Green Orbital Propulsion System for a Small Satellite

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1 Reference Case Definition

During our internet research the propulsion systems in Table 5 were found. All systems use monopropellants and are used for AOCS tasks of the spacecraft. In the following we will use the **XMM Thruster** as a reference case using a chamber pressure of $p_c = 5.5\text{bar} - 24\text{bar}$ and a nozzle expansion ratio of $\epsilon = 60$.

2 Propellants Comparision

Using the chamber pressure $p_c = 5.5\text{bar} - 24\text{bar}$ and the nozzle expansion ratio $\epsilon = 60$ of the reference case defined in Chapter 1 the following green propellants in Table 1 are investigated using NASA CEA. The initial temperature of each propellant is assumed to be 20°C.

Table 1: Comparison of green propellants to the reference case. Each calculation is done using the minimum and maximum feeding pressure of the reference case.

Propellant	Vacuum Specific Impulse [s]	Combustion Temperature [K]
LMP-103S	253.3	1865
AF-M315E	261	2102-2105
H2O2, 98%	188	1225

3 Propellant Optimization

To optimize the propellant composition of Methanol, ADN and Water a rocketCEA script was written in Python. It performs a search on a composition grid, with a step size of 1% weight fraction. It iterates through all possible composition permutations. We assume the chamber pressure to be again 24bar, the expansion ratio to be $\epsilon = 60$ and the initial propellant temperature of the composition to be $T_0 = 20°C$. The results are discussed in the following.

First results The top figure in Figure 1 shows the result of this optimization with a maximum $I_{sp} = 302.29s$ using 83% of Methanol, 17% ADN and no Water.

Considering combustion temperature and solubility Since the task is to find a propellant composition with a combustion temperature below 1000°C we cut all results that do not comply with this boundary condition. The result is shown in the lower Figure 1 with a maximum $I_{sp} = 220.23s$ using 54% of Methanol, 46% ADN and no Water.

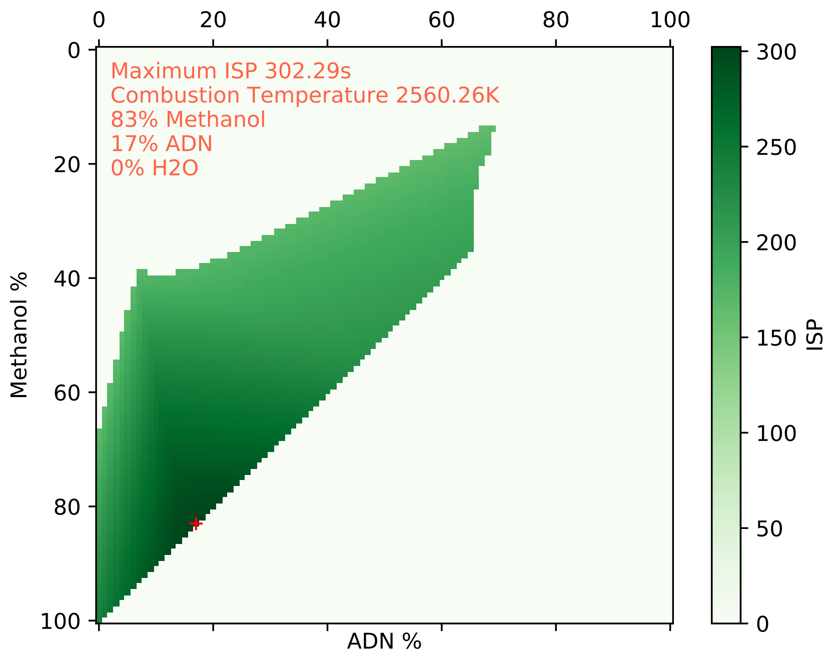
Furthermore, we need to consider that the solid ADN will need to be dissolved in the other two components of the propellant. At a temperature of $20°C$, which is coherent with our initial propellant temperature, 3.56 times more Water than ADN is needed to completely dissolve the ADN. Methanol can dissolve much more ADN at a rate of only 0.86 [?].

$$\frac{wt\%_{\text{Methanol}}}{wt\%_{\text{ADN}}} = \frac{54\%}{46\%} = 1.174 \geq 0.86 \tag{1}$$

According to equation 1 the amount of Methanol in our result is sufficient to completely dissolve the used ADN. Adding water will only lower the I_{sp} of the propellant composition. Therefore, the final result is chosen to be at 54% of Methanol, 46% ADN and no Water.

4 Thruster Preliminary Design

5 Detailed Design Blow-Down Feed System



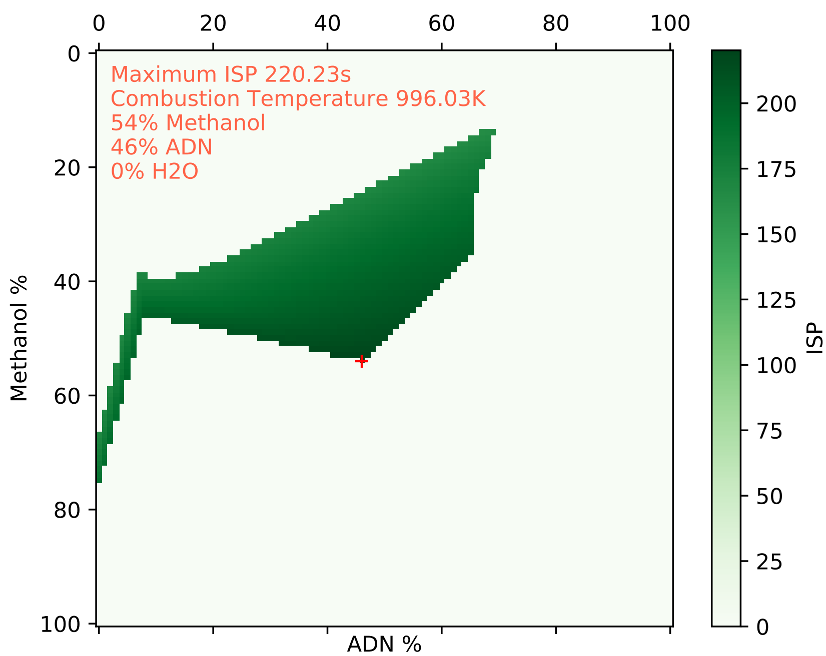


Figure 1: Figure showing the fuel optimization using Nasa CEA to compute the highest possible ISP (top). The best results are highlighted with a red cross. The second figure shows the best result after all reactions with a combustion temperature above 1000°C are cut (bottom).

Name	Propellants	Number of Thrusters	Thruster Class [N]	Total Impulse [Ns]	Other	Reference
XMM Thruster	N2H4	8	20	> 517000	$I_{sp} = 222 - 230s$, $p_c = 5.5 - 24$bar, $\epsilon = 60$	ESA Doc, Page 209; Ariane Group
TanDEM-X Thruster	N2H4	4	1	> 135000	$I_{sp} = 200 - 223s$, $p_c = 5.5 - 22$bar, $\epsilon = 80$	FD TanDEM-X; Ariane Group
Prisma Thruster	LMP-103S	2	1	≈ 108773[1]	$I_{sp} = 204 - 231s$, $p_c = 4.5 - 22$bar, $\epsilon = 100$	1N HPGP Thruster

Table 2: Overview of small propulsion systems using monopropellants.