Experimental study of hydrogen, syngas and methane ignition in CO_2 bath gas

Touqeer Anwar Kashif, James M. Harman-Thomas, Kevin Hughes, Aamir Farooq

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology
Clean Combustion Research Center

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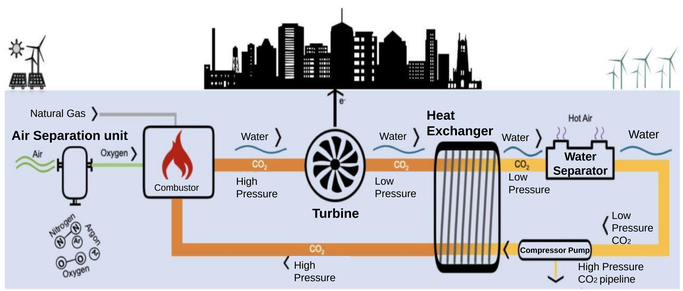
Aim & Objective

- Perform ignition delay time measurements for three fuels (H_2, syn gas, and H_2/CH_4 blend) at CO_2 dilution conditions.
- Validation and modeling of two detailed chemical kinetic mechanisms (AramcoMech 2.0 and UoS sCO_2).

Background and Motivation

- The burning of coal for electricity contributes to global warming by releasing CO_2 into the atmosphere.
- Alternative strategies exist to produce electricity one of which is the Direct-fired super critical cycle.
- Allam Fetvedt cycle is a best working example of a direct-fired super critical cycle.

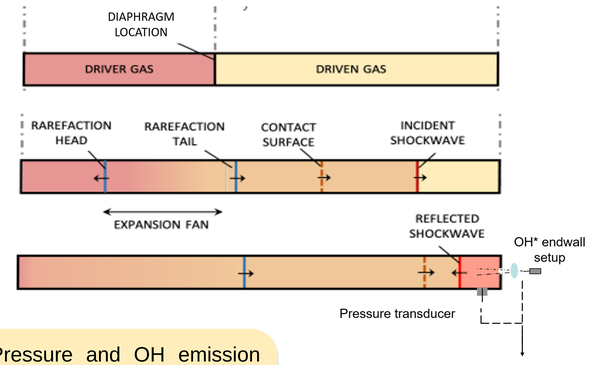
Working principle of Allam-Fetvedt cycle



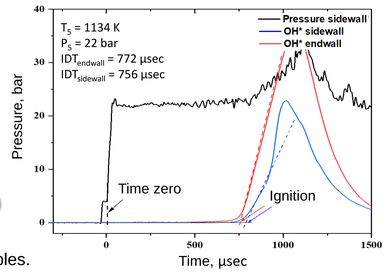
- Allam's cycle captures all exhaust gases and feeds them back into the combustion chamber.
- In the absence of nitrogen as a diluent, NOx emissions are completely eliminated.
- As of now, multiple pilot plants have been built up to 300 MW.
- Ignition studies in CO_2 as bath gas are scarce in literature, inhibiting the development and validation of chemical kinetic mechanisms.

Ignition delay time measurements

- Ignition delay time (IDT) is defined as the time the fuel/oxygen mixture takes to ignite after attaining high pressure and temperature.
- IDTs were measured in the KAUST's high pressure shock tube at 20 bar of pressure.



- Pressure and OH emission at the sidewall/endwall of the shock tube were recorded to determine the time zero and the onset of ignition



Mixtures investigated

Mole fraction of reactants are listed in the tables.

H_2 mixtures

S. No	H_2	O_2	N_2	CO_2
1	10	5	85	0
2	10	5	35	50
3	10	5	0	85

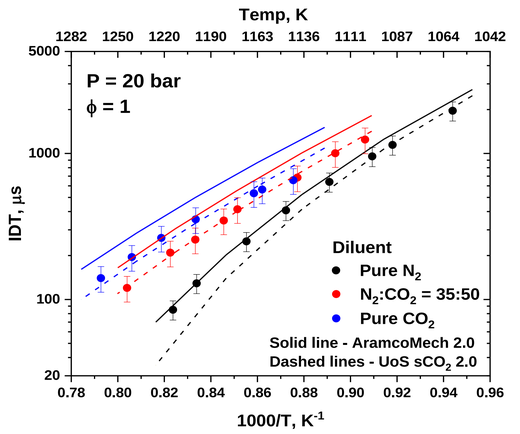
Syngas mixtures

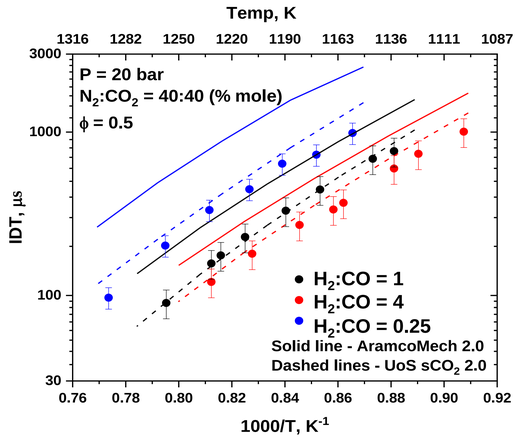
S. No	H_2	CO	O_2	N_2	CO_2
1	8	2	10	40	40
2	5	5	10	40	40
3	2	8	10	40	40

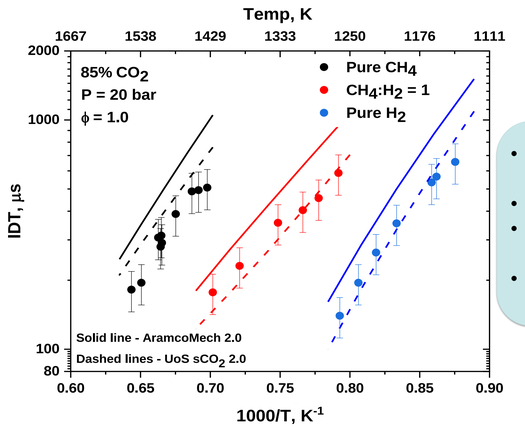
H_2/CH_4 blends

S. No	H_2	CH_4	O_2	CO_2
1	0	5	10	85
2	3.4	3.4	8.2	85
3	10	0	5	85

Results - IDTs







Summary

- CO_2 addition lowers the reactivity of the mixture, evident from higher IDTs of H_2 mixture.
- H_2 is more a reactive fuel than CO.
- In an H_2:CH_4 blend, pure H_2 mixture is the most reactive mixture.
- CH_4 addition slows down the reactivity quite significantly.

Ongoing work

- Extensive investigation on the performance of chemical kinetic mechanisms by performing sensitivity analysis to determine the key reactions controlling the IDTs.
- Updating the rates of key reactions in AramcoMech 2.0 from literature and modifying the mechanism to improve its performance for CO_2 diluted mixtures.