Coil engine performances

The performances of a coil engine depend on many parameters (material, inner and outer diameter of the pipe, coil diameter, number of turns, length of the pipes, bending and/or inclination of the pipes, water temperature, heating power…). These parameters are so numerous that to start we decided to standardize most of them and to build engines as simple as possible. We made a mistake by using horizontal pipes. Today it is evident but it was our first approach of coil engines.

The three engines on the top of the picture have a bigger coil diameter than the others.

The one at the bottom is theoretically identical to the one in the middle, but we built a new one when we encountered a problem described further.

For a more exhaustive testing we built some engines with opposite pipes. Obviously, it is only for test purpose. It wouldn't be realistic on a boat.

The engine on the right is shorter than the others, but it has been connected to the test bench with a longer nozzle to compensate.

To build these engines we used copper pipe 6x1. For annealing the pipe was heated to become dark red or slightly more (cherry red) and then we let it cool down gently. Then we used a cylindrical piece of metal to roll the pipe around. You can find how to do this on several web sites.

Moteurs qui ont été testés en premier:

Tube outer diameter	Tube inner diameter	Coil inner diameter	Number of turns	Pipe length (straight one)
6mm	4mm	12mm	2	200mm
6mm	4mm	12mm	2.5	200mm
6mm	4mm	12mm	3	200mm
6mm	4mm	12mm	3.5	200mm
6mm	4mm	12mm	4	200mm
6mm	4mm	12mm	4.5	200mm
6mm	4mm	12mm	6	200mm
6mm	4mm	12mm	7	200mm
6mm	4mm	21mm	2.5	200mm
6mm	4mm	21mm	3.5	200mm
6mm	4mm	21mm	4.5	200mm

Test bench :

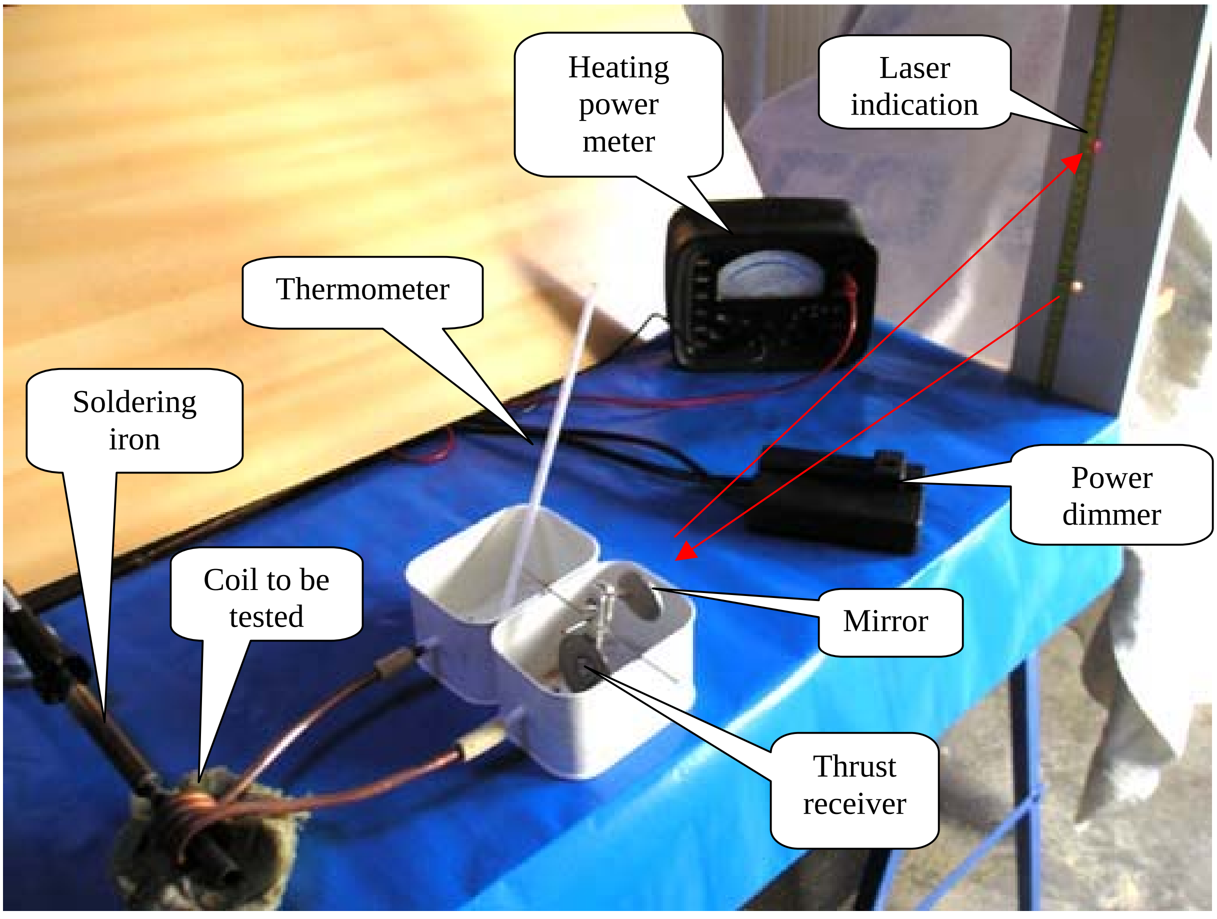
All the engines were tested on the same test bench.

One pipe end connected to a tank provided with a thrust measuring device.

The other one connected to an identical tank (but without measuring device).

Heat source: an electrical soldering iron with power control. The use of an electrical heating source allowed to control the power transferred to the coil, but not to know its sharing between the different turns.

Thrust measuring device: assembly of a target and a mirror fitted on a horizontal axis. A laser beam is deviated by the mirror. The deviation of the beam is measured and the corresponding thrust is calculated.



The laser emitter is located behind the vertical white board. The beam goes through a hole in the board. A rock wool mattress is visible below the coil. During the test another mattress was set above to limit heat losses.

What has been observed :

- Starting occurs after a time much longer than the one needed to get 100°C.
- Burnout (stop of the pulsed jet) could exist. It is rare compared with other types of engines (drum or diaphragm types), but we got it.
- The temperature of the tank water has no visible influence on the frequency and thrust (between 20°C and 40°C)
- Both ends are not always working equal.
- Several pulsing phenomena are superimposed.
- The thrust is bigger when the pipes are above the coil.
- When the coil axis is vertical, the thrust is almost nil on the lower pipe.

- With the same engine and apparently the same conditions the thrust could vary from one to five or even more.

Comments :

Start delay

The heated part was for instance 40 grams of copper and 5 grams of water. To reach 100°C with a 100W heat source should have needed approx 1 minute (including soldering iron heating). Every time it took roughly 6 minutes.

Burnout

It is rare compared with other types of engines, but testing the engine at the limits we got it many times. Every time the whole coil was overheated. Without changing anything, we poured with a little sponge some drops of cold water on the coil and the engine restarted by itself. (Same observation was made with drum engines and diaphragm ones.) It sets as evidence that the burnout –at least in this case- is not due to air ingress.
Note: The burnout is more unlikely to occur on a boat because of its movements.

Temperature

Without any other change, ice cubes were added in the tanks and equal quantity of water was taken off. The temperature decreased quickly from 40°C to 22°C without visible change on frequency and thrust. This test was repeated three times for confirmation.

Dissymmetry

Sometimes, one pipe end works as expected though nothing or nearly nothing is visible on the other end. Such phenomenon could exist on a boat without being known. As the test bench has been designed it was easy to see it. A more detailed explanation is given in the file “Pulsed waterjet or pump?”.

Water movements and thrust are not the only visible differences. Several observations are associated to this dissymmetry:

- ❖ The engine sucked slowly in one tank and filled in the other tank. We got up to 14mm level difference. And the maximum flow was roughly 5cc per minute. Very often we got a final level difference of 8 to 10 millimeters. This occurred sometimes with engine pulsating, sometimes without pulsations.
- ❖ By refraction into the water we could see very hot water going out of one pipe when the engine was not pulsating.
- ❖ The pipe on the suction side was cold.
- At the end of a several hour test the tank on the good side was hotter than the other one. Ex: 39°C on one side and 28°C on the other side with an initial temperature of 20°C on both sides.

Pulsing phenomena

The frequencies governing an engine depend on the size of this engine. This was demonstrated with diaphragm engines and drum engines. During the test of coil engines we had no accurate tool to measure the frequencies. This will be done later. Nevertheless, we observed up to four different phenomena on the same engine. At a given time one, two or three were seen. There could be four (or even more) but it was only a visual observation… Example with the 6 turn engine:

- ❖ Higher frequency: approx 7 Hz.

- Second frequency: approx 3 Hz. Later we realized that it is the natural frequency of the measuring device. Perhaps it is not a frequency of the engine.
- Third frequency: approx 0.8 Hz.
- Fourth frequency: This one was observed during the first minutes when the engine was delivering a weak thrust. There was a burst of energy every 8 seconds.
- Fifth frequency: Once the engine delivers a big power there is a stop of the pulsations for 5 seconds every 40 to 60 seconds. Due to the agitation of the water and the natural frequency of the measuring pendulum we cannot guarantee that the thrust was zero, but it was less than 5% of the mean thrust.
- Bursts of energy (steam blasts) without periodic characteristics. Steam blast probably occurs as with other engines when a drop of liquid water reaches a highly overheated surface.

<u>Position of the coil</u>

The use of horizontal pipes was a fault. It is useless to comment the result.

<u>Orientation of the coil</u>

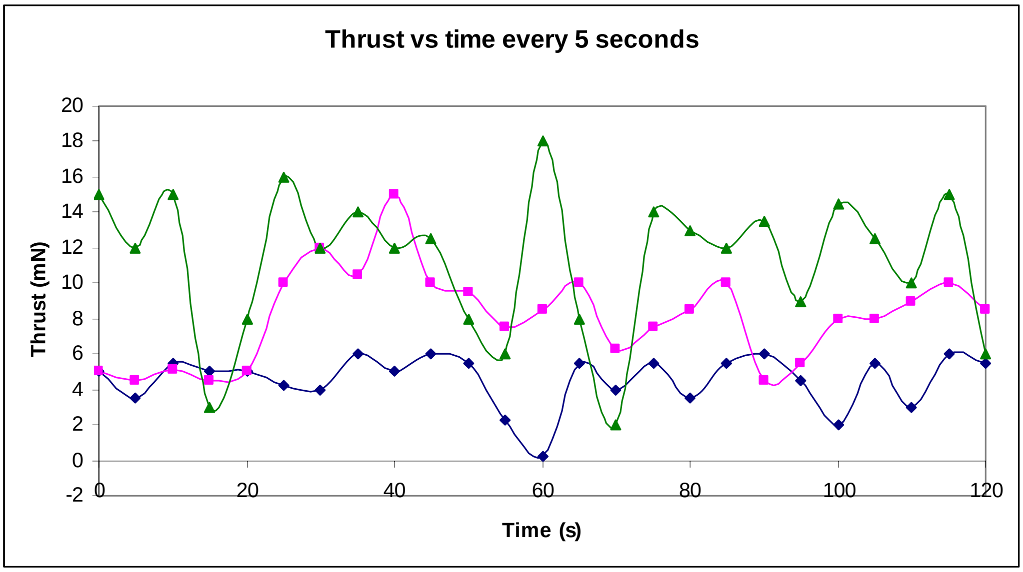
Our observation has been confirmed by Guus who came to the same conclusion.

<u>Thrust variations</u>

As for other engines the thrust is fluctuating. What is “frustrating” is the fact the mean value could be very different during consecutive tests which are run in similar conditions. With a moderate heating power we succeeded to get a very slow increase of the mean thrust during approximately one hour before stabilization.

We have many records (manual records) of thrust versus time for a given heating power, but sometimes one turn is overheated, sometimes two, three…, sometimes they are the inner turns, sometimes the outer ones. And due to the use of rock wool all around the coil we couldn’t check that while the engine was running.

Hereunder is given a graph just to show how the instantaneous thrust is changing. And this is damped by the measuring pendulum, the time constant of which is 0.3 second. The reality is worse, most of the thrust being given by the 7 hertz pulses not at all visible here.



The best mean thrust measured with horizontal pipes was 9mN with peaks up to 13.5mN. The arrangement with horizontal pipes was very likely the cause of some of our difficulties to get a good steam liquid interface on both sides.

Later with the engine visible on the picture we measured a mean thrust of 12 mN (on each pipe) with peaks up to 18 for half a second. And this time, we could reproduce the result. A short record of this mean thrust is given above with the green curve. For more details look at the document "Test of a coil engine".