Master Thesis
Lean burning of a renewable fuel such as syngas

Premixed or partially premixed turbulent combustion processes are widely used in ground transportation (e.g., car engines), aviation (e.g., aero-engine afterburners), and stationary power generation (e.g., gas turbines) worldwide and, in particular, in Sweden (e.g., Volvo Car, Siemens, etc.). To satisfy stringent requirements for ultra low emission and highly efficient combustion technology and to secure the sustainable growth of the European industry under the conditions of the increasing instability of the oil market, new solutions are strongly needed. In particular, the use of renewable fuels is an important trend of the EU and Swedish energy strategies, aimed at securing the European and Swedish society from increasing ecological and economical risks associated with the usage of conventional hydrocarbons such as oil and natural gas.

Since combustion in engines occur in the turbulent regime, profound knowledge about influence of turbulence on flames is required to effectively burn renewable fuels and to assess the advantages and disadvantages of using them. As far as a renewable fuel such as syngas ($CH_4/CO/H_2$ blend) is concerned, the most important and challenging feature of lean turbulent syngas-air flames consists of abnormally high (when compared to common paraffin/air mixtures) turbulent burning rates. This phenomenon is well documented in various experiments, but still strongly challenges combustion models. A promising approach to predict the phenomenon is based on a hypothesis that turbulent burning rate is controlled by characteristics of highly perturbed laminar flames, rather than by characteristics of unperturbed laminar flames, which are used by the vast majority of available models.

The present project aims at assessing this hypothesis and a newly developed model based on it in steady 2D RANS simulations of recent experiments performed in China (Xi'an Jiaotong Technical University, XJTU).

The following issues should be addressed within the framework of the project:

- What are the major physical mechanisms of the influence of turbulence on premixed combustion?
- What methods and models are available for computing turbulent flame speeds and what modifications of these methods and models are required to study lean syngas-air mixtures?
- What kinds of physical data are required for such numerical studies and how can they be generated?
- How can experimental data on turbulent flame speeds be used to test results of numerical simulations?

Project description: More specifically,

- Software CHEMKIN-PRO and a CFD package Open-FOAM or Converge will be learnt.
- Highly perturbed laminar syngas-air flames will be simulated using a detailed chemical mechanism and CHEMKIN-PRO for mixture compositions investigated in the XJTU experiments.
- Computed characteristics of the highly perturbed laminar flames will be used as input parameters for steady 2D RANS simulations of the XJTU experiments with turbulent flames.
- Finally, the obtained results will be compared with the experimental data, will be summarized in a report (and/or, eventually, a paper), and will be presented orally at a seminar.

Suitable background: Studying a master program related to thermodynamics, chemistry, internal combustion engines, or fluid mechanics from e.g. mechanical, chemical, or automotive engineering. Interest and knowledge on turbulent flames and combustion chemistry is an advantage, but not a prerequisite. We will learn a lot about combustion chemistry and turbulent flames during the project.

Thesis level: Master, 20 weeks (30 HP) per student.

Language: English

Starting date: Flexible

Number of students: Two. One will run simulations of laminar flames using Open-FOAM, another will simulate turbulent flames using Open-FOAM or Converge.

Miscellaneous: Do not hesitate to contact us if you would like additional information. Please provide covering letter and CV in your application.

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