Shape of a nozzle for pop-pop propulsion

By Jean-Yves

It exists nozzle shapes that are optimized for ships or scooters propelled by waterjets. But, due to the alternate working of a pop-pop engine, what is the best shape to be used? What follows doesn't answer fully the question. Some things are sure. They are dictated by the laws of hydromechanics and they have been checked by some experiments. Others will necessitate trial and error approach. That is a reason why pop-pop engine is interesting. Everybody has a chance to improve something…

<u>Free the nozzle end :</u>

Prefer boats with thin stern (or catamarans with nozzle located between the hulls).

Let the pipe exceed the hull stern by at least 3 times its diameter. (See justification in "Pop-pop engine and electrical analogy" and/or in "Working principle of a pulsed waterjet").

Use a thin tube, or sharpen it at its outlet. (See conclusions of the studies "Hydraulic test bench" and "Thrust measuring test bench")

The purpose of these three recommendations is to ease the relaxation phase.

<u>Select the right nozzle diameter :</u>

Ce qui propulse le bateau, c'est la quantité de mouvement T=Q.V (Q étant le débit et V la vitesse de l'eau sortant de la tuyère).
Ceci incite à penser qu'il suffit de choisir un petit diamètre. Malheureusement, le problème n'est pas si simple car un petit diamètre implique une perte de charge élevée qui a des répercussions (assez mal connues) sur le fonctionnement (débit et fréquence) du moteur pop-pop. Il faut donc tâtonner pour trouver le meilleur compromis.

<u>Use a converging nozzle :</u>

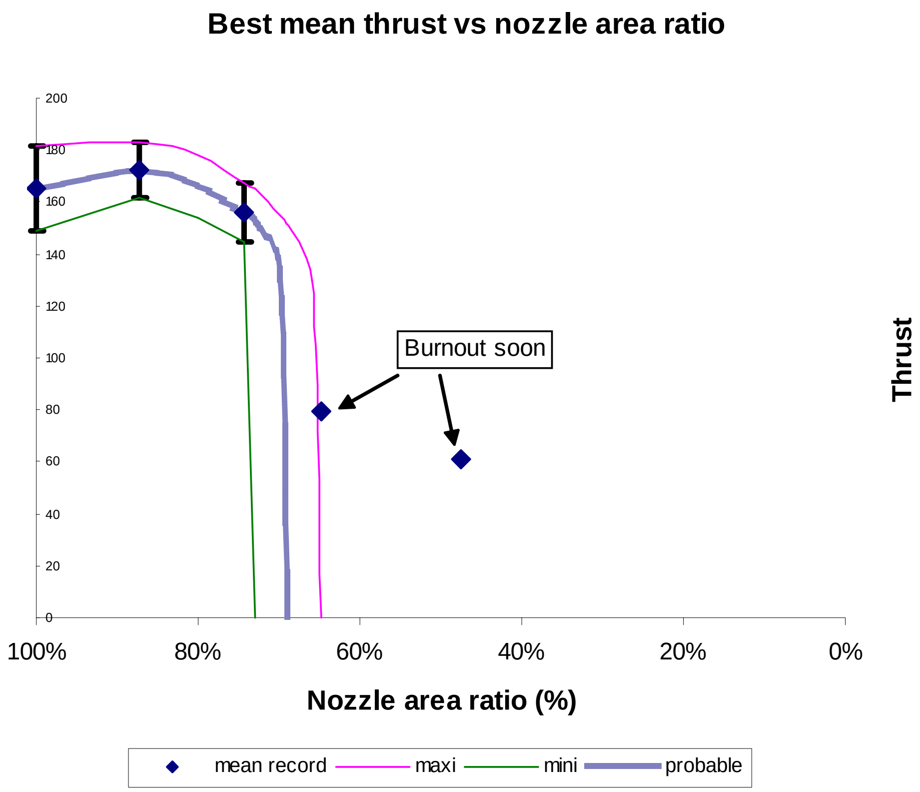
We have checked (with direct flow as well as with alternate flow) that a converging nozzle is more performing than a cylindrical nozzle of the same output diameter. This is mainly due to the *vena contracta* phenomenon. Indeed, hydraulically the fluid vein follows the direction given by the nozzle, and slightly downstream (at the vena contracta location) the cross section is minimal and the velocity is maximal. One could object that the result would be the same as when using a cylindrical nozzle having the diameter of the vena contracta. In the propulsion phase that would be approximately true, but now let's compare this cylindrical nozzle with the previous one during the relaxation phase. In that direction there is no more vena contracta phenomenon. Water comes from every direction towards the two nozzles, and it encounters fewer difficulties to enter the bigger orifice… which is the one of the convergent nozzle.

What conicity? 15, 20°? What area ratio (between nozzle outlet and pipe)? There, once again, the door is open for experiments.

On a rather big performing engine we tried to measure the efficiency of several nozzles. Each nozzle was a small part more or less conical. All of them had the some inlet diameter (8.7mm) and the same length (36mm).

Nozzle #1. Cylinder. Inner diameter 8.7
Nozzle #2. Flattened cylinder. Oval outlet 11x6
Nozzle #3. Cone. Outlet diameter 7.5
Nozzle #4. Cone. Outlet diameter 7
Nozzle #5. Cone. Outlet diameter 6

We ran many tests with each nozzle. We succeeded to get a permanent and powerful running of the engine with nozzles #1, 2 and 3. With nozzles #4 and 5 we got less thrust and every time the engine went soon to burnout. We have plotted the results on a graph, including those of nozzles #4 and 5. Then we have added the curves as we “feel” they look like.



Looking at this diagram it seems that a nozzle with a small area reduction (*) improves the thrust, but the standard deviations (vertical black dashes on the graph) are rather big and it is difficult to assert this.
One thing is more evident: a too narrow nozzle is detrimental.
* Small area reduction. In our case it was 13%. It means diameter reduced by 6 or 7%.

To end at this stage of the knowledge, let’s greet our ancestors! The boat *Le Racer* very common between both world wars had a thin stern shape, it was provided with only one pipe (that I recommend - maybe I’m wrong - since the beginning for other reasons), this pipe was free and thin, and (on some models) it was pinched to become convergent. The full!...except the fact it had a diaphragm type engine giving a lower efficiency, but the counterpart was a wonderful sound and a smaller (lighter and shorter) engine easier to locate inside the hull.