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Computer Methods in Combustion

Combustion of kerosene in turbine engine

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Contents

1 Introduction

The purpose of this paper is to investigate available models of combustion of the jet fuel surrogates. Detailed modeling of this process is a useful tool to solve the problem of combustion control, as well as to reduce emissions and fuel consumption. Due to complex composition of jet fuel, there is a necessity to analyse only surrogates, which consist of much lower number of different hydrocarbons. Three models will be discussed in this paper and obtained results, mainly temperature and pressure, will be compared with available experimental data.

2 Literature survey

Quite a high number of available mechanisms for a surrogate kerosene can be found on the website [1], ran by Centre Europeen de Recherche et de Formation Avancee en Calcul Scientifique in Toulouse. From those few mechanisms there were chosen three detailed ones: Dagaut's original, Dagaut's modified for high pressure and JetSurf. Reduced mechanisms require implementation of ABVP transportation mechanism, different from the default one, in order to work properly, so it was decided to not take them into consideration. Conditions of the air behind the last stage of compressor, air-fuel equivalence ratio and stoichiometric air-fuel ratio were assumed, basing on the knowledge gained during lectures [2]. The air mass flow and dimensions of combustion chamber were assessed on the dimensions of Rolls Royce AE3007 engine ([3]).

3 Model description

In order to make sure that computations would be conducted properly, combustor was simulated as an ideal gas reactor. For Dagaut's mechanisms, the kerosene surrogate has a mass composition of 74% $NC_{10}H_{22}$ (n-decane), 15% PhC_3H_7 and 11% CYC_9H_{18}. In JetSurf mechanism this surrogate is made up entirely of n-decane.
Whole system consists of four reservoirs: air, fuel, igniter (H radicals, identical solution as in [4]) and exhaust, and mentioned ideal gas reactor representing combustion chamber. Air and fuel flow into combustor, where they mix and get ignited by the flow of H radicals. Chamber and exhaust are initially filled with N_2 molecules. Reasons for some initial conditions have been explained in the code.

4 Results

Figures from 1 to 3 present the progress of temperature and pressure in exhaust reservoir for all three mechanisms.

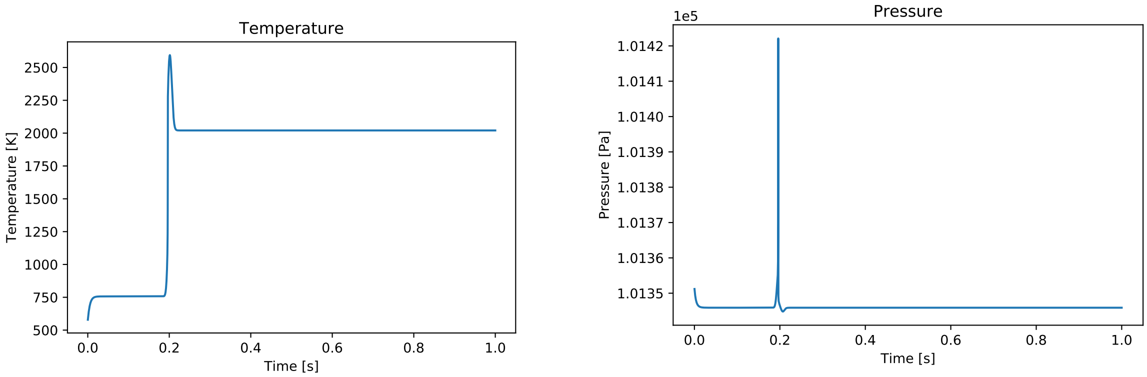

Figure 1: Progress of temperature and pressure for Dagaut's mechanism

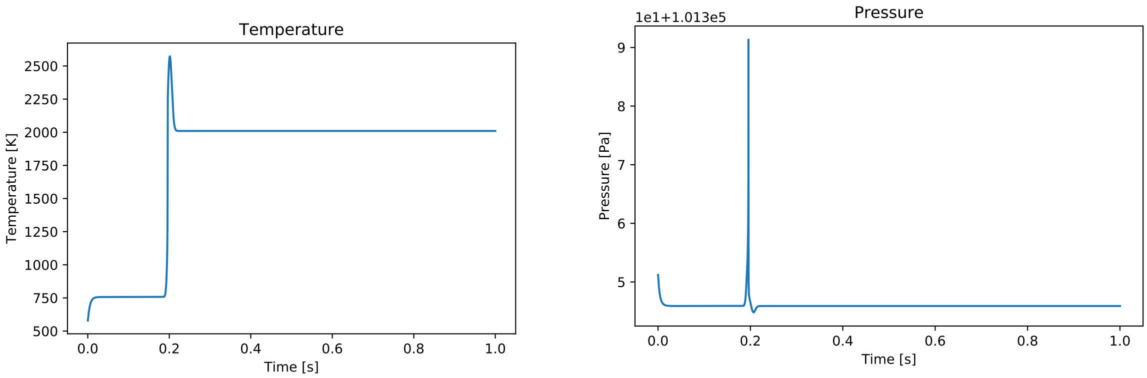

Figure 2: Progress of temperature and pressure for Dagaut's hig pressure mechanism

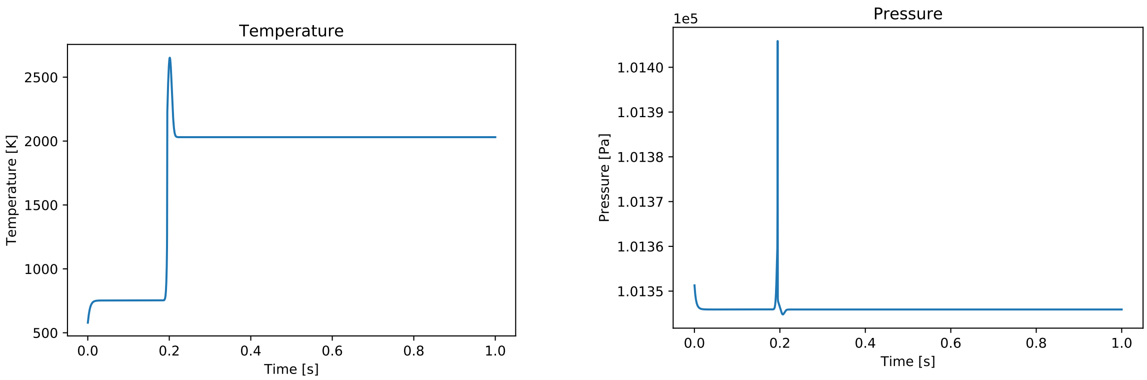

Figure 3: Progress of temperature and pressure for JetSurf mechanism

On each plot it is clearly visible that there is a delay in ignition and the peak in pressure appears slightly earlier than the peak in temperature. Variation in pressure is really unsignificant, especially in the Dagaut's high pressure mechanism, in overall pressure amplitude does not exceed 100 Pa. Obtained temperatures in peak and steady state are respectively:

- Dagaut's mechanism - 2594 K, 2020 K,

- Dagaut's high pressure mechanism - 2573 K, 2009 K,
- JetSurf mechanism - 2652 K, 2030 K.

Detailed composition of exhaust fumes can be found in attached .csv files.

5 Conclusions

As it was told in [2], the stagnation temperature in front of the turbine can reach 2000 K. Temperature of exhaust fumes needs to be then somewhat higher in order to lower to expected value after mixing with the air flowing around combustion chamber. Presented models occur to give similar results which seem to agree with reality in terms of temeprature, so there is a base to presume that such computations can also properly predict composition of exhaust fumes, which may make the reduction of harmful compounds easier.

References

[1] `http://www.cerfacs.fr/cantera/mechanisms/kero.php`

[2] Jan Kindracki PhD, *Aircraft Turbine Engines* lecture, winter semester 2017/2018

[3] `http://www.fi-powerweb.com/Engine/Rolls-Royce-AE-3007.html`

[4] `http://www.cantera.org/docs/sphinx/html/cython/examples/reactors_combustor.html`