Thrust of a pop-pop engine versus heating power

By Jean-Yves

We previously observed that the maximum thrust needs time to be reached. (refer to "Coil engine performance" and "Thrust of a pop-pop engine versus time") This maximum trust was got with a mixture of gas (other than steam) and steam inside the engine. On this occasion we saw that the maximum thrust was also linked to the heating power but the measurements were not accurate enough to define the corresponding relationship.

Knowing that, we built an engine including the favorable characteristics known for the moment:

- Coil with many (7) turns for a big gas volume.
- Rather long pipes for stability (of frequency and stroke).
- Pipes going upward at the coil outlet (to increase the gas volume)
- Pipes bent down further and then slightly up to help degassing (the excess of gas)

The result is visible on this picture.

Note: the second engine in background is half of the one being tested. It will be the object of another test and another paper.

We heated the coil with a soldering iron (visible on the picture) and we controlled the power by means of a dimmer. The rest of the test bench is described in "Coil engine performances".

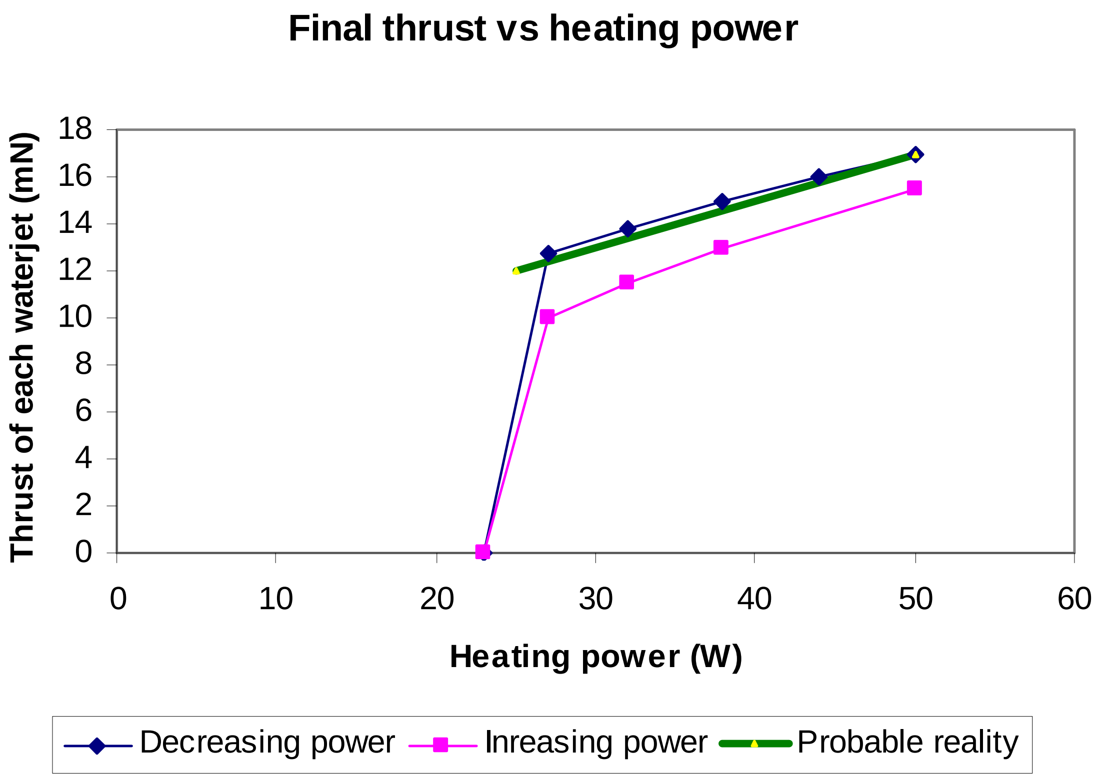
To save time we introduced voluntarily some air in the engine before heating it. To our surprise it started to vibrate very soon with stable conditions (constant mean thrust) and delivered the highest power we have ever seen up to now with pop-pop engines.
We maintained the heating power constant for 30 minutes. Then, we decreased it slightly and waited for the new thrust. Twenty minutes later we decreased again slightly the heating power…etc…until the engine stopped.

Note 1: It stopped by burnout. Though the power was weak, the whole coil was overheated. We cooled the engine by pouring some water on the coil. Then, we increased the power to restart the engine.

Note 2: If we except the above mentioned burnout which was voluntarily provoked, we were happy to see neither burnout nor steam blast during this test which lasted more than 4 hours.

To confirm the result, we increased the power step by step and again the thrust was measured. However, in order no to wait for hours and hours this test was run more quickly and the real final thrust might have been slightly more than the one we measured.

The graph given hereafter shows the mean results of our records. The blue curve corresponds to the measurements got when decreasing the power step by step. The upper value (17mN for 50W) is reliable. It was verified many times. The purple curve shows the measurements got when increasing the power. The looking like hysteresis between both curves is due to the fact we have not waited hours for stabilization at any step; particularly when going upward. The truth is necessarily in between the two curves, close to the blue one, and passing through (50W ; 17mN), and limited somewhere between 23 and 27W. We think it is something as the green curve.



Conclusion :

- Below a certain heating power there is no thrust at all (no vibration).
- Above this limit the engine works satisfactorily in a wide range of heating power.
- The thrust evolves approximately linearly with the heating power. ($T=T_0+kP$).

Note: Here, T_0=12mN and k=0.2, but obviously To and k depend on the engine.

Appendix :

<u>Possible modes :</u>

As described in the previous pages above a minimum heating power the engine works satisfactorily in a wide range of heating power and the thrust evolves approximately linearly with the heating power. ($T=T_0+kP$). However, there is not only one mode. Let's examine deeper what could happen depending on the heating power.

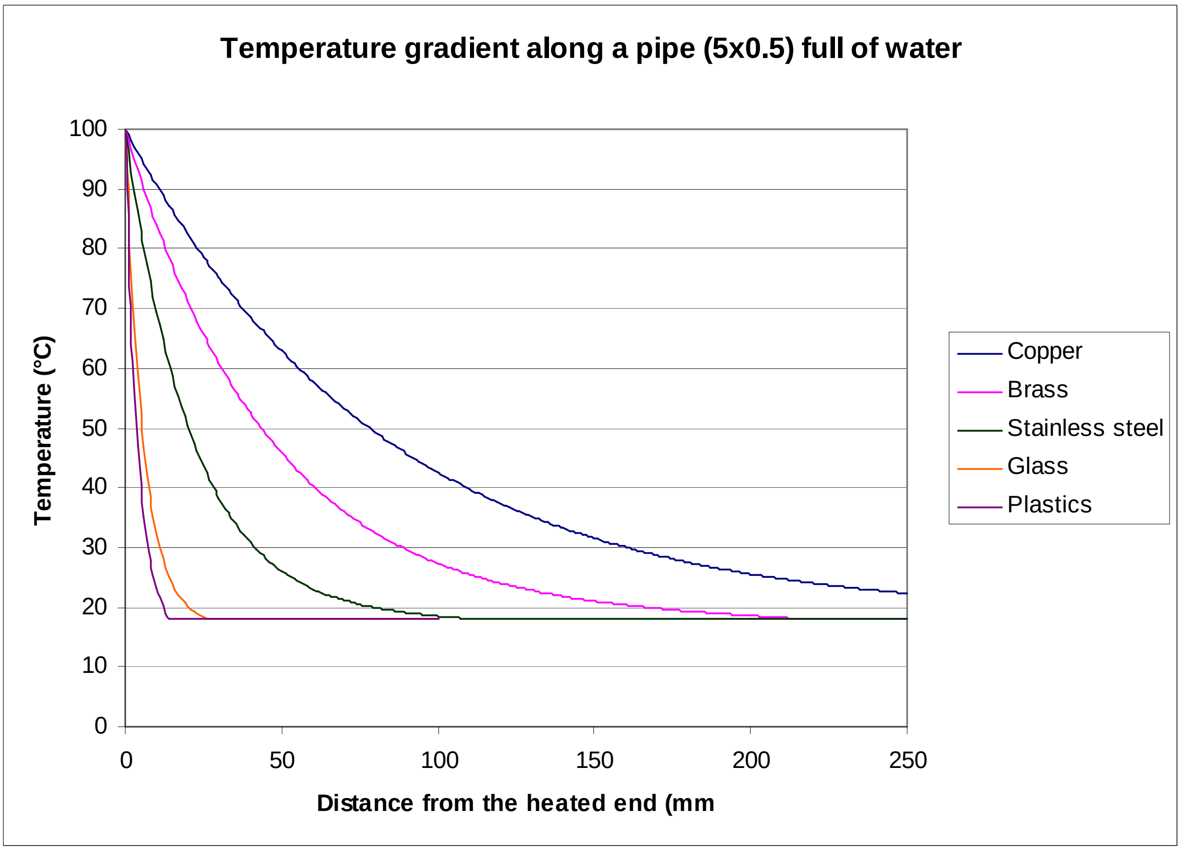
1) If the heating power is less than the steam temperature at the drum pressure (generally approx atmospheric pressure) the water will never boil.
2) If the heating power is just slightly more, the water will boil gently and the steam will push slowly the water down (without oscillations) until equilibrium is reached. The steam water interface will be lower. From this location when following the pipe the temperature will decrease more or less rapidly depending on the material (see the graph given in appendix).
3) If the heating power is more, the water will climb down more rapidly and the engine will start propelling. (The "normal" expected situation).
4) If the heating power is too much, climbing down of the water is fast and leads to steam blasts. Then, from that situation one can meet 3 alternatives.
   4.1) Either burn out. Steady state condition with meniscus located far below in the pipe. Nothing more.
   4.2) Or cold little water ingress. Restart of the engine and soon a new steam blast followed by water ingress, restart, steam blast…at regular interval.
   4.3) Or big cold water ingress, cold drum and long time for boiling, restarting for a short period and new steam blast…

The second alternative (4.2 and only this one) is very interesting because the engine delivers a big mean thrust. Several of us worked on that. Up to now we have observed the phenomenon, there are some records (see for instance http://smg.photobucket.com/albums/v347/highstorrsprom/other/pop%20pop%20boat/?action=view&current=moving.flv where the engine runs at approximately 5Hz with in addition regular steam blasts every 3 seconds) but we don't handle this process.

In addition, with some coil engines we have observed 3 and even 4 different frequencies at a time with the same engine. It depends on the number of turns and on the heating power. But these running modes are not handled at all.

Temperature gradient :

The following " theoretical" graph displays the temperature depending on the material and depending on the distance from the water steam interface.



Reminder: This concerns a steady situation. Obviously, when the engine is pulsating the heat transfer between hot source and cold one is different.