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Review

A review on the laminar flame speed and ignition delay time of Syngas mixtures

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ABSTRACT

Syngas has shown great success in Integrated Gasification Combined Cycle (IGCC) technology for providing cleaner and higher efficiency energy production with minimal environment impact. Thus, it is promising that Syngas is able to replace the conventional fossil fuel resources, while at the same time minimizing pollutants. The drawback of traditional Gas Turbines that burn Syngas is that they use diffusion flame combustion technology that suffers from low efficiency and high emissions. Recently, Lean premixed combustion technique has emerged as a promising solution, but the variation of hydrogen fraction in Syngas has prohibited its usage. Besides, other gases such as CO_2, N_2, H_2O, NH_3, and CH_4 in Syngas have adverse effects on the combustion characteristics. To address these issues, better understanding of the Syngas's fundamental combustion properties are vital. Hence, recent works published on Syngas combustion at lean-premixed and Gas Turbine relevant conditions are reviewed, classified according to their objectives, and remarks were concluded.

1. Introduction

Combustion of conventional oil drives the required energy for industries. However, the constantly rising in crude oil price and pollutants emitted from fossil fuels combustion have led Gas Turbine manufacturers to search for renewable, environmental friendly and secure fuel supplies that will meet the ever stringent emission regulations. Syngas as an alternative fuel has recently drawn considerable amount of interest to Gas Turbines manufacturers because hydrogen is ubiquitous and burns without emitting unburned hydrocarbon, CO_2, and CO [1]. Integrated Gasification Combined Cycle (IGCC) power plants that combust Syngas have been in commercial operation for more than a decade [2] and they have proved to be capable of offering better energy efficiency and environmental performance compared to conventional coal fired power generators [3,4]. There is a potential to realize zero CO_2 emissions from IGCC power plants by implementing carbon capture and storage (CCS) techniques [5]. Furthermore, the gasification technology employed in the IGCC power plant allows a wide range of feedstocks such as municipal solid waste [6], agriculture residues [7–9], herbaceous energy crops [10–12], and others to be converted into Syngas.

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Table 1 – Available experimental kinetic data for the combustion of syngas fuel (ignition delay time).

Technique	Mixture	Conditions	Data type and comments	Ref.
Bunsen burner	H_2/CO/air	The laminar flame speed of H_2:CO (ratios from 0.25 to 4.0) were measured at atmospheric pressure and uncontrolled burner temperature, for equivalence ratios of 0.5–1.2.	Flame speed measured versus equivalence ratios (0.5–1.2) for H_2:CO ratios varied from 0.25 to 4.0.	[26]
Cylindrical chamber	H_2/CO/CO_2/O_2	The laminar flame speed of H_2/CO/CO_2 with $ZH_2 = 0.1–0.7$ ($ZH_2 = XH_2/(XCO + XH_2)$) and $Z = 0.4–0.7$ ($Z = XCO_2/(XCO_2 + XO_2)$) were measured at $P = 1$ and 2 atm and $T = 300$ K, for equivalence ratio of 0.4.	Flame speed measured versus H concentrations (0.1–0.7) for $Z = 0.4–0.7$.	[27]
Bunsen burner & Wall Stagnation Flame	H_2/CO/CO_2/air	The laminar flame speed of H_2:CO – 50:50 and 5:95 diluted with 0% and 20% of CO_2 were measured at $P = 1$ and 5 atm and $T = 300–700$ K, for equivalence ratios of 0.6–1.0.	Flame speed measured versus equivalence ratios (0.6–1.0) at atmospheric condition using bunsen method. Flame speed measured versus strain rate for equivalence ratios of 0.59, 0.6, 0.68, 0.78, and 0.8 using wall stagnation flame method.	[28]
Cylindrical bomb	H_2/CO/air and H_2/CO/O_2/He	The laminar flame speed of H_2:CO – 50:50, 25:75, 5:95, and 1:99 were measured at $P = 1$, 2, 5, 10, 20, and 40 atm, and $T = 298$ K, for equivalence ratios of 0.5–5.0.	Flame speed measured versus equivalence ratios (0.5–5.0) at six different pressures.	[31]
Cylindrical Chamber	H_2/CO/N_2/air	The laminar flame speed of H_2:CO – 50:50 diluted with 0%–60% of N_2 were measured at $P = 1$ atm and $T = 302$ K, for equivalence ratios of 0.6–3.5.	Flame speed measured versus equivalence ratios (0.6–3.5) at atmospheric condition for 0%–60% of N_2	[32]
Bunsen burner	H_2/CO/air	The laminar flame speed of H_2:CO ratios varied from 0 to 1 with increment of 0.1 were measured at atmospheric and ambient conditions, for equivalence ratios of 0.4–2.1.	Flame speed measured versus equivalence ratios (0.4–2.1) at standard conditions for 0%–100% of H_2. Flame speed correlation derived from the laminar flame speed data.	[33]
Cylindrical Chamber	H_2/CO/air	The laminar flame speed of H_2:CO – 50:50, 25:75, 10:90, and 5:95 were measured at atmospheric and ambient conditions, for equivalence ratios of 0.4–5.0.	Flame speed measured versus equivalence ratios (0.5–5.0) at standard conditions. Flame speed deduced using linear and non-linear extrapolation methodologies.	[34]
Bunsen Burner	H_2/CO/CO_2/N_2/air	The laminar flame speed of H_2:CO – 50:50 diluted with 0–20% of CO_2 and 0–60% of N_2 were measured at atmospheric pressure and ambient temperature (303 K), for equivalence ratios of 0.6–4.25.	Flame speed measured versus equivalence ratios (0.6–4.25) at atmospheric conditions.	[35]
Cylindrical bomb	H_2/CO/H_2O/O_2/He	The laminar flame speed of H_2:CO – 100:0 and 50:50 diluted with 0–15% of H_2O were measured at atmospheric pressure and $T = 323–423$ K, for equivalence ratios of 0.5–5.0.	Flame speed measured versus equivalence ratios (0.5–5.0) at atmospheric pressure.	[36]
Cylindrical chamber	H_2/CO/H_2O/air	The laminar flame speed of H_2:CO – 50:50 and 5:95 diluted with 0–20% of H_2O were measured at atmospheric pressure and $T = 298$, 400, and 500 K, for equivalence ratios of 0.6–3.0.	Flame speed measured versus equivalence ratios (0.6–3.0) for H_2:CO – 50:50 and 5:95 at atmospheric pressure, and $T = 298$, 400, and 500 K. Flame speed measured versus %H_2O in fuel mixture (0%–40%) for equimolar H_2:CO and 5:95 at $P = 1$ atm and $T = 400$ K.	[37]
Shock tube	H_2/CO/O_2/Ar	H_2:CO –10:90, 20:80, 40:60, 50:50, and 80:20 diluted in 98% of Ar were ignited at $\phi = 0.5$, $P = 1.6$, 12, and 32 atm, and $T = 960–2000$ K	Ignition delay measured versus temperature (960–2000 K) at one equivalence ratio. Pressure profile recorded versus time for $T = 1375$ K at 1.65 atm	[40]