WYDZIAŁ MECHANICZNY ENERGETYKI I LOTNICTWA
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# PROJECT 1
# Combustion parameters for propane-air mixture

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15.04.2019

# Contents

# 1 Introduction

The aim of this project was to observe the process of burning a propane-air mixture and influence of initial parameters on this process. Four burning parameters for different initial parameters were calculated in Cantera program. The results were presented on graphs (four graphs for each experiment) showing dependencies between time and:

- temperature
- hydrogen mole fraction
- oxygen mole fraction
- propane mole fraction

The experiment was divided into three sections. In each section two initial parameters were defined in the beginning and remained constant, and the other parameter was changed for each experiment in a section. It allows to observe the influence of every parameter individually.

An assumed simplification was that the air in burning reaction consists of oxygen and nitrogen only and their ratio is 1:3,76. With this assumption stoichiometric chemical reaction takes the following form:

$$C_3H_8 + 5(O_2 + 3,76N_2) \longrightarrow 3\mathrm{CO}_2 + 4H_2O + 18.8N_2$$

Assuming that combustion is complete and that nitrogen does not take part in combustion and doea not convert into $NO_x$

# 2 Variable pressure

In this section four experiments were run. The temperature and the equivalence ratio were constant and equal to:

T=1000K
$\phi = 0.5$

The pressure was different for each experiment

## 2.1 p=50000Pa

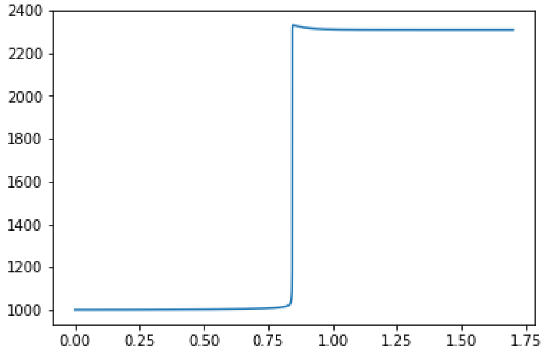


**Figure 1:** T [K]

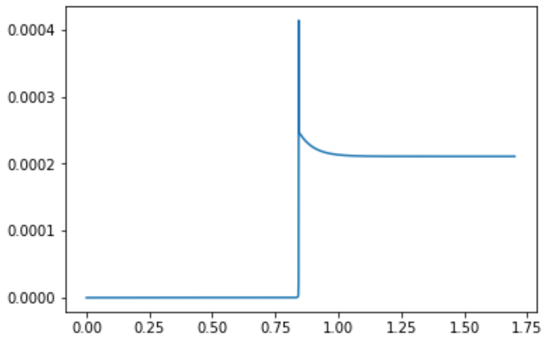


**Figure 2:** H mole fraction

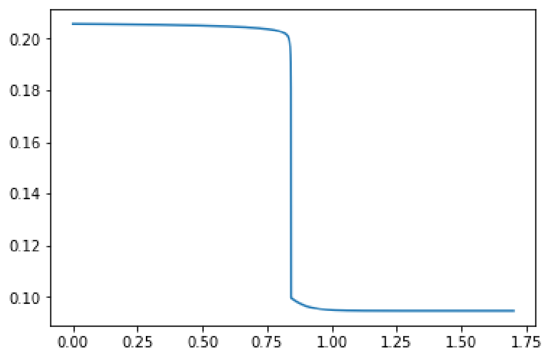


**Figure 3:** $O_2$ mole fraction

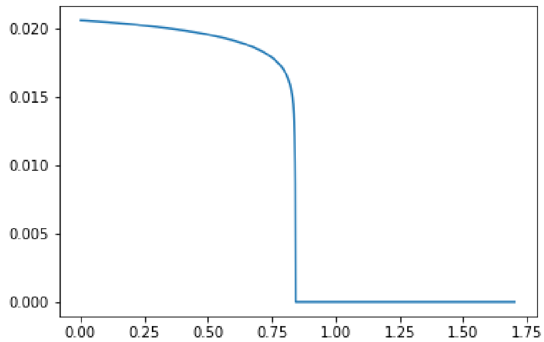


**Figure 4:** $C_3H_8$ mole fraction

## 2.2 p=150000Pa

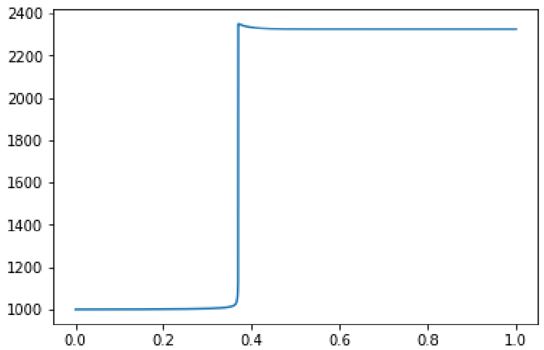


**Figure 5:** T [K]

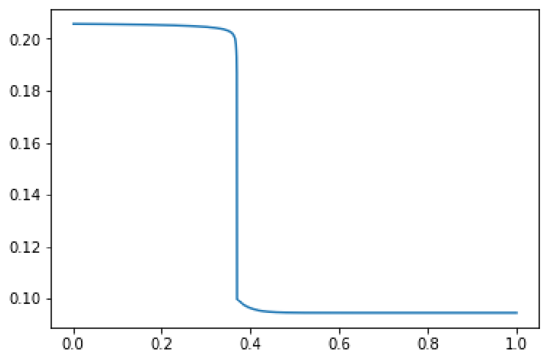


**Figure 6:** $O_2$ mole fraction

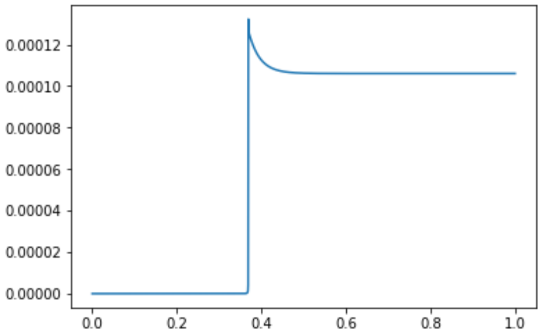


**Figure 7:** H mole fraction

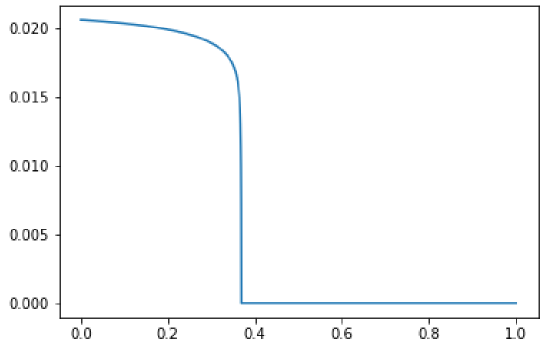


**Figure 8:** C3H8 mole fraction

## 2.3 p=300000Pa

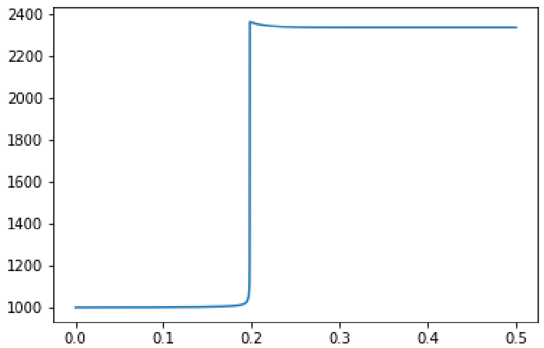


**Figure 9:** T [K]

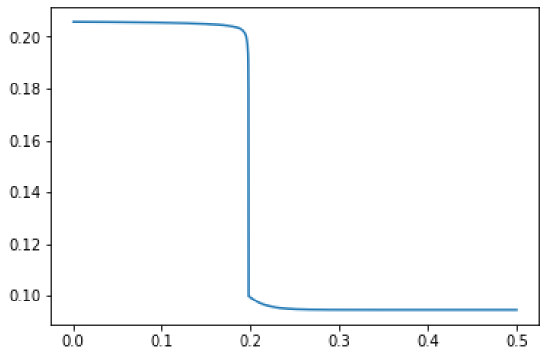


**Figure 11:** $O_2$ mole fraction

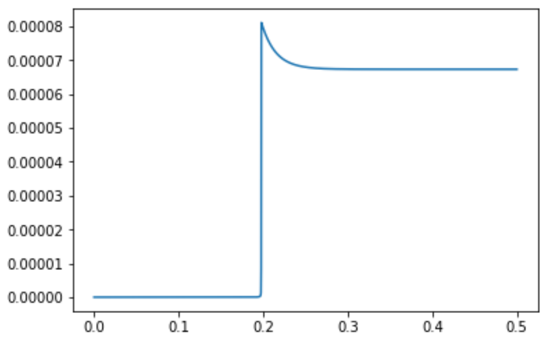


**Figure 10:** H mole fraction

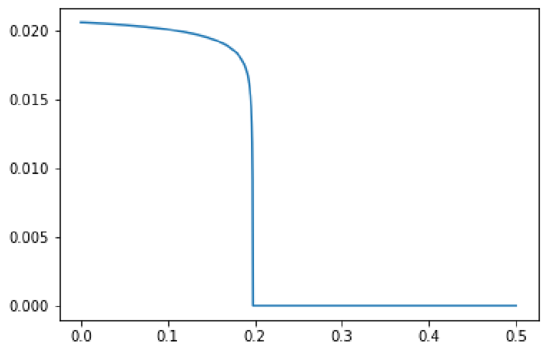


**Figure 12:** $C_3H_8$ mole fraction

## 2.4 p=600000Pa

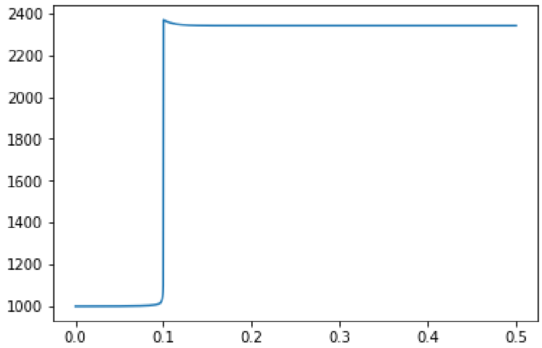


**Figure 13:** T [K]

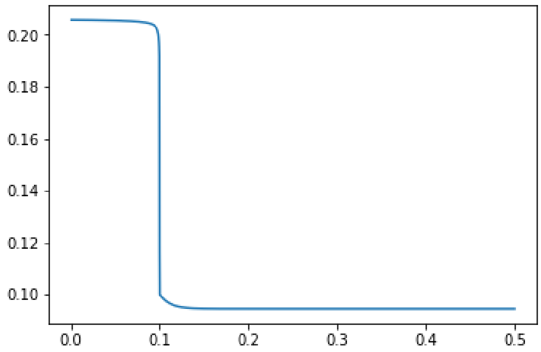


**Figure 15:** $O_2$ mole fraction

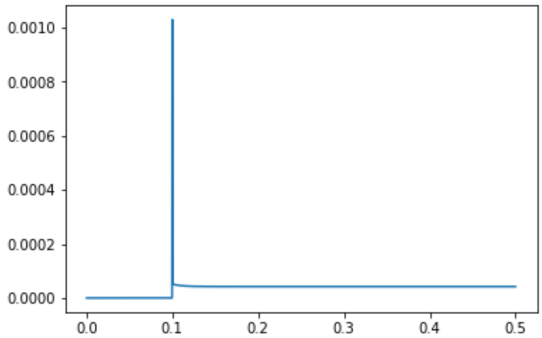


**Figure 14:** H mole fraction

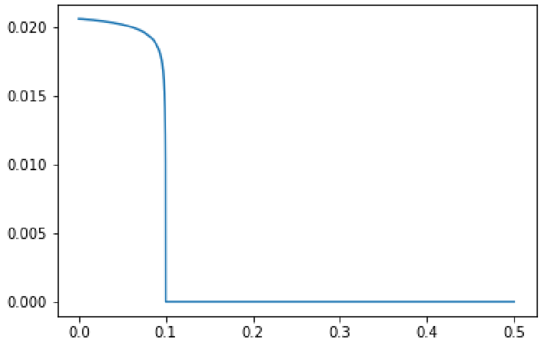


**Figure 16:** $C_3H_8$ mole fraction

We can see that the higher the initial pressure, the faster the combustion occurs. In fourth experiment the initial pressure is 12 times higher than in the first one and the combustion in the fourth one takes place circa 8 times faster than in the first one.

The miximum temperatures in all experiments are similar (circa 2350K), which means that initial pressure has no influence on maximum combustion temperature.

Characteristics all similar accept for hydrogen mole fraction characteristic. The maximum value (the peak) and the output value (when returns to const.) decreases as the pressure increases. The exceptence is the last experiment for which the max value is the highest of all.

# 3 Variable temperature

In this section four experiments were performed. The pressure and the equivalence ratio were constant and equal to:

p = 101325Pa = 1atm
$\phi = 1$

The temperature was different for each experiment.

## 3.1 T=900K

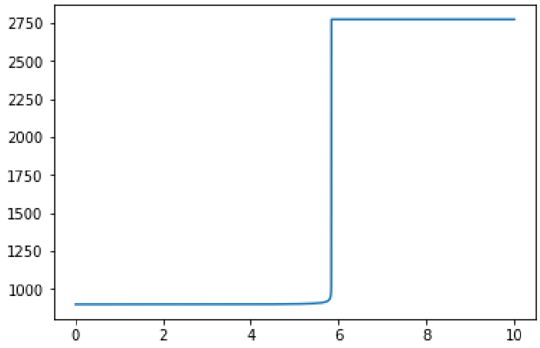


**Figure 17:** T [K]

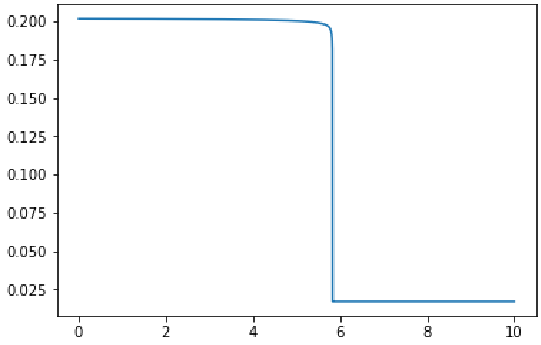


**Figure 19:** $O_2$ mole fraction

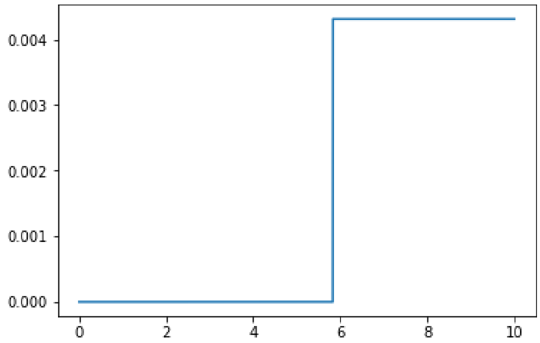


**Figure 18:** H mole fraction

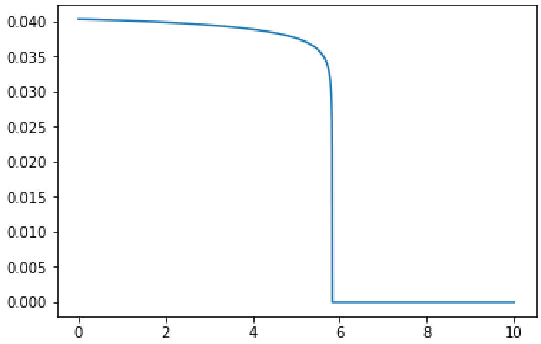


**Figure 20:** $C_3H_8$ mole fraction

## 3.2 T=1000K

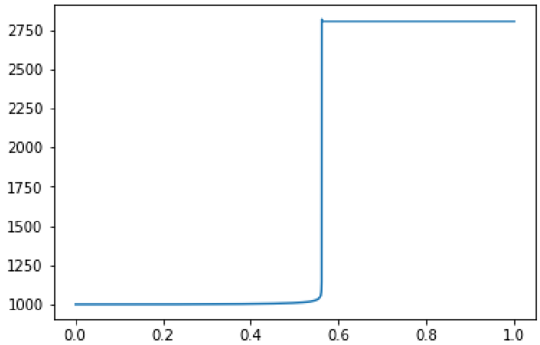


**Figure 21:** T [K]

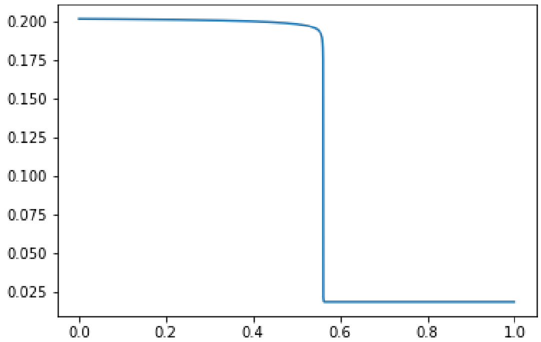


**Figure 22:** $O_2$ mole fraction

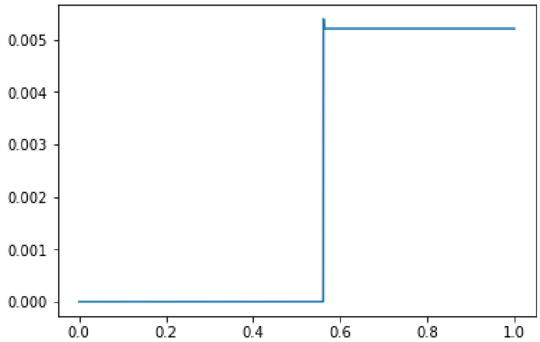


**Figure 23:** H mole fraction

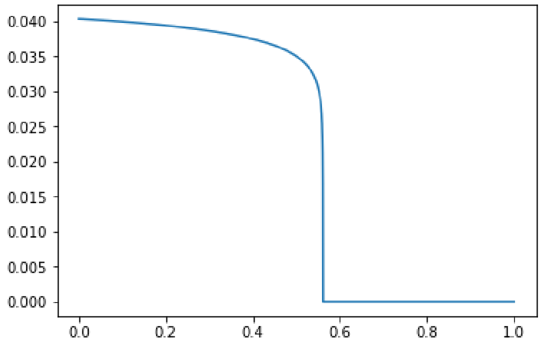


**Figure 24:** $C_3H_8$ mole fraction

## 3.3 T=1100K

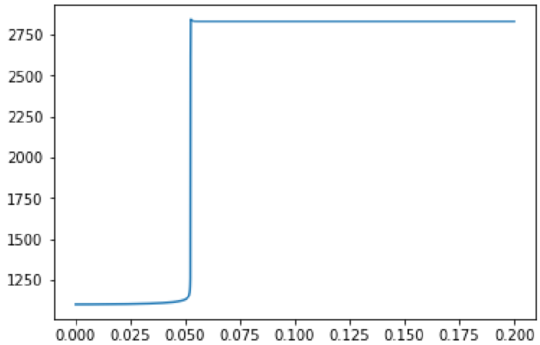


**Figure 25:** T [K]

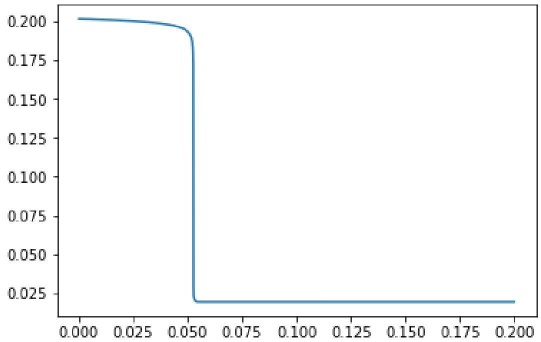


**Figure 26:** $O_2$ mole fraction

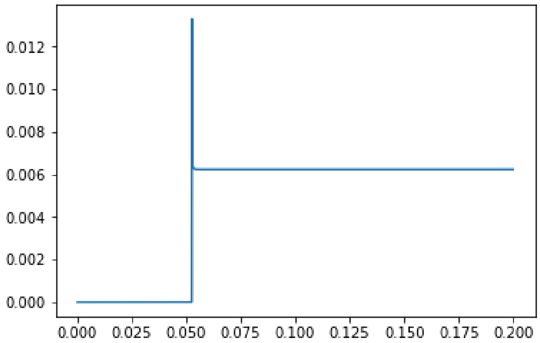


**Figure 27:** H mole fraction

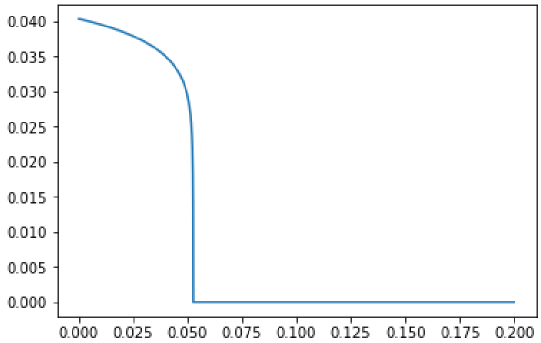


**Figure 28:** $C_3H_8$ mole fraction

## 3.4 T=1200K

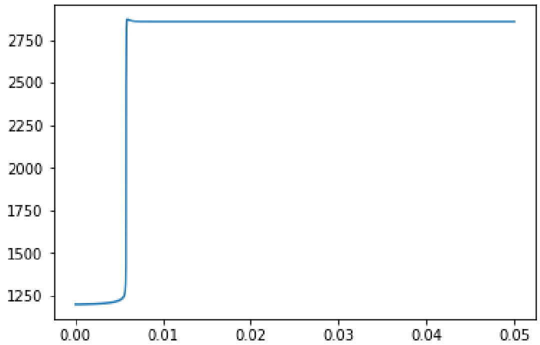


**Figure 29:** T [K]

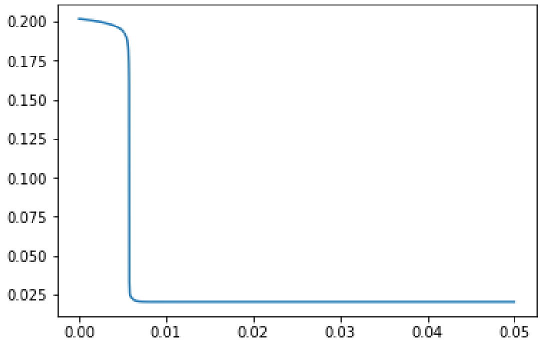


**Figure 31:** $O_2$ mole fraction

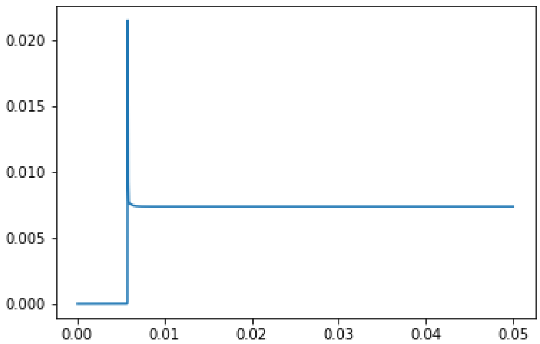


**Figure 30:** H mole fraction

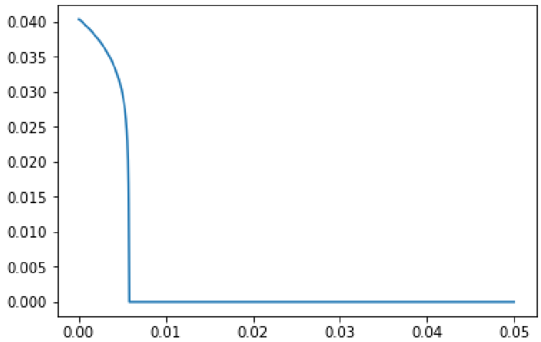


**Figure 32:** $C_3H_8$ mole fraction

As with the pressure, higher initial temperature causes faster combustion of the mixture. Temperatures difference 300K causes delay to increase circa 100 times.

We can observe a minor differences in maximum temperature value caused by peaks or lack of them in the moment of combustion.

A major difference is visible on 'H mole fraction' graphs. The higher the initial temperature, the greater H mole fraction peak as well as const. value after combustion are.
In the first experiment there is no step change after combustion on any graph. We can assume that the process is more stable, when initial temperature is lower.

# 4 Variable equivalence ratio

In this section five experiments were run. The pressure and the temperature were constant and equal to:

p = 101325Pa = 1atm
T = 1000K

The equivalence ratio was different for each experiment.

The graphs for the same initial parameters (T=1000K, p=1atm) and stoichiometric mixture $\phi = 1$ were already presented in section Variable temperature (Figures 21-24).

Air to fuel ratio for stoichiometric mixture:
$(A/F)_{stoich} = \frac{5*2*16+5*2*3,76*14}{3*12+8*1} = 15,6$

According to literature flammability limits for propane in air are:
LFL=2,1%
UFL=9,5%

Air to fuel ratio for LFL and UFL mixtures
$(A/F)_{LFL} = \frac{1-0,021}{0,021} * 0,59 = 27,05$
$(A/F)_{UFL} = \frac{1-0,095}{0,095} * 0,59 = 5,62$

Equivalence ratios for 2,1% and 9,5% mixtures:
$\phi_{LFL} = 0,577$
$\phi_{UFL} = 2,78$

That means that theoretically propane-air mixture is flammable for $\phi$ greater than 0,577 but not greater than 2,78.

## 4.1 $\phi = 0.1$

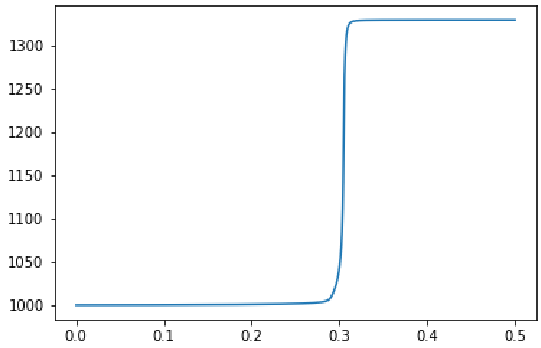


**Figure 33:** T [K]

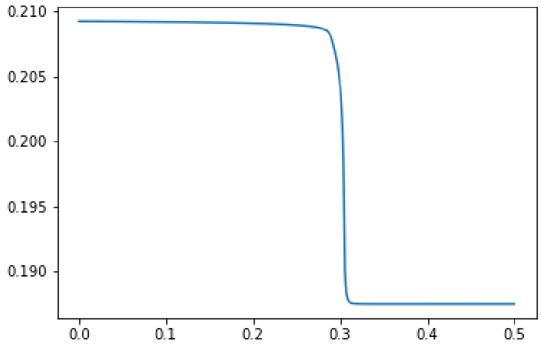


**Figure 35:** $O_2$ mole fraction

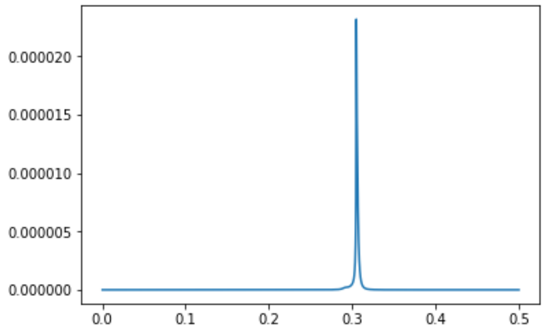


**Figure 34:** H mole fraction

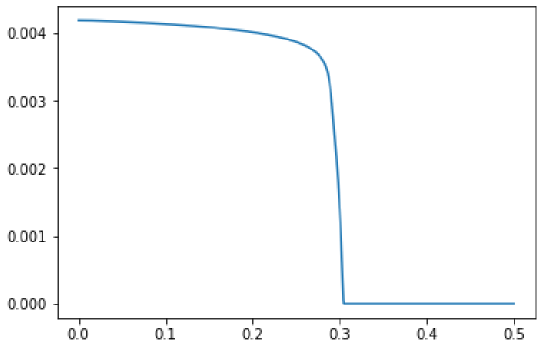


**Figure 36:** $C_3H_8$ mole fraction

## 4.2 $\phi = 0.75$

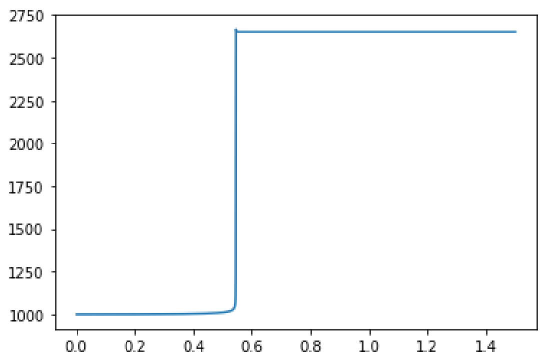


**Figure 37:** T [K]

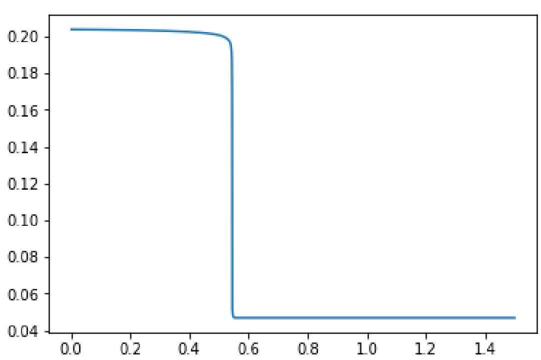


**Figure 38:** $O_2$ mole fraction

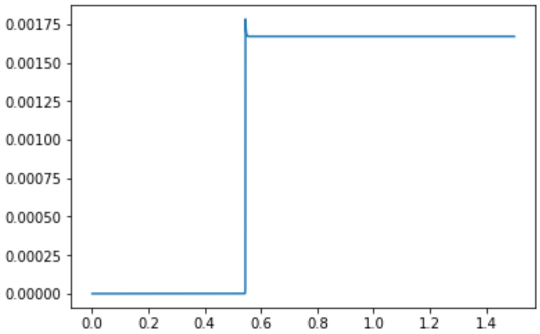


**Figure 39:** H mole fraction

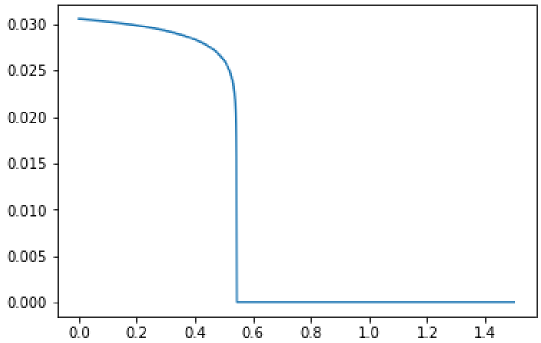


**Figure 40:** $C_3H_8$ mole fraction

## 4.3 $\phi = 1.5$

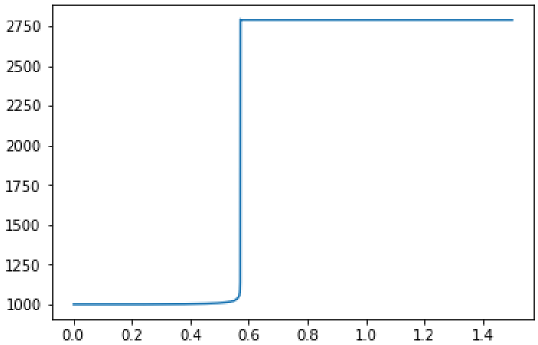


**Figure 41:** T [K]

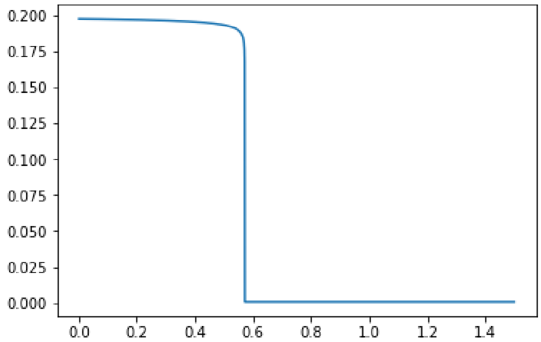


**Figure 43:** $O_2$ mole fraction

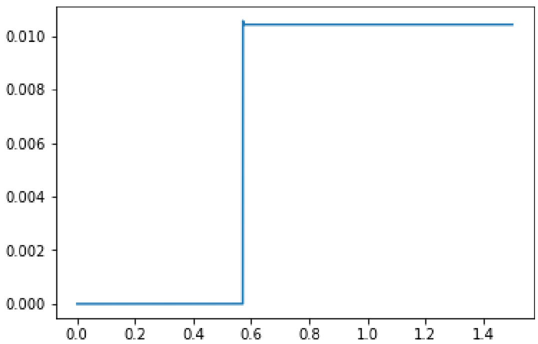


**Figure 42:** H mole fraction

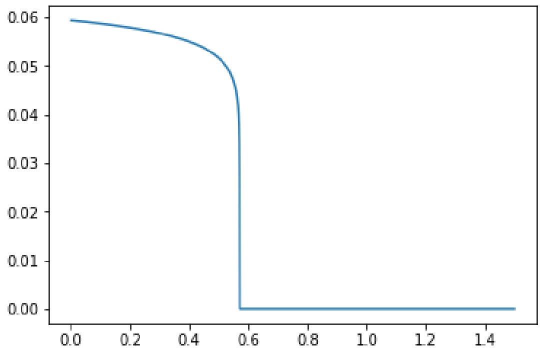


**Figure 44:** $C_3H_8$ mole fraction

## 4.4 $\phi = 3$

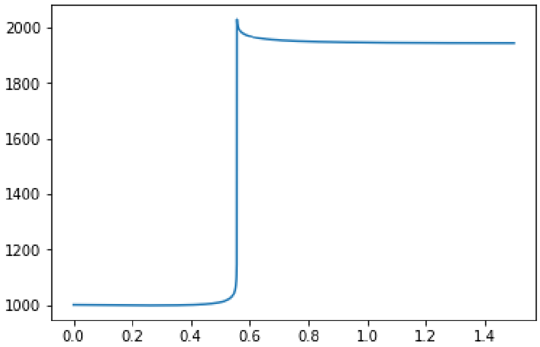


**Figure 45:** T [K]

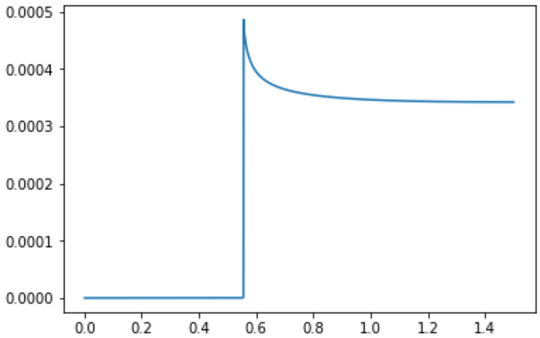


**Figure 46:** H mole fraction

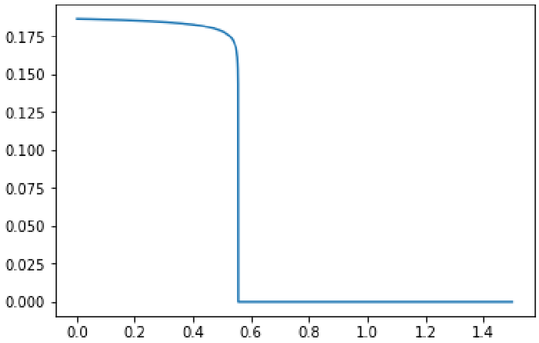


**Figure 47:** $O_2$ mole fraction

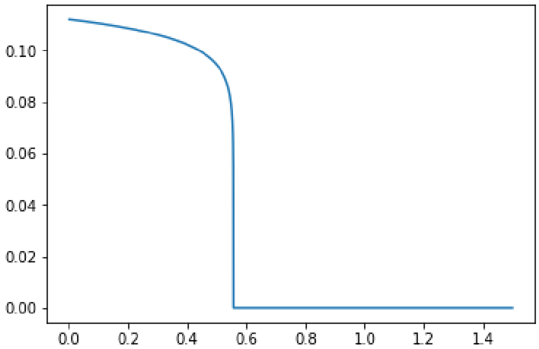


**Figure 48:** $C_3H_8$ mole fraction

## 4.5 $\phi = 5$

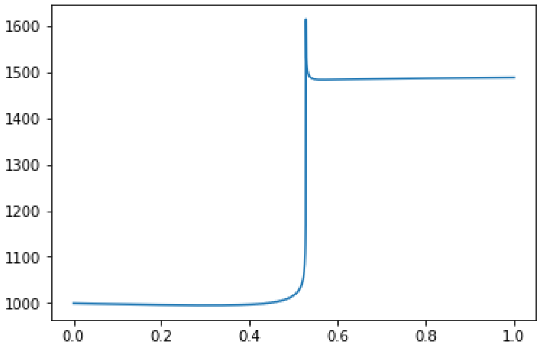


**Figure 49:** T [K]

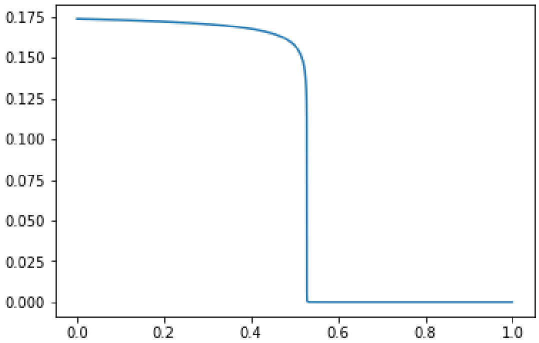


**Figure 50:** $O_2$ mole fraction

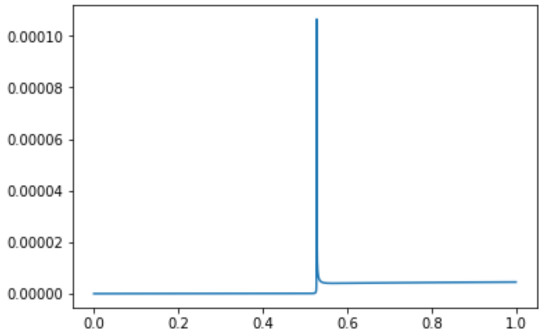


**Figure 51:** H mole fraction

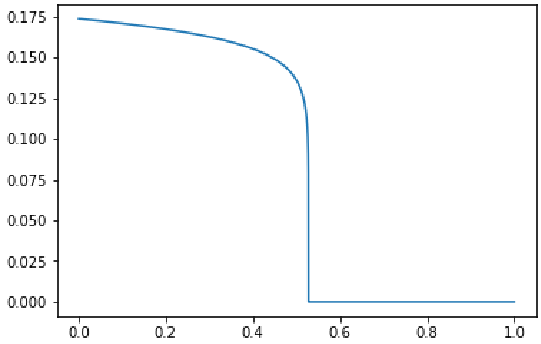


**Figure 52:** $C_3H_8$ mole fraction

In the first and the two last experiments where equivalence ratios are smaller or greater than flammability limits a full combustion process does not occur. T[K] and H mole fraction characteristics differ from the others.

Within flammability limits equivalence ratio doesn't have a significant influence on maximum temperature or combustion delay time.

# 5 Summary

Conclusions

- Influencing the time after which the combustion occurs is possible by changing initial temperature or pressure.
- Combustion is more stable for lower initial temperatures.
- Combustion is possible only within flammability limits. Outside limits we can observe a process in which temperature rises but it is not a combustion.
- Changes in initial parameters don't have a significant influence on $C_3H_8$ or $O_2$ mole fraction characteristics.

# 6 Bibliography

`http://fluid.wme.pwr.wroc.pl/~spalanie/dydaktyka/spalanie_instrukcje/spalanie_labor_instr_stezeniowe_granice_palnosci_gazow.pdf`