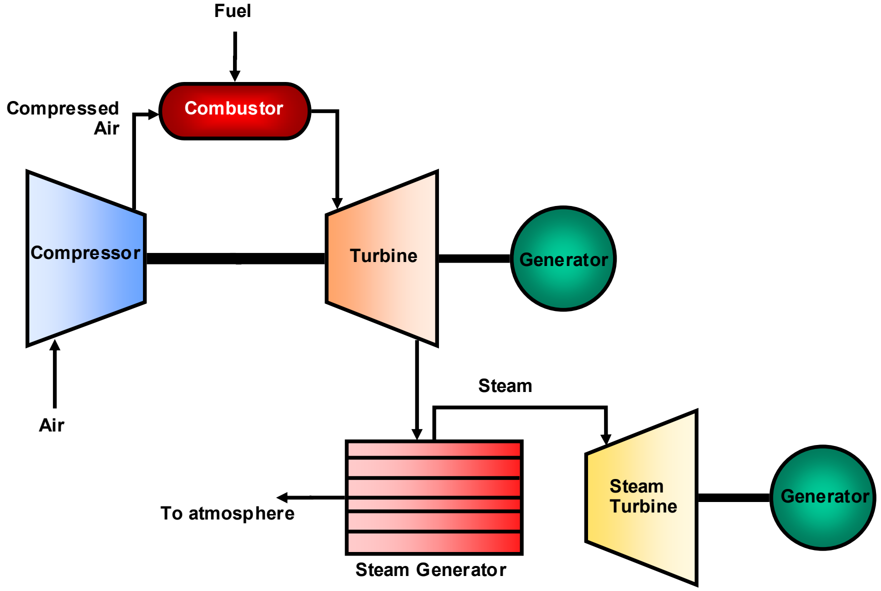

Figure 4.1 Schematic diagram of gas turbine combined cycle plant

A possible way of enhancing biofuels combustion is adopting the dual-fuel combustion strategy, whereby a relatively small quantity of secondary fuel with higher reactivity is used to support the combustion of less volatile primary biofuel (Kahila et al., 2019). The rising demands for biofuels have urged researchers to conduct extensive studies to enhance their combustion performances. This chapter examines flame spectra for biodiesel/natural gas (NG) dual-fuel combustion. Section 4.2 of this chapter presents published relevant works on dual-fuel gas turbine combustion. Section 2.3 delineates research method. Sections 4.4 and 4.5 discusses and concludes key-findings from this study, respectively.

4.2 PAST INSIGHTS AND CURRENT ADVANCES IN THE FIELD

Kurji et al. (2017) employed a generic gas turbine combustor to study the co-combustion of methane (CH_4)/biodiesel/carbon dioxide (CO_2). It was reported that when the CO_2 volumetric ratio was elevated by 10%, the emission of carbon monoxide (CO) declined by approximately 85%. Moreover, this also resulted in a nearly 55% of reduction in nitrogen oxide (NO_x). Jiang and Agrawal (2014) also used generic gas turbine combustors for their study. However, a flow-blurring atomiser instead of a typical ais-assisted atomiser was adopted for their study. The CH_4 was introduced to assist the combustion of very low volatile glycerol. It was unveiled that the existence of CH_4 raises glycerol droplet evaporation rate noticeably, leading to an increased glycerol reactivity. This was reflected by CO emission of dual-fuel combustion below 35 ppm (CO emission of neat glycerol was more than 50 ppm). Due to the lower reaction temperature in neat glycerin combustion, nitrogen oxide (NO) was reduced by a factor of 4.

Queiros, Costa, and Carvalho (2013) investigated swirl combustion of NG/crude glycerol/hydrogen (H_2) blend. Increased glycerol fraction in the fuel mixture was found leading to faster deposit formation in the combustor. Such deposition can reduce the life expectancy of the combustor. At fuel-lean operation where global flame equivalence ratio (φ) < 1, glycerol/NG/hydrogen combustion with 22/58/20 volumetric fraction led to lower NO emission than neat NG by nearly 15 ppm. However, at $\varphi = 0.5$, CO emission from the combustion of this fuel mixture was ~400 ppm higher than that of neat NG. Previous works on dual-fuel gas turbine combustion are scarce. Due to the limited understanding of biodiesel/NG dual-fuel combustion, this study aims to investigate the flame spectra for soy biodiesel soybean methyl ester (SME)/NG swirl combustion. Soy was chosen as biodiesel feedstock mainly because it is one of the common feedstocks for biodiesel production worldwide. NG is chosen as supplementary fuel primarily due to its considerably lower price compared to liquid fuels (Chiong et al. 2018).