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GASEOUS METHANE \ GASEOUS OXYGEN ROCKET ENGINE – COMPUTATIONS AND DESIGN

Experimental investigations' purposes

The Warsaw University of Technology started their research on ecologically-safe rocket propellants in 2007. One of the two engines, which was designed and built in this project till today, is the rocket engine fed by gaseous methane and gaseous oxygen.

The main purpose of experimental investigations on the rocket engine is to check the proposed cooling system's efficiency. This will be determined by the temperature measurements on the test engine. Thrust pressure and temperature measurements will be also required in order to obtain experimental data for numerical model's refinement and validation. The valid numerical model of cooling system, which will be obtained from this investigations will be used in further design of similar rocket engines.

Geometry of the engine

The zero-dimensional thermodynamical analysis were the point of the reference for the design of the test engine. Computations were made with computer program VisualCEA, which is modified version of CEA[2] (NASA Glenn Chemical Equilibrium Program) with some features and graphical interface added to it by authors.

Table 1.

Visual CEA computations' results

Parameter	Combustion chamber	Throat	Nozzle exit
p, atm	7	4,1	1
T, K	3304	3170	2861
Mach number	-	1	1,97
A/A _{THROAT}	4	1	1,935
ISP, m/s	-	-	2097,0

Assumed and calculated thermodynamical parameters are presented in table 1. These results stood as the basis to calculate some other important values representing engine's performance and dimensions (table 2).

Table 2.

Specifications of the engine

Mass flow rate	0,0483	kg/s
Optimal O/F (maximization of Isp)	2,7	-
Stoichiometric O/F	4	-
Oxidant mass flow rate	0,0388	kg/s
Fuel mass flow rate	0,0097	kg/s
Mass flow rate of fuel used for cooling	8,78%	-
Feeding pressure (predicted)	10	atm
Chamber pressure (assumed)	7	atm
Throat diameter	12,2	mm
Thrust (expected)	10	daN

Every part of the engine was made of steel. The chamber thickness equals 1 millimeter. Combustion chamber and cooling system's annular gap are separated by this wall (fig. 1). Five concentric injection elements are placed on injector's face in a circular way. Other 8 injection elements are used for the cooling system's feeding.

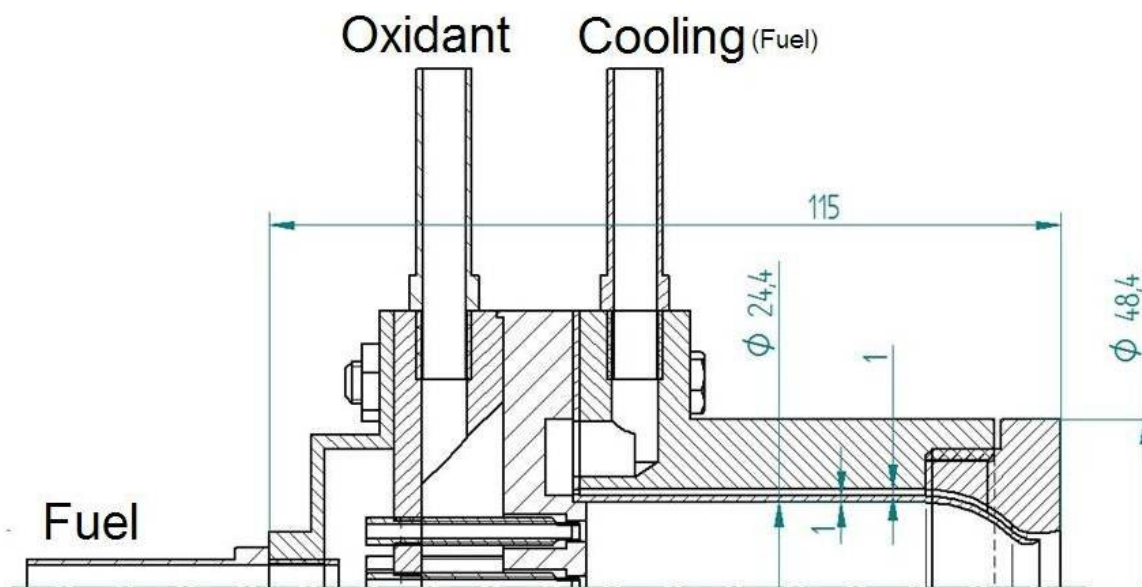


Fig. 1. Engine's geometry

Computations

Thermodynamical computations of combustion and cooling were made in Ansys Fluent 6.x computer program. Computational grid was 2-dimensional, axisymmetric and consisted of 15'000 cells. Chemical reactions' set was

reduced to consist of 84 reactions and was based on GriMech 1.2. Results of these computations are presented on figures 2-8.

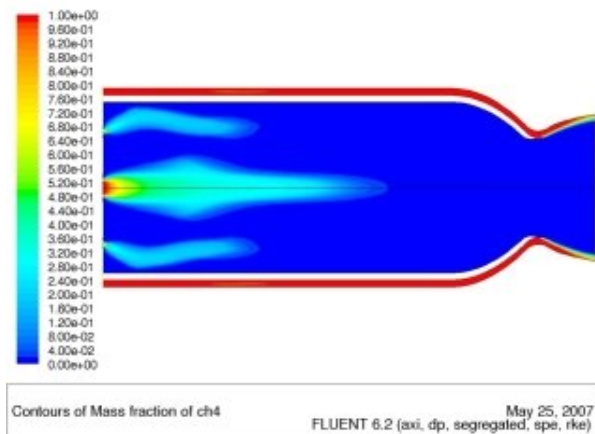


Fig. 2. Contours of Mass fraction of CH_4

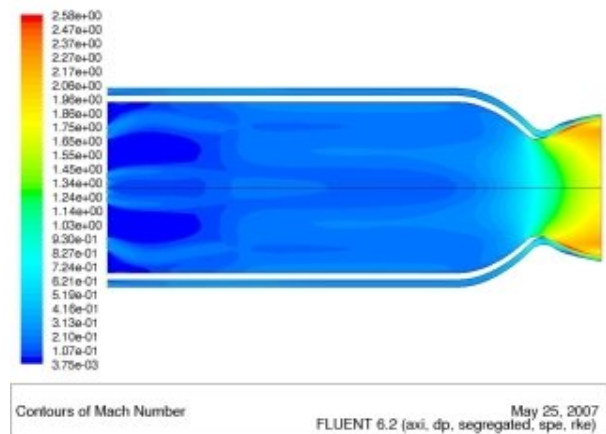


Fig. 3. Contours of Mach number

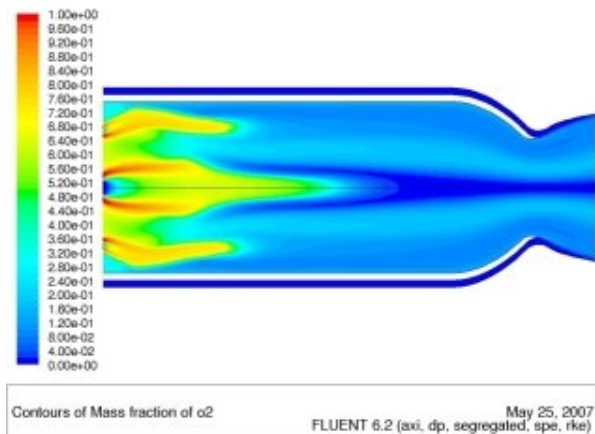


Fig. 4. Contours of Mass fraction of O_2

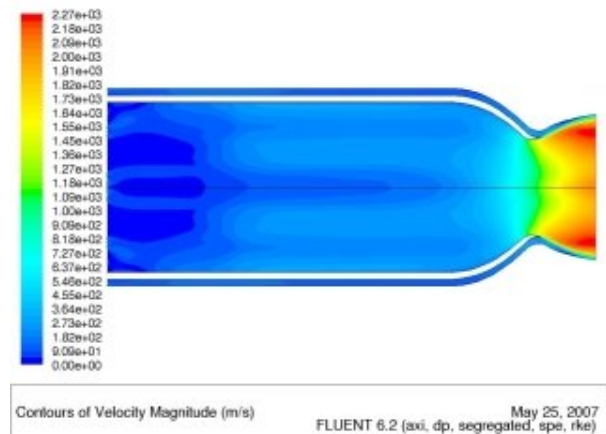


Fig. 5. Contours of Velocity Magnitude

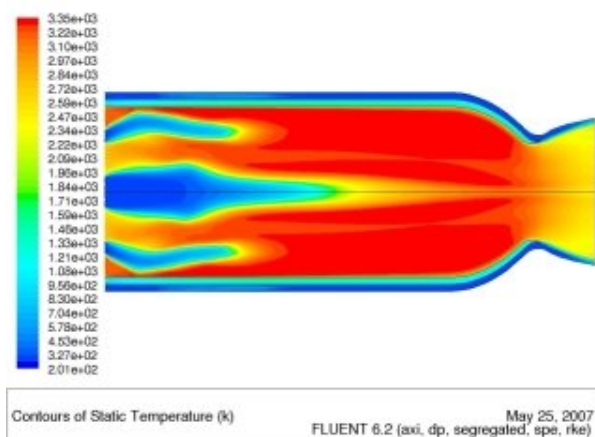


Fig. 6. Contours of Static Temperature

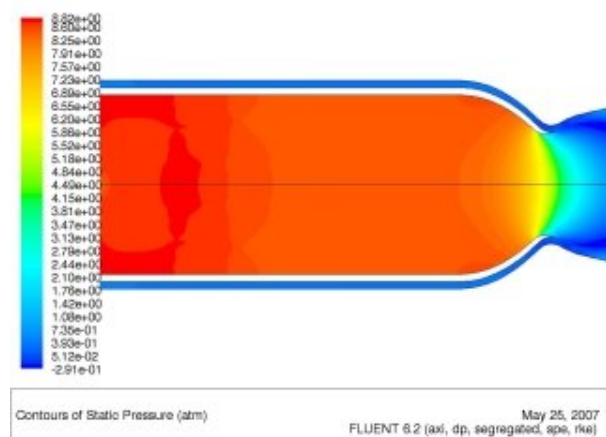


Fig. 7. Contours of Static Pressure

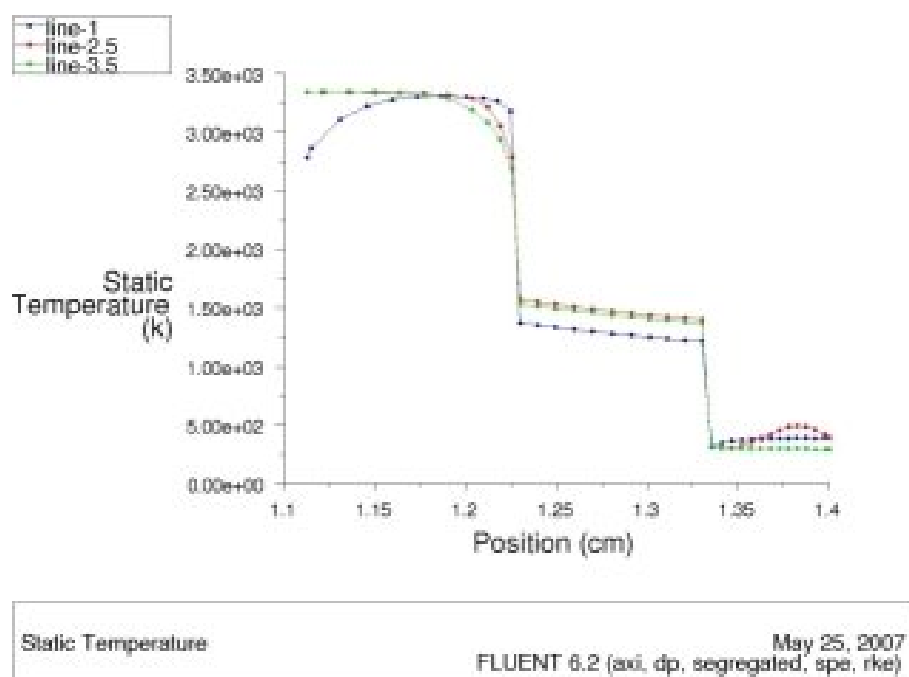


Fig. 8. Temperature near the chamber wall versus radial distance from the chamber axis (1, 2.5 and 3.5 cm from injector)

Fig. 8 shows the influence of the convective heat transfer on the temperature of the combustion chamber's wall. Temperature on both sides of the wall highly depends on the turbulence intensity in the combustor and cooling system. What is more, during fire tests, temperature will need some time to reach calculated values. This confirms the need of experimental investigations on the test engine.

Experimental investigations

Till today, only a few fire tests were performed (Fig. 9,10). During these experiments water was used instead of methane as a coolant, thus only thrust measurements were applied. Problems encountered during this initial fire tests led authors to apply some modifications to cooling system, ignition and nozzle geometry.

During further tests temperature measurements in the cooling annular gap and pressure measurements in combustion chamber will be performed. The data acquisition system is designed, such that this measurements can be performed simultaneously.

Some other design modifications will be applied to the engine in order to achieve better performance and test other configurations and cooling systems (e.g. regenerative cooling).



Fig. 9. Test stand

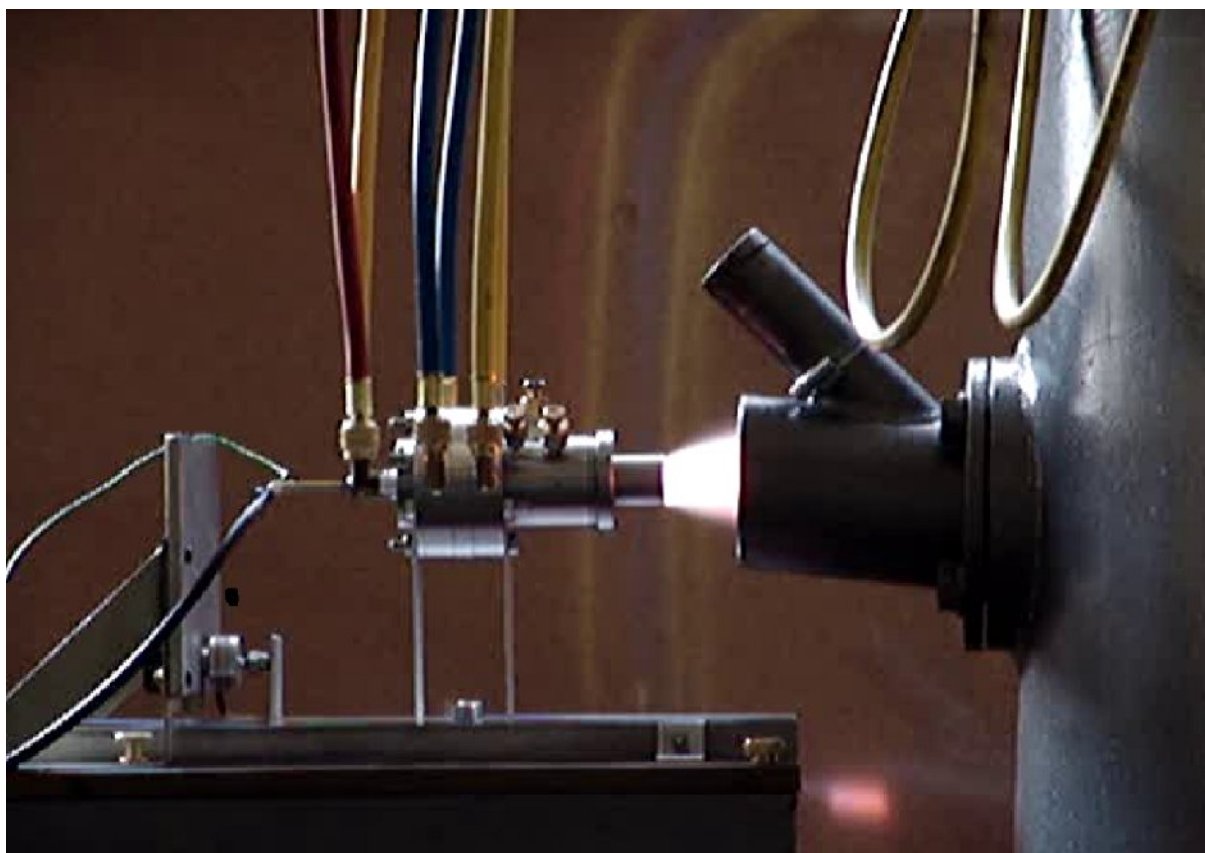


Fig. 10. Fire test

Conclusion

The main purpose of the research on the gaseous rocket engine was to check computations' validity, and to upgrade numerical model, to be suitable as a point of reference for further designs of methane rocket engines. This research cannot be the only which will stand as the basis for further design of full-scale liquid rocket engine. To do this, some other research and many CFD simulations of atomization, vaporization, combustion and heat transfer should be performed.

References

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ДИНАМИКА ЭЛЕКТРИЧЕСКОЙ СКОЛЬЗЯЩЕЙ КОНТАКТНОЙ ГРУППЫ УПРАВЛЯЮЩЕЙ АППАРАТУРЫ

Введение

Проблема повышения надежности приборов и их комплексов остро ставится в ряде современных видов техники, например, в ракетостроении, авиации, радиолокации и т.п.

Успешное функционирование аппаратуры в значительной степени зависит от безотказной работы многочисленных электрических элементов и, в частности, от скользящих электрических контактов.

Тенденция к миниатюризации элементов управляющей аппаратуры вызвала необходимость создания слаботочных скользящих электрических контактов, в связи с чем встала проблема обеспечения надежного контактирования.