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. The input parameters were taken from the reference case. Which resulted in a chamber pressure of 24bar, an expansion ratio of $\epsilon = 60$ and an initial propellant temperature of $T_0 = 20°C$. The results are discussed in the following.

All results The top figure in Figure 1 shows the result of the optimization with a maximum specific impulse in vacuum of $I_{sp} = 302.29s$ using 83% of Methanol, 17% ADN and 0% Water.

Final result The task demanded a combustion temperature below 1000°C (1273.15K). Hence, all results with a higher combustion temperature were removed from the lower figure of Figure 1. This lead to the final result with a maximum specific impulse in vacuum of $I_{sp} = 236.52s$ using 59% of Methanol, 39% ADN and 2% 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 [LW11].

According our final result the amount of Methanol and Water is sufficient to completely dissolve the used ADN.

4 Thruster Preliminary Design

5 Detailed Design Blow-Down Feed System

References

[19a] "1 N HPGP Thruster". In: Available at http://ecaps.space/products-1n.php. June 2019.

[19b] "1N Monopropellant Hydrazine Thruster". In: Available at http://www.space-propulsion.com/spacecraft-propulsion/hydrazine-thrusters/1n-hydrazine-thruster.html. June 2019.

[19c] "20N Monopropellant Hydrazine Thruster". In: Available at http://www.space-propulsion.com/spacecraft-propulsion/hydrazine-thrusters/20n-hydrazine-thruster.html. June 2019.

[19d] "ESA Achievements BR 250". In: Available at http://www.esa.int/esapub/br/br250/br250.pdf. June 2019.

[19e] "Flight Dynamics Operations of the TanDEM-X Formation". In: Available at https://www.researchgate.net/profile/Ralph_Kahle/publication/259897316_Flight_Dynamics_Operations_of_the_TanDEM-X_Formation/links/0a85e53c3b917d441a000000/Flight-Dynamics-Operations-of-the-TanDEM-X-Formation.pdf. June 2019.

[LW11] Anders Larsson and Niklas Wingborg. "Green Propellants Based on Ammonium Dinitramide (ADN)". In: *Advances in Spacecraft Technologies*. InTech, Feb. 2011. DOI: 10.5772/13640. URL: https://doi.org/10.5772/13640.

Table 2: Overview of small propulsion systems using monopropellants.

Name	Propellants	Number of Thrusters	Thruster Class [N]	Total Impulse [Ns]	Other	References
XMM Thruster	N2H4	8	20	> 517000	$I_{sp} = 222 - 230s$, $p_c = 5.5 - 24$bar, $\epsilon = 60$	[19d] [19c]
TanDEM-X Thruster	N2H4	4	1	> 135000	$I_{sp} = 200 - 223s$, $p_c = 5.5 - 22$bar, $\epsilon = 80$	[19e] [19b]
Prisma Thruster	LMP-103S	2	1	≈ 108773	$I_{sp} = 204 - 231s$, $p_c = 4.5 - 22$bar, $\epsilon = 100$	[19a]

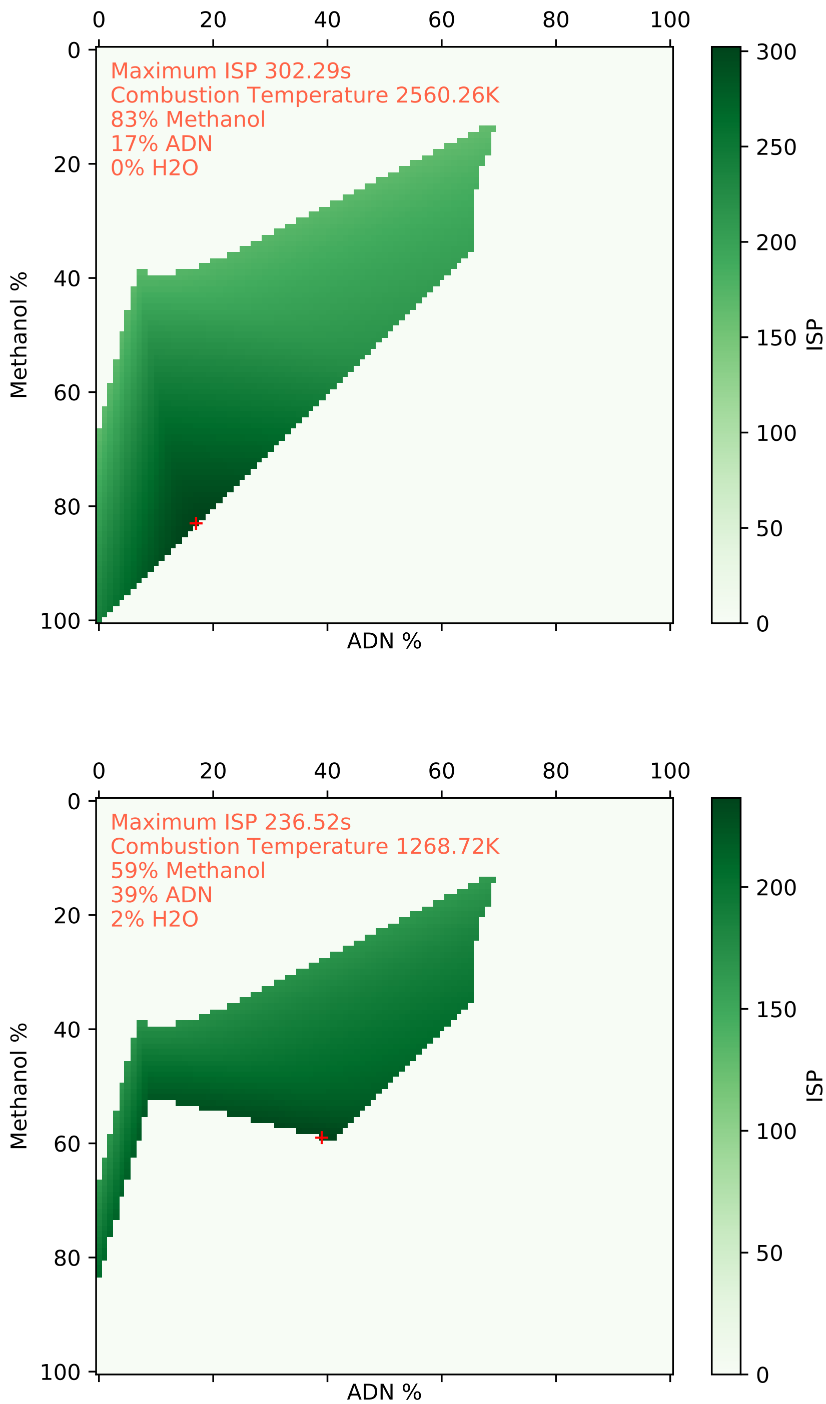

Figure 1: Figure showing the fuel optimization using Nasa CEA to compute the highest possible ISP (top). The best results are highlighted with a red cross. The second figure shows the best result after all reactions with a combustion temperature above 1000°C (1273.15K) are removed (bottom).