Abstract

A research project has been initiated at ULB and RMA in Belgium in the frame of the FAST20XX European FP7 project to assess the performance of paraffin based hybrid rocket engines, to obtain a representative 1 kN thrust engine and to find ways to improve the fuel regression rate. With this objective, a test engine was developed with numerous sensors to capture pressure and temperature along the engine (Fig. 1). It is composed of four parts:

- The injection line is composed of 3 nitrous oxide bottles in parallel each one equipped with a ¼” solenoid valve merging on a ½” cross connected to the injector. The individual solenoid valves permit the control of the flow,
- The precombustion chamber contains the ignition cartridge and constitutes a empty space where nitrous oxide vaporizes and dissociates prior to reaction with the paraffin,
- The combustion chamber contains the paraffin grain,
- The post-combustion chamber where the mixture is further mixed before exiting the engine through a graphitic nozzle.

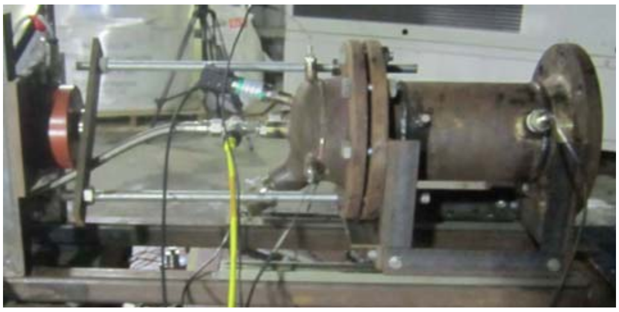

Figure 1: Hybrid rocket engine test bench

The injection line delivers a two-phase N_2O flow of maximum 0.3 kg/s through a full or a hollow cone injector depending on the configuration to be tested. The former delivers the flow under a 50° spray angle and the second one has a 60° spray angle. The combustion chamber contains the cylindrical paraffin grain with a 125mm outside diameter and a 40 mm or 27 mm inside diameter depending on the configuration.

In order to ignite the mixture and start the self-sustaining combustion, a pyrotechnic cartridge, developed in collaboration with the Royal Military Academy of Belgium is used. The pyrotechnic chain is composed of a professional igniter, spherical powder, and an igniting powder that finally burns a grain composed of perchlorate ammonium, kraton and aluminium that releases the necessary energy to dissociate the nitrous oxide, to melt the paraffin and start the auto-sustaining combustion. Figure 2 and 3 show the cartridge components and a validation test.

22 hot tests were done in order to characterize the regression rate. They are launched by a LabView interface controlling the phase sequence and the time. The test starts with the cartridge ignition followed by the nitrous oxide injection. After a pre-defined combustion duration, the injection is stopped and nitrogen is injected to vent the engine and prevent any explosion hazard. Paraffin grain is weighted prior to the test and at the end to know how much fuel has reacted.

Figure 2: Pyrotechnic cartridge components

Figure 3: Pyrotechnic cartridge validation test

The time-space averaged regression rate is given for each test in Figure 4 and the experimental specific impulse is compared to the theoretical one in Figure 5. As seen, the mean regression rate is around 5 mm/s for our couple of propellants.

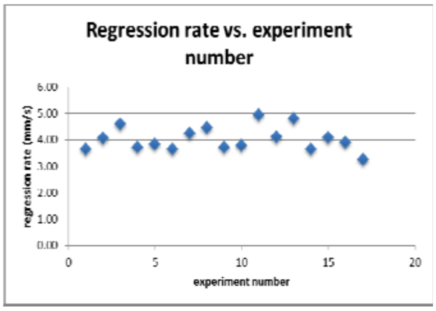

Figure 4: Regression rate vs experiment number

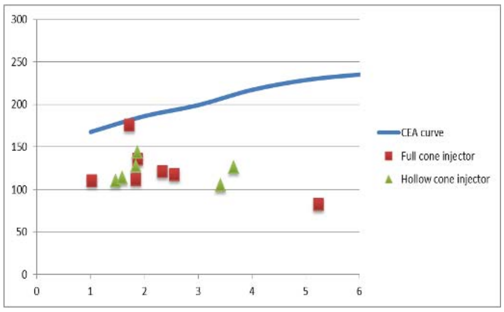

Figure 5: Comparison between experimental and theoretical specific impulse

As referenced in existing literature, it is higher than for HTPB/N2O (1 mm/s) [2] as expected but more surprisingly, the value is also higher than the values found in literature for the same fuel/oxidant (3mm/s) [3]. In fact, the results were found to be equivalent to the SP-1a paraffin/Gox used by the University of Stanford [1].

When observing the specific impulse, we are below the theoretical value as a high proportion of paraffin is extracted without reacting with the nitrous oxide. This is clearly visible on the test video (Figure. 6).

Figure 6: A first combustion test

A second engine was constructed in order to increase the O/F ratio and have a better combustion. The performance was improved with a regression rate of about 6 mm/s and a specific impulse of about 170 s that were reached.

Acknowledgments

The authors of this study would like express their thanks and acknowledgments to ESA-ESTEC for their support and financial assistance in this project. This work was performed within the "Future High Altitude High Speed Transport 20XX" (FAST20XX) project investigating high speed transport concepts. The project is coordinated by ESA-ESTEC and supported by the European Union within the 7th Framework program theme 7 transport, Contract no: ACP8-GA-2009-233816. Further information on FAST20XX can be found on http://www/esa.int/fast20xx

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