SHARK-GILL-INSPIRED NOZZLE IMPROVES NUCLEAR REACTOR SAFETY

Jonathan Sarfati

NUCLEAR REACTORS are powered by certain types of reactions that occur in the atomic nucleus, the inner part of an atom made up of protons and neutrons. Nuclear reactions produce far more energy than chemical reactions which only involve the atoms' outer electrons. Thus, nuclear power is much more energy-dense than any other practical power source.

In particular, reactors work by fission, the breaking of a big nucleus into two smaller ones. 'Slow' neutrons are used to bombard heavy nuclei—usually uranium-235, or sometimes plutonium-239—and cause the nucleus to split. Fission occurs in a very fast, runaway fashion in a nuclear explosion. Conversely, in nuclear power generation, it is much more controlled. The heat energy from the nuclear fission is used to generate electricity.

Pressurized water reactor

Most of the world's nuclear power plants (except in the UK, Japan, and Canada) are *pressurized water reactors* (PWRs). Such a design lets high-pressure liquid water flow into the reactor. The water picks up the heat, and the pressure *prevents boiling inside the reactor.* (Water is also a *neutron moderator*; i.e., it slows down the neutrons.) The hot, high-pressure water is pumped through pipes to heat ordinary-pressure liquid water and turn it into steam. *This steam is non-radioactive.* The steam then spins a turbine. The turbine spins a generator—invented by creationist physicist Michael Faraday (1781–1867)—to produce electricity.

Jet flow mixing

Jet flow with turbulent mixing is essential for heat transfer. For safety, in case of a *loss-of-coolant accident* (LOCA), surrounding metal plates are drilled with LOCA holes and slots. However, they cause LOCA jet cross-flows, which can induce vibrations in fuel rod assemblies. Another problem is 'baffle jetting', where the cooling water pushes through small gaps and emerges as high-speed jets. These can cause further vibrations that can wear out the fuel cladding.

Shark gill ventilation

Two Polytechnique Montréal (Canada) engineers realized that "eco-design" could be very useful.[1] They listed several examples of engineers copying design in nature, called *biomimetics*. (They included several we have previously written about, such as gecko adhesives.[2]) Then they looked closely at how sharks breathe through five to seven gill slits.

Shark gills also work by jet flow, called *ram ventilation*, where the forward motion of the fish forces water through its mouth over the gill filaments (*primary lamellae*). These branch into many tiny plate-like structures (*secondary lamellae*), running parallel to the direction of water flow. These provide a large surface area for gas exchange between the flowing water and blood flowing in the opposite direction (fig. 1). Such

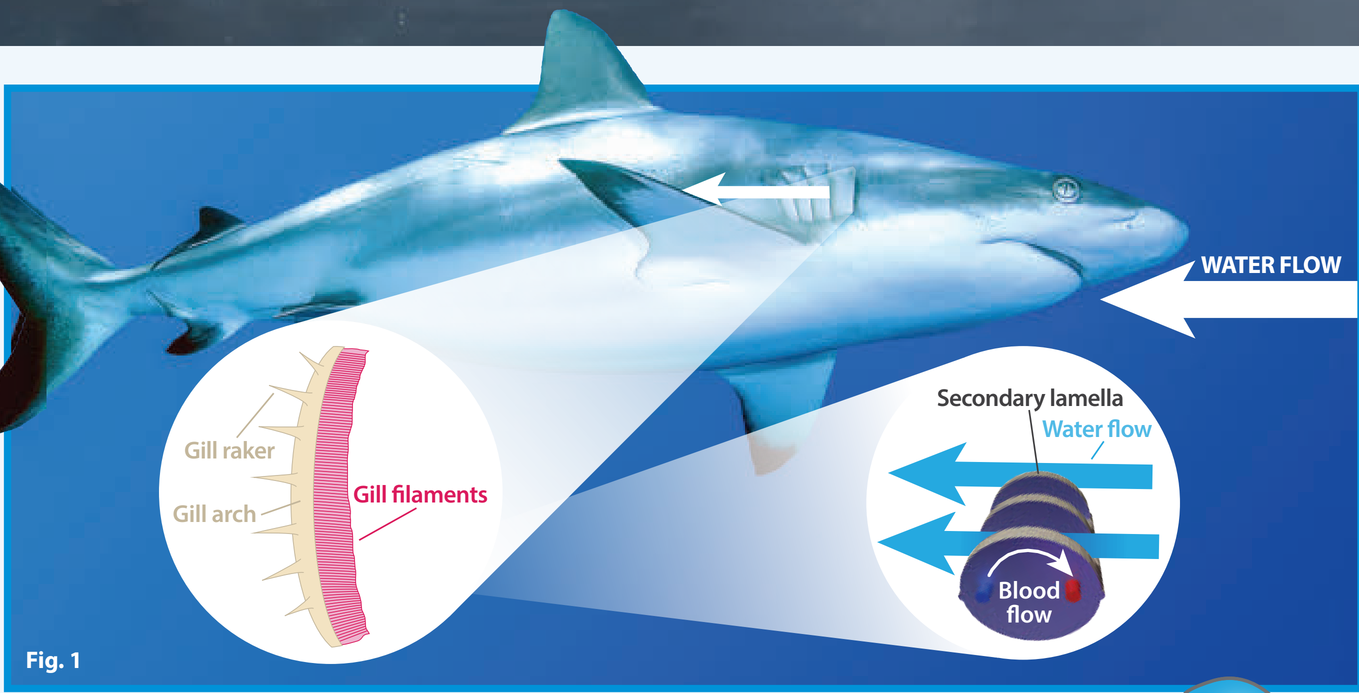

Fig. 1

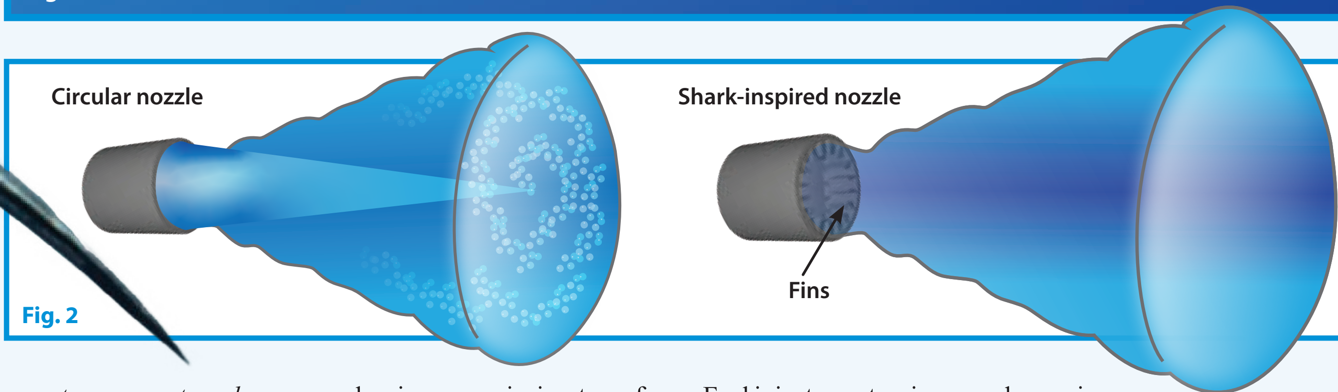

Fig. 2

counter-current exchange mechanisms maximize transfer between one medium and another—whether oxygen as in this case, heat, or something else.

Then the jet flow is ejected. The secondary lamellae cause the jet flow to mix efficiently with the surrounding water. In this way, the shark's swimming speed and agility are not impaired.

Biomimetic mixing nozzles

The researchers made nozzles modelled on the shark gill design concept. These nozzles had either 10 or 15 fins—each 11 mm thick and 12.7 mm long—that mimic secondary lamellae. They filmed their function with very high-speed imaging—400 frames per second.

As they expected, they found that the shark gill design enhanced mixing between the jet flow and coolant, allowing more efficient heat transfer. Safety was also greatly improved. They found a 20% increase in critical velocity, i.e., the flow speed above which unstable vibration increases sharply. A higher critical velocity means less chance of unstable vibrations occurring. Furthermore, the vibration amplitude was reduced by up to 85% in the 15-fin design.[3]

The researchers pointed out that highly efficient mixing nozzles have a much wider importance than nuclear reactors. Fuel injectors, atomizers, and gas mixers should also benefit from the biomimetic design.[1]

Conclusion

The fast-growing biomimetic field is a testament to the ingenuity of scientists and engineers copying design in nature. *A fortiori* (all the more so), it is a greater testament to the ingenuity of the Maker of the originals.

References and notes

1. Gad-el-Hak, I. and Mureithi, N., Mitigation of jet cross-flow induced vibrations using an innovative biomimetic nozzle design inspired by shark gill geometry, *Scientific Reports* **12**(1):11107, 20 Jun 2022.
2. Cox, G., The toes of the tokay, *Creation* **45**(4):1–14, 2023. See also creation.com/gecko and related articles.
3. SVS-Vistek, Shark-inspired nozzle may reduce wear in nuclear reactors, designdevelopmenttoday.com, 12 Jun 2024.

JONATHAN SARFATI B.Sc.(Hons.), Ph.D., F.M.
Dr Sarfati is a physical chemist, chess master, and prolific author of some of the world's most popular and influential books defending biblical creation and countering evolution. This includes the most comprehensive scientific and theological commentary on Genesis 1–11 to date. For more: creation.com/sarfati.