Thrust of a pop-pop engine versus time

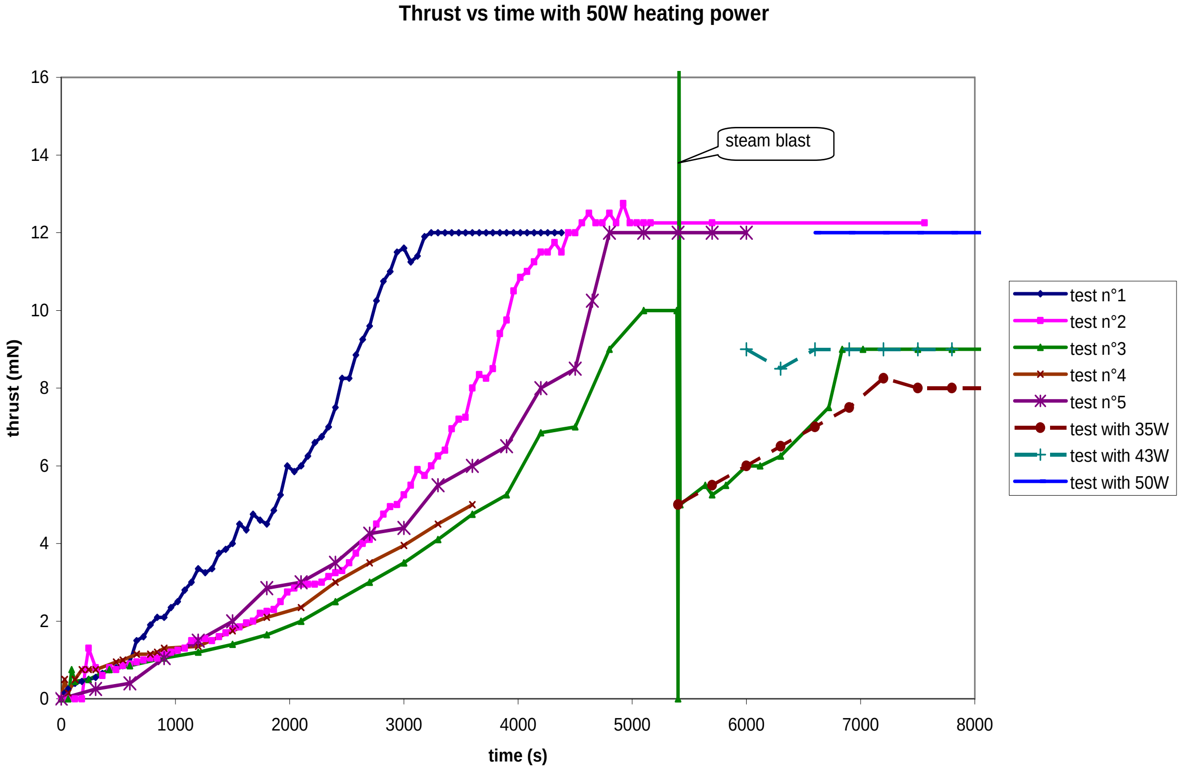
By Jean-Yves

Thanks to an electrical heating source on the test bench, we discovered that the thrust can increase considerably with time (see "Coil engine performances").

First, we used trial and error method to define the power giving the best final thrust. It took time, but the conclusion was that for this engine the optimum heating power is 50W (including heat losses). Below 50W the restituted power is less. Above 50W the engine goes to burnout in a few minutes. With 50W the final thrust can reach 12mN on each end of the pipes (we recorded only on one outlet).

Then, several tests were run with 50W. If we had used a candle, the duration of the test would have been very short and we would have concluded that the thrust was roughly 1mN. In fact, it can be much more for those who can wait.

The following diagram shows the thrust measured on the same engine during different tests using the same heating power + final result of other tests with less power.



What worried us in a first approach is the fact the results (slope of the curves) differ from each other though the initial conditions were the same: same engine, same heating power, same temperature.

However, there could be an explanation due to the reuse of the same water of which the characteristics could have changed (degassing and chloride off).

Test n°1 ran on Sept 29, 2006 with fresh water just taken from the tap.
Test n°2 ran on Oct 1, 2006
Tests n°3 and n°4 ran on Oct 2, 2006
Test n°5 and others ran on Oct 3, 2006

Comments:

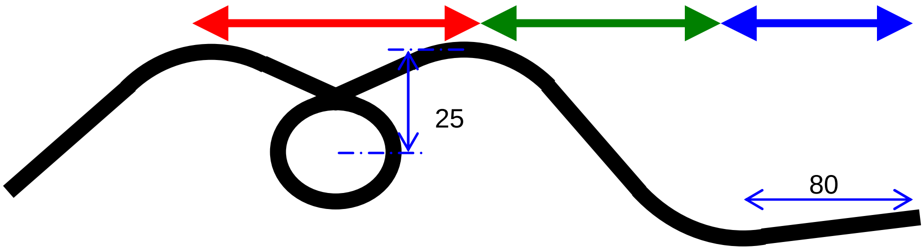
For an unknown reason there has been a violent steam blast during the third test. Then the engine restarted by itself but couldn't reach the 12mN thrust. We have no sure explanation to this. We have not noted, but perhaps we reduced the heating power to "reset" the process and forgot to come back to 50W. The other curves are coherent (the degassing of the water being taken as granted).

Each dot is the visual estimated mean value of the thrust during the 15 seconds before. Sometimes there were very big low frequency variations and the error could be 10% or even more. We know that, but the plots are the ones we noted as objectively as possible.

The chronometer was started at the first visible pulse, but the engine took sometimes a few minutes to really start. Therefore, the time zero of the curves can be shifted up or down by up to 300 seconds.

The fourth test was voluntarily stopped early to measure the quantity of gas in the engine. If not, it could have been very similar to test n°5 and to test n°3 up to 10mN.

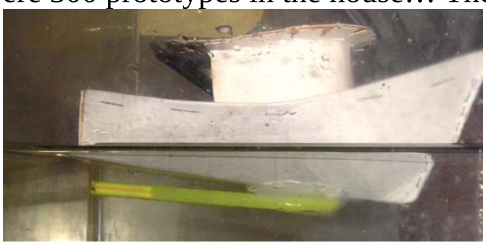
At the end of each test, we put some drops of water on the pipe to know where it was overheated. Every time, the area limited by the big red arrow on the sketch below was overheated. The coil highly overheated and the temperature was decreasing along the pipe to reach 100°C on top of the bends (where red and green arrows meet).



Note: To expect the same flow on both ends this engine has two opposite pipes. This symmetry is for the test bench only.

During tests n°1, 2, 3, 5 and others we observed some gas bubbles going out of the tubes. At the end of the third test we waited for water cooling and then measured the quantity of gas inside the engine. We got 1.8cc. We stopped the fourth test early to do the same measurement. We got 1,0cc. At the end of test n°5 we got 1.2cc but it was slightly more (some bubbles escaped). Later, during another test we measured 1.7cc, which is consistent with the first measurement.

At this stage, we remembered Slater's procedure to start his powerful diaphragm engine: "put some water in, shake the engine, empty the water and fill only the tubes. There you will get the best performances." (I don't remember his words, but the meaning is this one.) Yes Slater. You are right! And to allow the excess gas bubbles to escape without braking the water snake (of which the inertia is needed for the vibrations) the end of the pipe must be slightly going upward. That is the case on Slater's boat. I have heard from Naomi that there were 300 prototypes in the house… The result is there.



Here is a picture of Slater's boat through the glass of an aquarium. Thanks to the thin bow the pipes are inclined upward.

Our ancestor could have guessed this because some old pop-pop boats have a pipe going up (The Racer and the Battleship from Sutcliffe for example).

Amount of air (assuming it is air):

We noticed on many occasions that once the final thrust was reached small bubbles escaped. The engine (as all pop-pop engines we have tested) didn't run regularly. Roughly, every forty to sixty second this engine stopped for 5 seconds. Just at that moment, sometimes we could see very small bubbles escaping. When it restarted a few small bubbles escaped.

The volume of the red section (4 turns and 2 legs) is theoretically 3,85cc. The volume of red+green is theoretically 4,85cc. This volume is very likely the one occupied by air + steam at the bottom dead center.

At the end of test n°3, the gas volume was 1.8cc at 20°C, roughly confirmed by another test with 1.7cc measured. Above 100°C it was more than 2,3cc.

Therefore, at the utmost conditions of power there is more than 50% air inside the engine.

Stroke of the water snake (or water piston) :

Knowing the thrust (12mN) and the nozzle diameter (4mm) we found that the product Frequency x Stroke volume is 7cm3/s. To get that, we used the results got when we studied the "Thrust measuring test bench" (refer to this document). As the frequency is approximately 8 Hertz this leads to a 70mm stroke.

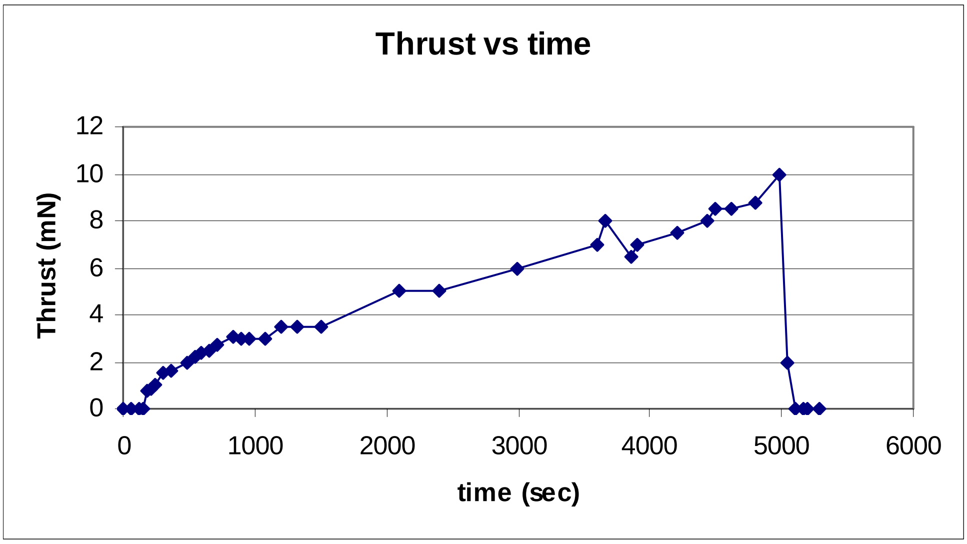
Conclusions:

- The final thrust increases with the heating power, but this one is to be limited because too much power involves a burnout. The accuracy of the measurements was not sufficient to allow defining the relationship between heating power and thrust.
- The best thrust is delivered when there is some air in the engine.
- This amount of air seems dependant on the heating power (or thrust).
- A good mean to let air excess escape is to incline slightly the waterjet pipes.
- Assuming the movement of the water snake is sinusoidal, its mean stroke is approximately 70mm for 12mN.

We tried to measure the gas flow versus time, but doing that we disturbed the engine equilibrium. We stopped there. According to the size of the bubbles and their frequency, a very rough estimate is 5cc per hour.

Each test when it runs satisfactorily requires more than one hour. And as 50W is on the edge many starts led to burnout or pump effect. For instance, five attempts failed by burnout before we succeeded to start the fifth test. And there could be again a steam blast as in test n°3. We don't intend to spend more time on this…unless somebody finds something new or something wrong.

In addition to these tests, we tried to see how the maximum mean value is influenced by the length of the outlet pipes. We lengthened both pipes by 90mm. Several tests with 50W lead to burnouts. We succeeded with 35W and got roughly the same maximum mean thrust as with the short pipes (10mN)…but unfortunately the engine went to burnout.



Compared with other engines, this one was running much more regularly (no burst of energy, no steam blast) up to (3600s, 7mN).

Addition (October 2008) :

This report was written in October 2006. Since that time, there has been some improvements in the knowledge of the pop-pop engines. On one hand we know the gas inside the engine is not exactly air. See “Gas in a pop-pop engine”. On the other hand, if 35W (instead of 50W) were enough for a lengthened engine, it is because the 90mm additional copper pipes were connected by means of rubber hoses. Break of the thermal bridge between hot source (electrical heater) and cold source (test tank).