Metody Komputerowe w Spalaniu
Project - Laminar Flame Speed Calculations Using Cantera

Mikołaj Dżugaj

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1 Introduction

Laminar flame speed is the propagation rate of the normal flame front relative to the unburned premixed mixture at low Mach number. Its value is solely dependent on stoichiometric composition of the fuel-air mixture, temperature and pressure at the moment of ignition. It is an important parameter for fuels used in engines, as higher speed results in higher efficiency. Laminar flame speed is usually determined experimentally - by visual measurment of spherical flame propagation in test chamber. In this project its value is calculated using Cantera software. Flame is simulated via FreeFlame class and calculations are repeated for a series of equivalence ratios.

2 Literature

Main sources of knowledge about thermodynamics for this project were:
book "Biojet Fuel in Aviation Applications"by Cheng Tung Chong and Jo-Han Ng.
lecture "Laminar Premixed Flames: Kinematics and Burning Velocity"by Prof. Dr.-Ing. Heinz Pitsch
tutorial "One-Dimensional Flame"by David G. Goodwin

Informations about Cantera calculations were gathered from following websites:
https://cantera.org/science/flames.html
https://cantera.org/examples/jupyter/flames/flame_speed_with_sensitivity_analysis.ipynb.html
https://cantera.org/documentation/docs-2.0/doxygen/html/classCantera_1_1FreeFlame.html

3 Mathematical model

Laminar Flame Speed was calculated for ethylene-air mixture using a set of governing conservation equations:

Continuity:

$$\frac{d(\rho u)}{dz} = 0$$

Species:

$$\rho u \frac{dY_i}{dz} = -\frac{dj_i}{dz} + W_k \dot{\omega}_k$$

Energy:

$$\rho c_p u \frac{dT}{dz} = \frac{d}{dz}\left(\lambda \frac{dT}{dz}\right) - \sum_k j_k c_{p.k} \frac{dT}{dz} - \sum_k h_k W_k \dot{\omega}_k$$

Initial conditions:
T = 298K
p = 1atm
Range of equivalence ratios:
$0.7 < \phi < 1.3$

4 Results

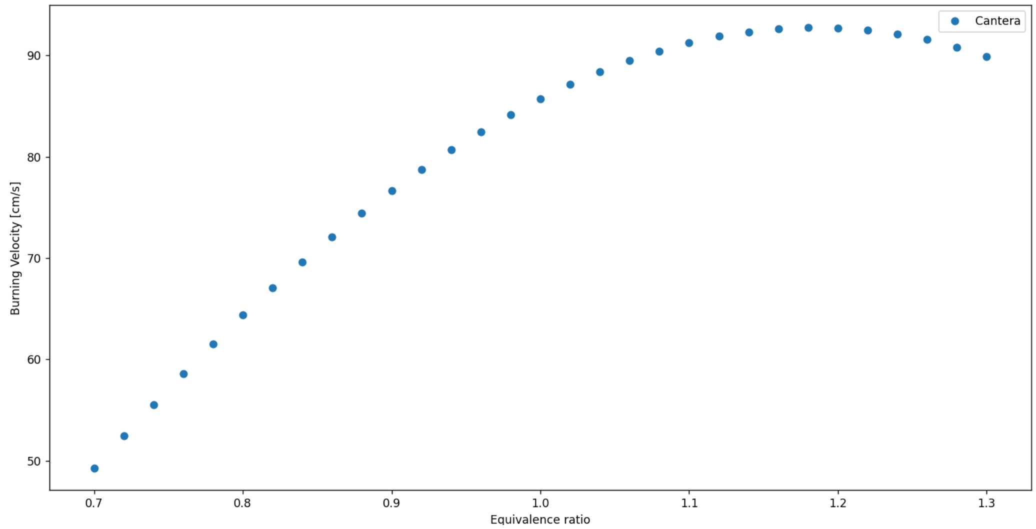

Chart 1. Effect of equivalence ratio on laminar flame velocity

Highest flame speed was calculated at equivalence ratio 1.18 and equals 92.77 cm/s.

5 Summary

Calculations resulted in maximal value slightly higher than ones usually seen in literature, which range between 70 and 80 cm/s. The peak of the chart is between equivalence ratios 1 and 1.3, which is typical for most fuels.