Considerations about the static fire of the RATTworks H70 rocket motor

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June 5, 2016

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Sponsors

Introduction

During the degree of aeronautical engineering the students improve their theoretical knowledge about this discipline. But the feeling among the students is that we cant apply this knowledge until we finish studding and start working. This is the reason why some of us join an students team such as Terrassa Rocket Team (TRT) where we can join other students interested in rocket modeling. Together we improve our skills in making different types of rockets like a two-stage rocket, a supersonic one, rockets with deployable wings, etc. Some of us inside TRT are focusing in a new challenge: an hybrid rocket. All the same, before launching a rocket with an hybrid motor, we've organized an static fire to asses the thrust curve and test the launching process.

Objectives

The main objectives that need to be accomplished with the static fire are:

- Perfect the launch and ignition sequence and assesses its correct operation. The work on this sequence is not done from scratch since several years ago former and current students of the TRT already ignited the hybrid motor. All the same they never managed to fly a rocket with the motor.

- Familiarize the part of the team that has never worked with this engine with the sequences, peculiarities and behavior of this type of rocket engines.
- Improve the security measures. Since the operation of this rocket engine requires high pressure oxidant gas security measures are more important than ever.
- Improve the thrust curve quality. The completely new test bench and electronics will ensure more reliable and constant data.

How does the engine work?

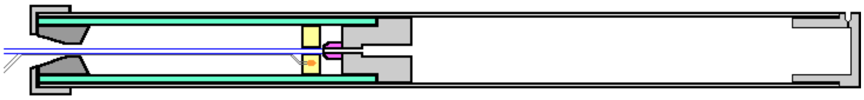

Figure 1: Empty motor

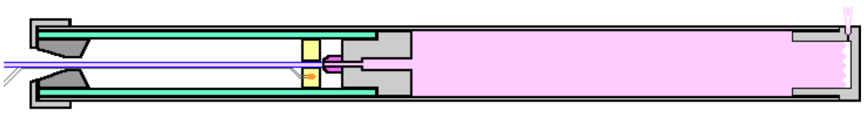

Figure 2: Motor filled with N_2O and venting

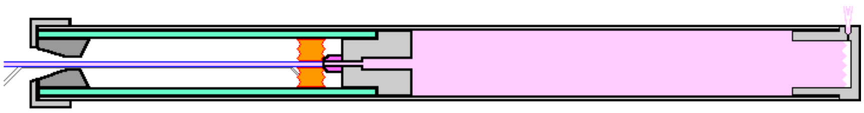

Figure 3: The ignitor starts the combustion of the solid grain

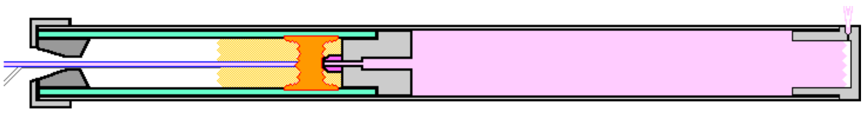

Figure 4: The combustion of the solid grain burns the gas tube

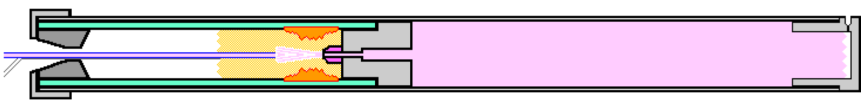

Figure 5: The gas leaks through the tube

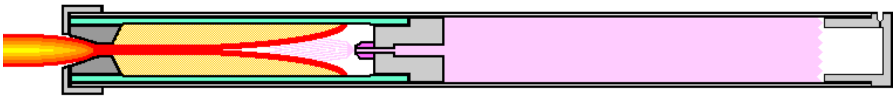

Figure 6: The motor is now functioning

Gas considerations

Gas state and pressure

A basic theoretical study of the gas state and pressure inside the tanks has been conducted. To do so, the properties of the N_2O have been extracted from [3]. With the equations presented on the former source, a simple Matlab code has been built that generate the chart in Figure 7, said code can be found in [1].

It's important to realize that its difficult to measure the amount of nitrous oxide remaining in the tank because the pressure inside the tank remains constant until the tank is almost empty. The reason why this happens is because inside the tank there is N_2O in both vapor and liquid states. When this happens the pressure inside the tank remains constant at a value named vapor pressure.

This state where the two phases co-exist can only happen at a given pressure temperature and specific volume of the substance. A graphic representing this can be seen on the figure 7.

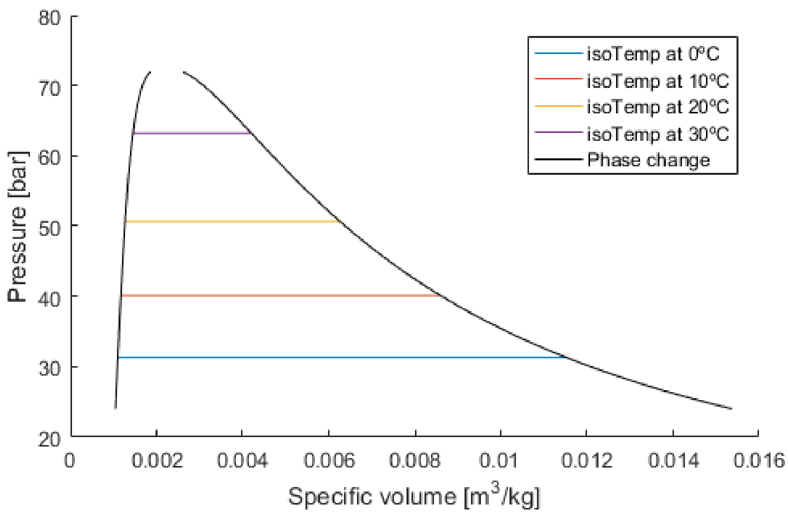

Figure 7: N_2O pressure vs specific volume chart

The tank currently used to supply the gas is 5L and stored 3.75Kg of gas when it was full. That is $(0.005m^3)/(3.75kg) = 0.00133m^3/kg$. Looking at the previous chart it's possible to see that this point was at the limit of the vapor-liquid zone and thus the tank was probably full of liquid at atmospheric temperature. However, this tank has already been used once and it's estimated that one-fourth of the content is gone. Then, the current specific volume is $(0.005m^3)/(2.625kg) = 0.0019m^3/kg$. This value ensures that the substance will remain at vapor-liquid phase at any reasonable temperature.

When the rocket engine is connected to the gas tank and the valves are open, the pressure and the specific volume stabilize between the two recipients; this fills the engine integrated tank with liquid and vapor nitrous oxide.

The previous graph also shows the vapor pressure of the gas at different temperatures. It's important to notice the difference in pressure between common atmospheric temperatures. The current loading system has been prepared to withstand up to 70 bars plus security margins. This means that the launch or test ignition should be delayed if the temperatures are superior to 34.7žC.

However, it must be noted, that thanks to the security margins and the fact that the gas colds down when expanded, the system would probably withstand a launch at more than this ambient temperature. All the same, security is a top priority and ANY LAUNCH WILL BE DELAYED if it's not possible to assure a tank temperature lower that.

Engine position

The

Control system

In order to control the launch remotely a simple electronic system has been build. This system is connected to different power sources and to a data-logger that connects to a computer acting as a server.

Software

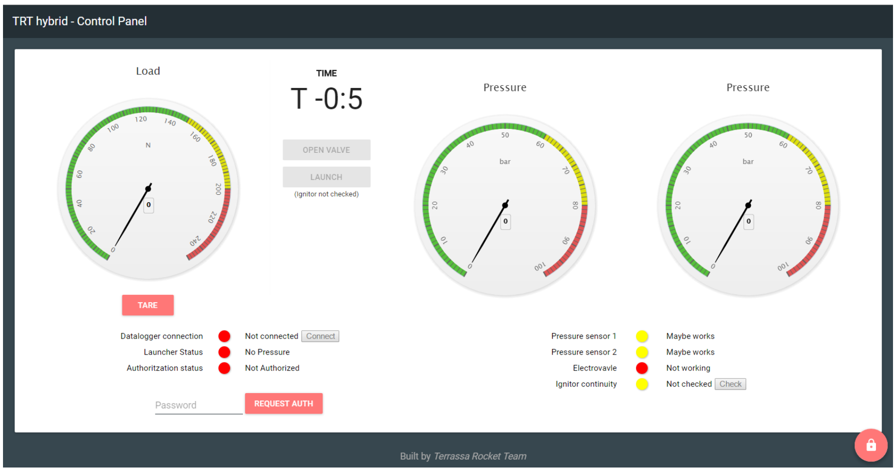

Figure 8: Software screenshot

After the server is initialized, clients can connect to it using an standard web-browser from any device. Any client is able to see the data from the sensors and, after proper authentication, they are able to control the gas valve and, the continuity check of the ignitor and the ignitor trigger. The data is always stored in the server at the full sampling rate, but the clients only receive the mean of the last 0.1 seconds.

The server is implemented using javascript and node.js. The server connects to the serial port using the ''serialport' package and uses ''websockets' to send the sensors data in real time to the clients. The interface between the data-logger and the server has been specially developed for this program based on previous experience writing an open-source library for Matlab for the same data-logger.

The clients web pages are implemented in React and Redux from Facebook. The charts use the library ''highcharts'.

The full implementation of the code can be found on [2]. An screenshot of the clients software can be seen on Figure 8.

Electronics

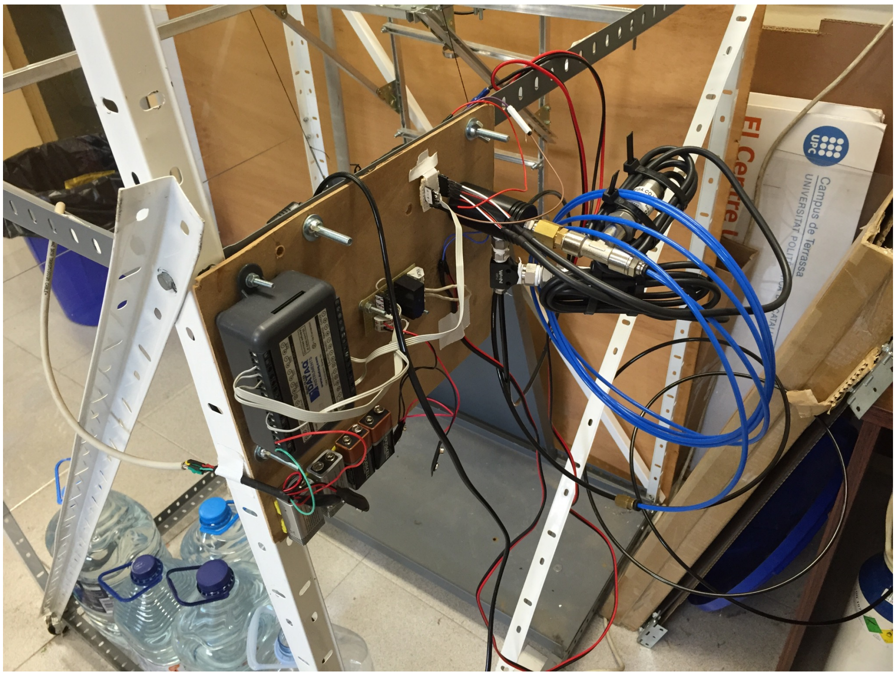

Figure 9: Electronics

The electronics to connect the sensors and actuators with the DI-155 data-logger from DataQ are also custom for this case.

There are 4 sensors attached to the fire test machine:

- 2 pressure transductors provided by Omega.
- 1 load cell for mesuring up to 50Kg of force.
- 1 continuity check for the ignitor

And 3 actuators:

- 1 ignitor check trigger
- 1 ignitor fire trigger
- 1 gas electrovavle trigger

An image of the electronics can be seen on the previous Figure 9.

Safety concerns

In this section, some of the safety concerns of the static launch will be addressed. If any of these concerns fail to pass the test, this will have to be postponed until they are solved.

As previously mentioned one of the safety concerns is related to the temperature and the pressure inside the tanks. As stated, the plumbing system can only safely withstand 70 bars. In order for this to happen, the gas -ergo, the tank- must be at less than 34.7žC; any higher temperature will overtake the limit pressure.

Another safety concern has to do with the risk of explosion of the combustion chamber. The main reason why the chamber would explode is if nozzle gets obstructed and the pressure in the chamber starts climbing. This motor, however, does not have the fuel and the oxidizer in the same chamber like a solid rocket does. For this reason, when the pressure is higher than the pressure in the oxidizer tank, no more oxidizer is let into the chamber and the combustion stops. However, if the pressure in the combustion chamber climbs to fast, the security valve of the oxidizer tank would kick in and start venting in order to lower the total pressure inside the oxidizer tank and the combustion chamber.

For further security, both the N_2O tank valve and the electro-valve will be closed when performing the test.

The test location has also been carefully selected. The test will be performed on a stainless steel bench, anchored on a concrete ground. Away from inflammable materials or people. Also, the motor itself will be covered with stainless steel mesh.

References

[1] Pep Rodeja Ferrer. *Matlab code for generating the P-V chart of N2O*. 2016. URL: `https://github.com/TerrassaRocketTeam/H70-rattworks-previousReport/tree/master/matlab`.

[2] Pep Rodeja. *Hybrid Control Panel - source code*. 2016. URL: `https://github.com/TerrassaRocketTeam/hybrid-control-panel-web`.

[3] *Thermophysical properties of nitrous oxide*. 1991. URL: `http://edge.rit.edu/edge/P07106/public/Nox.pdf`.