1-D flame speed analysis for methane and hydrogen combustion mechanism

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Contents

1 Introduction

The main purpose of the project was to learn how to conduct analysis and how to perform calculations in cloud computing. Nowadays, this type of performing calculations is getting more and more popular because of oportunities it gives to user.

Cloud computing is the on-demand availability of computer system resources (data storage and computing power) without direct active managment by the user [4]. It relies on sharing the resources for user. Cloud computing a is service which cost depends, among other things, on the used resources, the requirements for the speed of performed calculations and amount of stored data.

In this particular project Microsoft Azure - Cloud Computing Services has been used to conduct analysis of 1-D flame speed for methane and hydrogen combustion mechanism. The type of used computing cloud was "1 X Standard B1S".

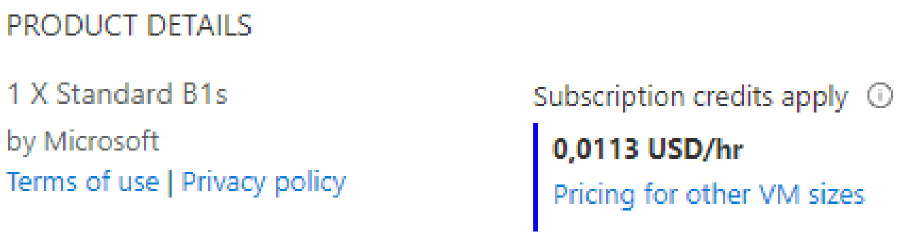


Figure 1.1: Type of used computing cloud

2 Description of the model

The analysis starts with writing down the equation of combustion of yhe mathane and for the next case the combustion equation for the hydrogen. For these project, we consider an equivalence ration of 0.9 (lean mixture).

Methane: $0.9CH_4 + 2(O_2 + 3.76N_2) \rightarrow 0.9CO_2 + 1.8H_2O + 7.52N_2 + 0.2O_2$

Hydrogen: $1.8H_2 + O_2 + 3.76N_2 \rightarrow 1.8H_2O + 3.76N_2 + 0.1O_2$

The initial pressures are set to 1, 2, 3, 4 atm and initial temperatures are set to 300, 325, 350, 375 and 400 K for different cases for both methane and hydrogen. The length of the domain is 0.05 m.

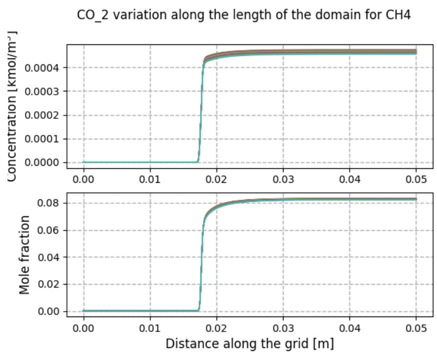
The Cantera solver obtains a solution for a coarse grid using the Newton-Raphson method. The solution is then monitored for gradients and curvature and subsequent grid refirement is done at the points of interest. The mechanism we use is the gri30.xml.

3 Literature

The flame speed and its temperature depends on the percentage of the elements in the mixture, the equivalence ratio and the initial conditions. The first factor affecting flammability is the mole fractions of the species in the mixture. The closer to the stoichiometric composition the better combustion conditions. If mixture is too lean or too rich it could be hard to combust it. The same applies to the equivalence ratio which corresponds to combustion under stoichiometric conditions [2]. The initial conditions are pressure and the temeprature at the start of the combustion. The adiabatic temperature of the flame is the temperature that occurs when during combustion without heat loss. For methane-oxygen mixture the temperature is 2233 K and for hydrogen-oxygen mixture it is 2365 K (according to [1]).

4 Results

4.1 Methane- oxygen mixture



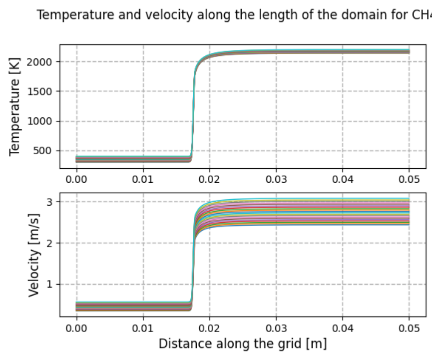
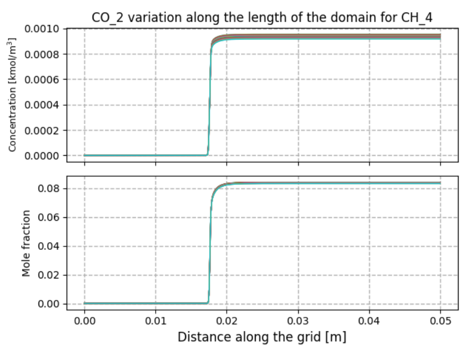


Figure 4.1: Methane- oxygen, p = 1atm, variation of CO_2

Figure 4.2: Methane- oxygen, p = 1atm, temperature and velocity



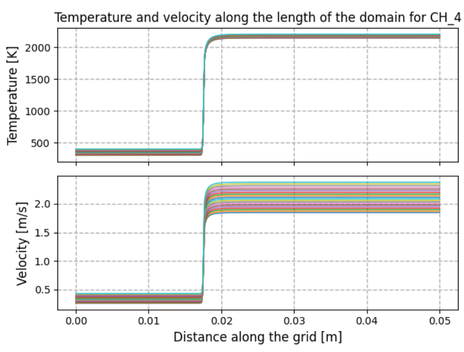
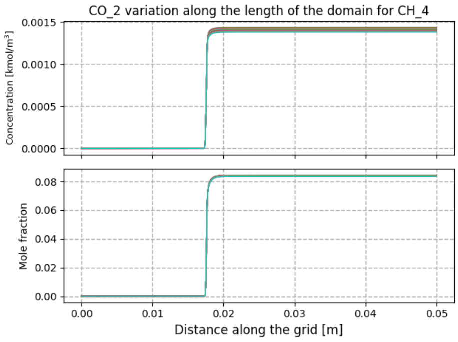


Figure 4.3: Methane- oxygen, p = 2atm, variation of CO_2

Figure 4.4: Methane- oxygen, p = 2atm, temperature and velocity



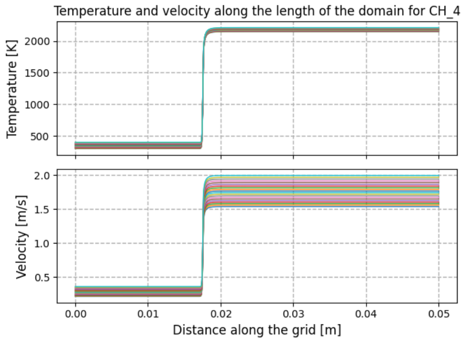
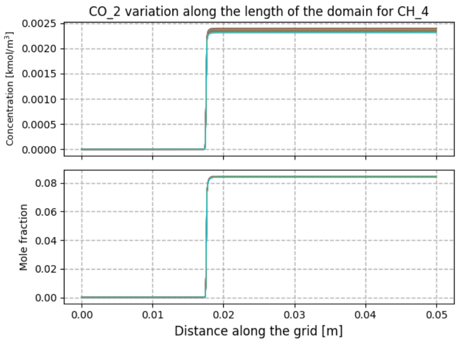


Figure 4.5: Methane- oxygen, p = 3atm, variation of CO_2

Figure 4.6: Methane- oxygen, p = 3atm, temperature and velocity



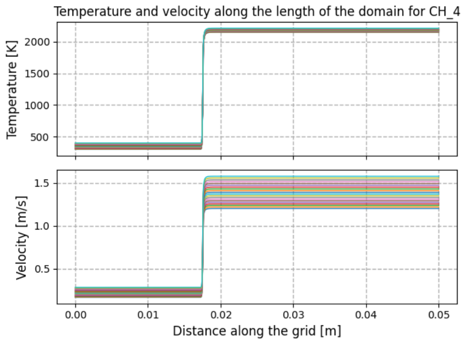
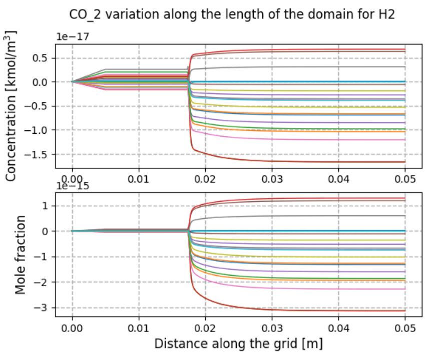


Figure 4.7: Methane- oxygen, p = 4atm, variation of CO_2

Figure 4.8: Methane- oxygen, p = 4atm, temperature and velocity

The graphs clearly show that the temperature and velocity increase rapidly about 0.017m from the begging of the domain. The temperature reaches about 2300 K. Shortly after the increase both parameters stabilize at a constant levels. The CO_2 variation along the length of the domain increases at the same point and in the same way as prevoiusly mentioned parameters.

4.2 Hydrogen- oxygen mixture



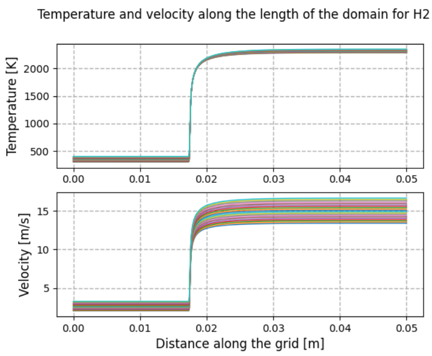


Figure 4.9: Hydrogen- oxygen, p = 1atm, variation of CO_2

Figure 4.10: Hydrogen- oxygen, p = 1atm, temperature and velocity

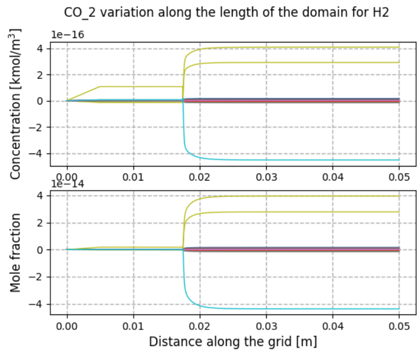


Figure 4.11: Hydrogen- oxygen, p = 2atm, variation of CO_2

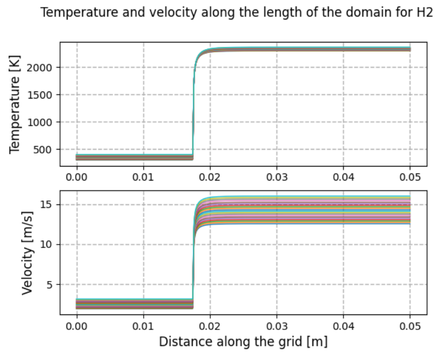


Figure 4.12: Hydrogen- oxygen, p = 2atm, temperature and velocity

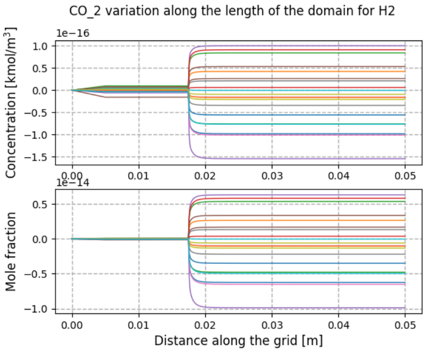


Figure 4.13: Hydrogen- oxygen, p = 3atm, variation of CO_2

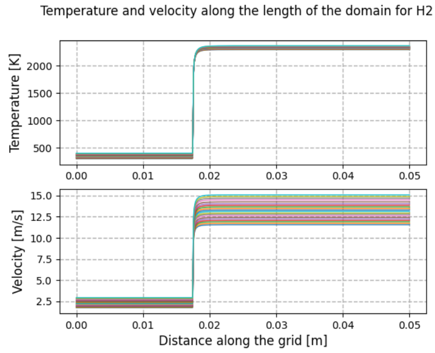


Figure 4.14: Hydrogen- oxygen, p = 3atm, temperature and velocity

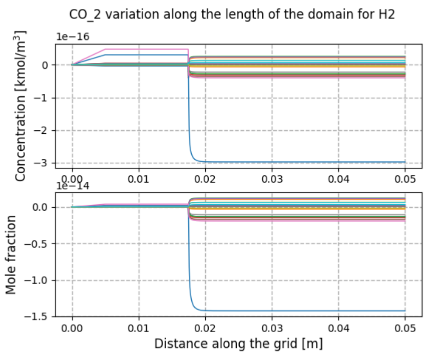


Figure 4.15: Hydrogen- oxygen, p = 4atm, variation of CO_2

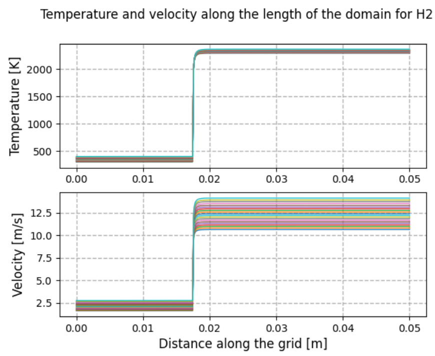


Figure 4.16: Hydrogen- oxygen, p = 4atm, temperature and velocity

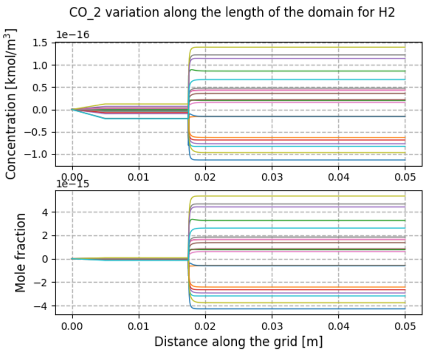


Figure 4.17: Hydrogen- oxygen, p = 5atm, variation of CO_2

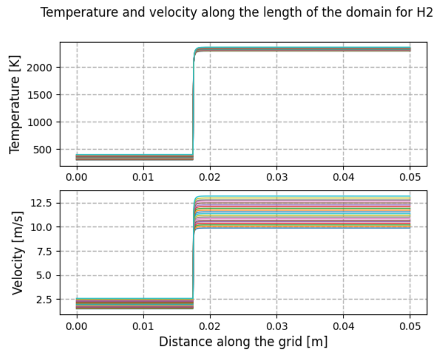


Figure 4.18: Hydrogen- oxygen, p = 5atm, temperature and velocity

The charts show the temperature and flame velocity increase dramatically for all cases. The graphs of the CO_2 variation along the length of the domain have different course depending on the initial temperature and pressure but the course of chart is unreliable.

5 Conclusions

During analysing of the graphs above you can see that the velocity of the flame accelerate proportionally to the initial temperature. The flame speed of the hydrogen- oxygen mixture is much higher than the flame speed of methane- oxygen mixture, which agrees with the literature values and the fact that hydrogen has a higher speed of laminar combustion than methane ([1]).

When examining the temperature graphs you can see that the temperature rises more rapidly for higher initial temperature.

The same conclusion comes during analysing the CO_2 variation along the length of the domain for the methane. The graphs for the hydrogen have an unstable course which can be caused by the gri30.xlm mechanism. That mechanism has been optimized for the combustion of hydrocarbones. What is more the CO_2 variation along the length of the domain for hydrogen shows that the hydrogen combustion occurs more aggressively than the methane combustion.

6 Cloud computing

Cloud computing could be useful tool for user. It processes data without the software instaled on private hardware. Cost saving, high computing power, mobility are some of potential benefits. This way of performing calculations is perfect if you need to use high computing power sporadically because you don't have to buy hardware and pay for cloud computing only for usage (pay-per-use manner) [5].

For this project conducting analysis with cloud computing was uneffective. Calculation time was longer than calculation conducted on private PC. That was the consequence of selected option of product.

7 Sources

[1] ”Adiabatyczna temperatura plomienia oraz prędkość spalania laminarnego dla mieszanin $CH_4/H_2/$powietrze"- W.Jerzak

[2] "Fundamental studies of premixed combustion"- Md. Z. Haq

[3] $https://skill-lync.com/projects/1-D-flame-speed-analysis-for-methane-and-hydrogen-combustion-mechanisms-using-Python-and-Cantera-27950?fbclid=IwAR1-ddZpbV-Wej_6jA7o_t0b2mV0GFZ-ak2cPs4xUZ3wWCBoxg5puDugznI$

[4] "An Introduction to Dew Computing: Definition, Concept and Implications" $https://ieeexplore.ieee.org/document/8114187$

[5] "Where's The Rub: Cloud Computing's Hidden Costs" $https://www.forbes.com/sites/$ $the-rub-cloud-computings-hidden-costs/?sh=32bee02d5f00$

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