The flying pop-pop

By Jean-Yves

One day, while trying to build a mathematical model of the pop-pop engine, I had a dream: the flying pop-pop. This dream came to reality. Here it is.

Just for fun it looks (roughly I must admit) like an aircraft. But behind this, there is something more scientific.

1°) Bollard pull conditions :

Thrust and frequency of the engine were measured at bollard pull conditions. Thus, I had an idea of its characteristics, and assuming the water movement is sinusoidal (which is not so far from reality as seen on some occasions, see "The water snake movements") it allowed me to estimate the maximum jet speed.

2°) Flying pop-pop :

I let the flying pop-pop rotate by itself and I measured its speed. Obviously, it was more than what it would have been on a boat because in this case there was less water resistance. No wave, no friction, no drag due to the hull… Only two short lengths of pipe dipped into the water.

3°) Sailing pop-pop :

To complete the previous tests, the seaplane was put on the water and its speed measured.

4°) Hydrodynamic resistance :

Skin friction, wave resistance, air resistance... whatever their individual effects were altogether measured. To do that, a well known torque (a weight suspended by a very thin thread rolled on a drum via a pulley) was exerted on the mobile and the corresponding speed (rpm of the mobile) was recorded.

Characteristics of the engine :

The first coil engine visible on the photo didn't give satisfaction. Therefore, I took the opportunity to use and test Slater's engine (see www.sciencetoymaker.org). The only modifications were an inclination of the pipes downward and the addition of two cylindrical nozzles of internal diameter 5mm.

Turning radius (between vertical axis and nozzles) = 220mm

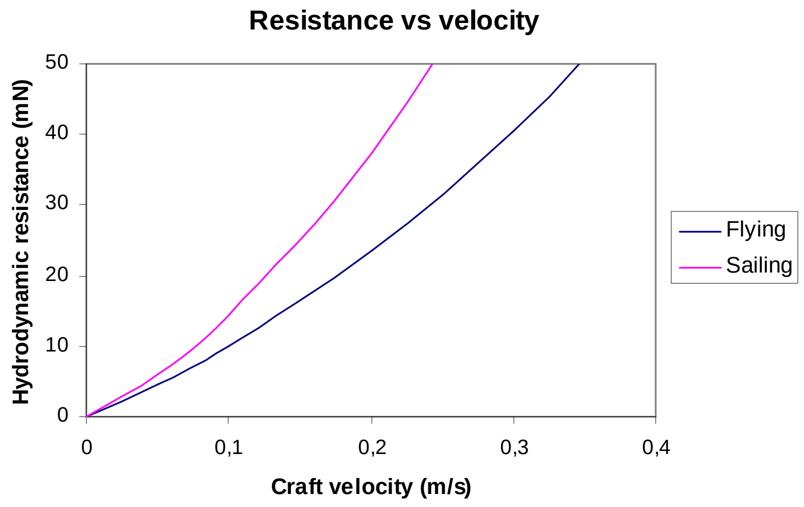
Results:

Accuracy: Each speed measure is the average of 10 records. WCE (Worse Case Error) 9% except for self propelled flying pop-pop (20%).TPE (Typical Probable Error) 4% for all the data.

Measured frequency: 6.6Hz.
Thrust at bollard pull: 19mN.
Speed of flying pop-pop: 13.6 rpm or 0.157m/s.
Speed of sailing pop-pop: 10.1 rpm or 0.116m/s.

Hydrodynamic resistance:

Thrust (mN)	0	21	42
Sailing pop-pop (m/s)	0	0,133	0,216
Flying pop-pop (m/s)	0	0,183	0,307



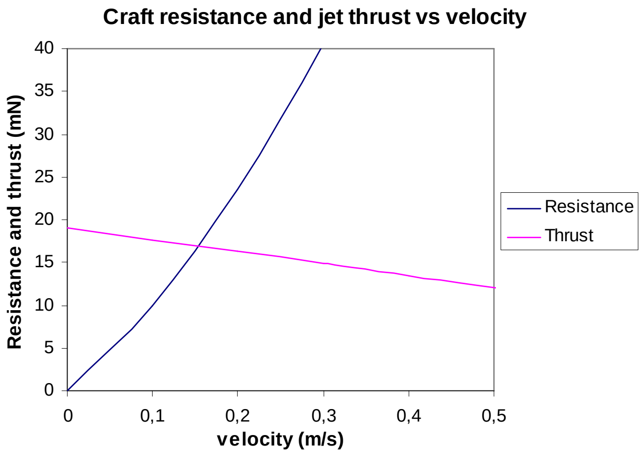
Note: Due to various factors (some friction in the bearings, calibration height limited to 3m, thrust variations of the pop-pop engine…) these are not laboratory measurements. However, most of the errors are the same in both cases. The trend is clearly visible. The purple curve is quite above the blue one.

Calculations :

Based on previous experiments and calculations, these data allowed to determining:

The stroke volume C = 1.31cm^3 per nozzle. (Because $T_{moy} = \pi\rho(\frac{CF}{d})^2$)

The maximum water velocity at the jet V = 1.38m/s. (Because $V_{max}=\pi CF/s$)



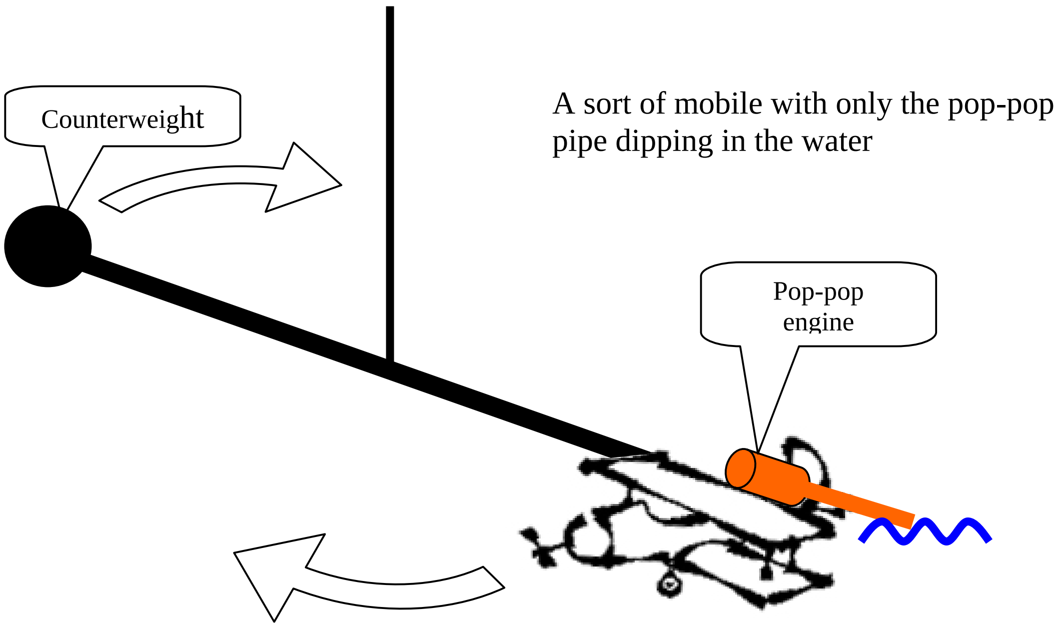
On the same graph we can draw the hydrodynamic resistance of the pipes dragged in the water and the thrust delivered by both waterjets versus nozzle speed.

We can deduce that the working point should be 0.155m/s (and 16.9mN) when we measured 0.157m/s. Close.

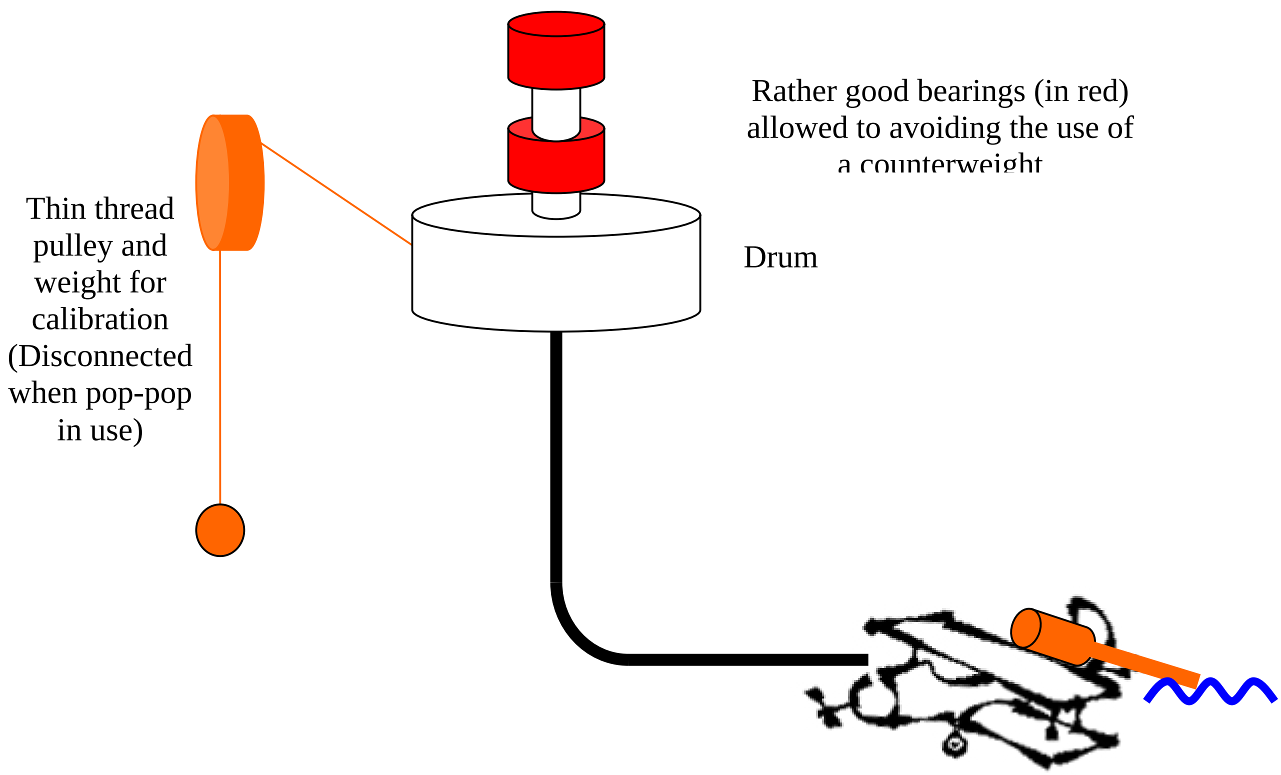
Note: The pipes of the pop-pop engine were very inclined and too much immersed deep in the water. With better precautions the result would have been better. Next time?...

Appendix :

1°) The dream :



2°) A more scientific approach :

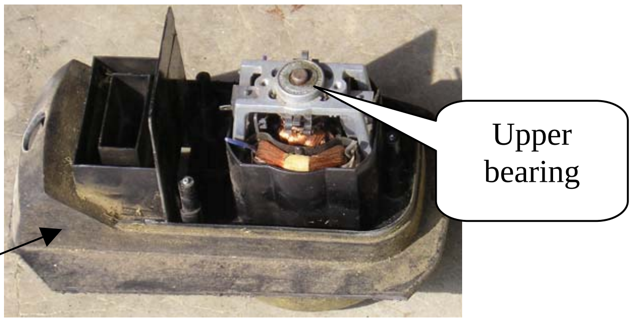


3°) Birth of a flying pop-pop.



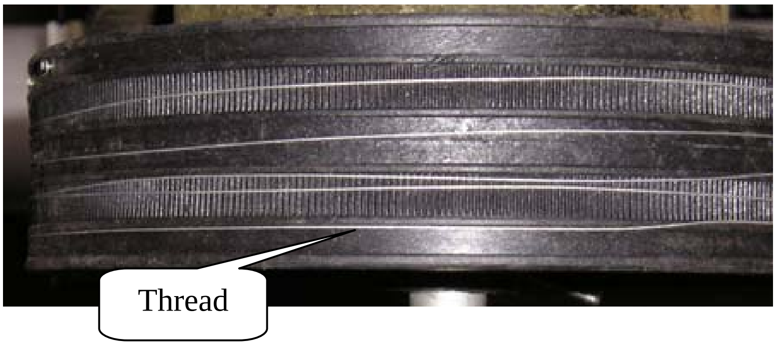
A broken mast of a sail boat, its crosstrees, and an Easter egg (it was Easter week-end) were the first raw materials. Four pop(-pop) rivets (too easy. I couldn't pass it), fibreglass and epoxy resin made the rest.

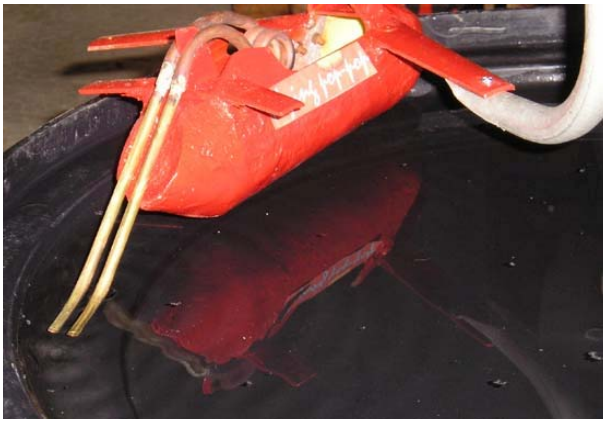
But I needed good bearings to sustain the so called flying pop-pop. By chance, my best friend Michel had some troubles with his old edge trimmer. He no longer has any problems with it. He doesn't have this edge trimmer any more. I used the bearings of the electric motor for the vertical axle of my merry-go-round. (Michel is still my friend).

Just below the lower bearing I fixed a drum with a very thin thread around for the calibrating torque generation.

The drum is a wheel of lawnmower. Not got from Michel! It's a brand new one bought on purpose at the nearest hardware store. Diameter 172mm.





And there, the craft is "flying" above the water (thanks to the arm connected to its right wing). Small wavelets are visible after the pipe outlets.

During this test I could observe the water movements. While the craft was turning in one direction, the water was turning in the tank in the opposite direction (Third Newton's law) at a speed approximately 20 times lower than the craft one