Propulsion by pulsed waterjet

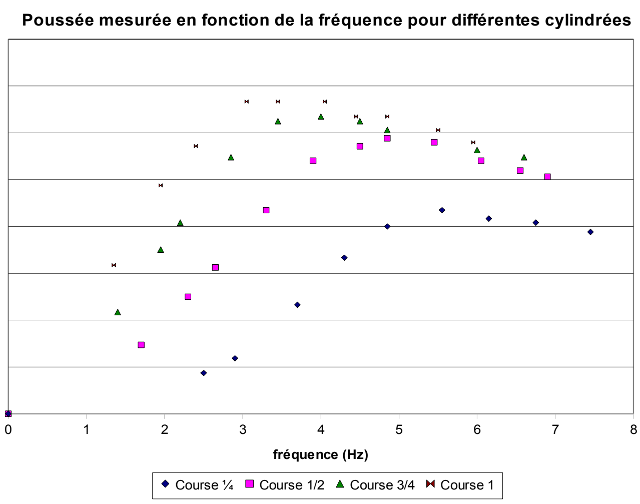
On the French wikipedia one can read (still at the time I'm writing this document) that the *pop-pop is not a waterjet*. Yes it is! WATER and JET are the characteristics of a pop-pop propulsion. It is not a direct waterjet, but it is a waterjet. A pulsed waterjet.

To study the behavior of this type of propulsion, in 2005 and 2006 I built several pulsed waterjet generators with more or less complicated kinematic.

My first simulator was built to check the relationship between a direct waterjet and a reciprocating one using a sine characteristic. To do that I used the fuel pump of my old car. I took off the check valves and connected both orifices together and to a single tube itself connected to a tank provided with a thrust measuring instrument.

The sine movement was generated by a cam driven by a controllable speed motor. At very low frequency I got a thrust evolving as the square of the frequency. Super! But above a few hertz the thrust increased not so fast, got to a maximum, and then decreased. The result was not the one I expected. Therefore, I sacrificed the pump to understand...and discover that it was designed with a cavity used as pneumatic damper. This was enough to explain the curve I had got.

Hence, I used an old controller from a water heater using gas to build a pump with a unrolling diaphragm so that it could not trap some air. The result was slightly better, but at high frequency, it is the diaphragm itself which -due to its elasticity- played the role of a low pass filter.

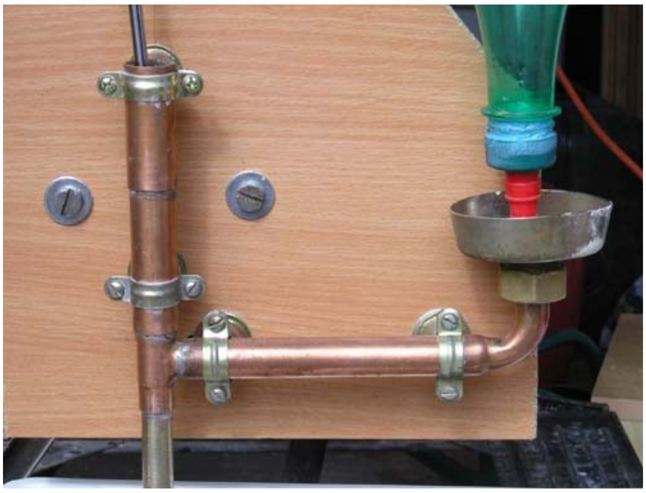


The graph on the right shows the measurements got for 4 different stroke volumes. For small stroke volumes and low frequencies the dots are approximately on parabolas. But as soon as the product Stroke*Frequency (ie, speed or flow) exceeds a certain threshold we can see that the dots don't follow the parabolas.

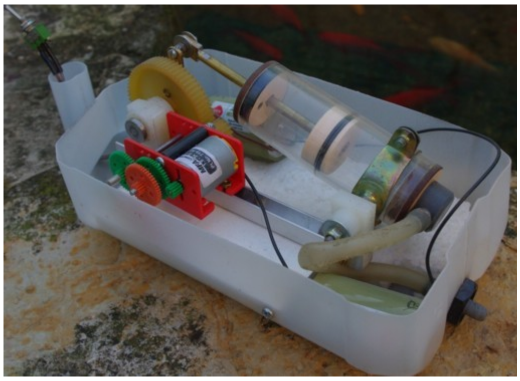
On December 5, 2006 I paid a visit to professor Le Bot, the man of the revival of pop-pop in France. He showed me his "Abeille Whisky", the model of a supply vessel provided with an electro-pump with diaphragm. On a gear box powered by an electric motor he had connected a diaphragm pump of his basic design. (In red on the photo).

He showed me the French article that he intended to translate and send to Model Engineer for publication. I proposed to read it but he didn't want to divulge the secret before publication. Result: in May 2007 his article was published in Model Engineer n°4300...with a wrong conclusion. The curve recorded by Pr Le Bot was similar to the ones of my two first pumps. After that, I exchanged several mails with Pr Le Bot to explain him that a pump with a diaphragm made of rubber could not follow at high frequencies. A stroke volume exactly proportional to the displacement was needed. Too late. The article was published.

In the meantime, after my first disappointments, I built solid piston pumps. The first one with a spherical piston was not enough watertight. Therefore, I added a crosshead to allow using a cylindrical piston with gaskets. For a watertight piston it was a watertight one! It was so tight that I had to use a big motor to move it...but it was only for a few hour testing. I foresee a water guard supplied by a bird feeding system to avoid the least air ingress. This precaution was later proven to be useless.



Pump details. The piston moves in the brass tube of the bottom. Above it, a crosshead moves into the copper tube. On the top we can see a small part of the rod which connects the crank to the crosshead. On the right, the water guard.



End 2011, thanks to Bloooo forum I got in touch with Gérard who, on his side, built also a pulsed waterjet. And his has the advantage to float...even though (light euphemism) the hull shape is not optimized.

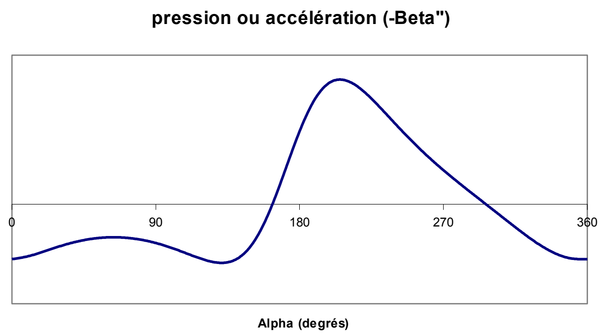
The piston movement of Gérard's transparent syringe is sinusoidal. His pulsed waterjet propels the float and set as evident what science teaches us...even if it is not intuitive: when the jet goes out it propels. When the water is sucked, the effect is negligible.

At the beginning, I too worked with a quasi sine movement. Very long connecting rod driven by a crank on which the pin could be set in 4 different positions. (Side photo). This allowed to simulate 4 stroke volumes. And the drive at controllable speed allowed to simulate any possible frequency.

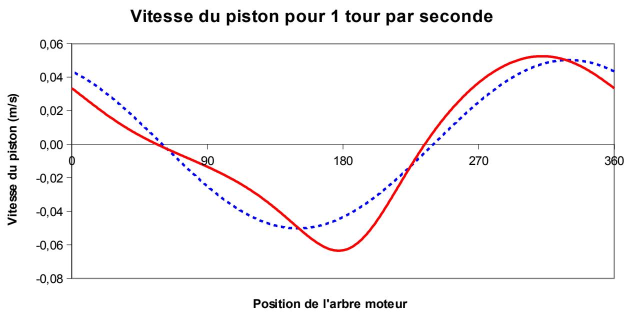
This simulator allowed me to draw the curves of thrust versus stroke volume and frequency, and … to check that the laws of physics discovered by renown scientists apply as well to the pop-pop propulsion.

Then, as I didn't know if the water movement inside a pop-pop engine was sinusoidal I complicated the kinematic in order to force water out faster than in.

With this kinematic I got for the piston the following acceleration.



Acceleration being the image of pressure into a pop-pop engine (P=F/S and F=Mχ) this would correspond to a fast pressure rising and a progressive pressure release.



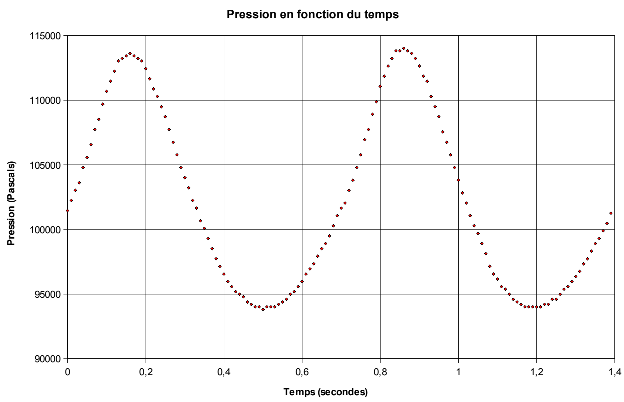
In spite of such an asymmetric acceleration, the speed is not so far from a sine signal as it can be seen on the side graph.

Note: Because in a pop-pop engine the higher pressure corresponds approximately to the top dead center (maxi length of the water column), for a pressure corresponding to the simulated one the speed would be closer to a sine signal.

After all this, as it was easy, I ran the simulator the wrong way just in case it would have been discovered later -though unlikely- that the amplitude of the underpressure in a pop-pop engine is higher than the one of the overpressure.

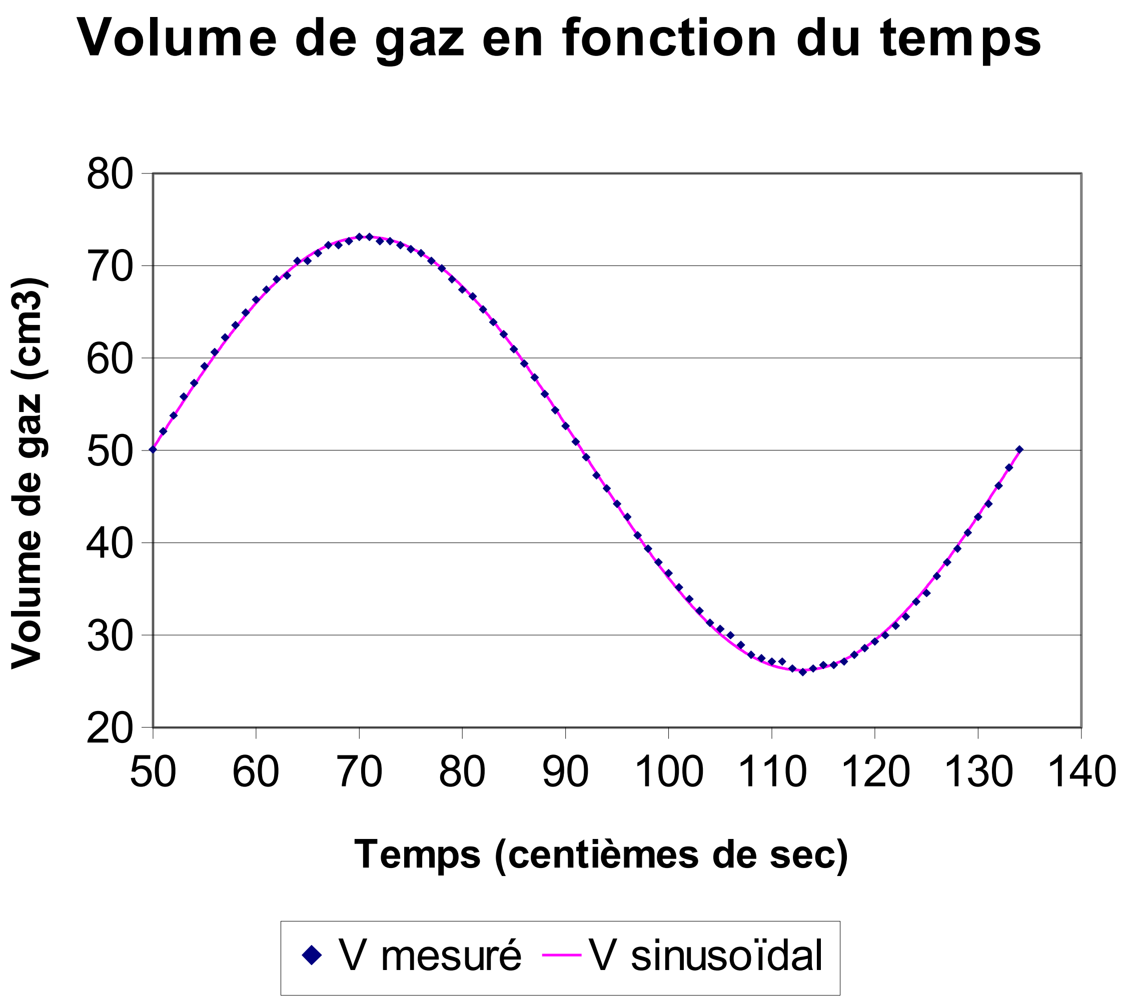
In any above related case (and in all the others), the thrust was seen proportional to the calculated momentum. (Integration of the square of the instantaneous positive speeds during a cycle).

3 years later (end 2009) I succeeded (First world record?) to record the cycle of a pop-pop engine. Pressure and volume of gas versus time.



It can be seen on the pressure record (on the side) that it evolves roughly as if the cycle was adiabatic...but this is another story.

Let's look at the movement of the water column! And this one, I put it in large format because it is very interesting..



It shows that with my hydromechanical simulators I spent much time for few useful results. The water movement in the tubes of a pop-pop engine is quasi sinusoidal. On the graph the blue dots are the measurements recorded during a cycle with a digital recorder. The pink curve is a perfect sine. Look for the differences!