WEEK 7

Article: Hong *et.al.*, A Wireless flow-- powered miniature robot capable of traversing tubular structures, *Science Robotics*, 2024.

QUESTIONS 7a

1. The article mention that testing indicated that scaled down version of giant industrial impellers were less efficient than there designs which doesn't use as short and as many fins. The reason given is that this system must work in open flows compared to bigger impeller that works in well-regulated flows. Can you explain and show the difference between these two environments? How does the design presented in the paper compensate for the non-regulated open flows environment? Can you explain in more detail why in an open flow context, having fewer longer fins is better compared to usual design of macroscopic impellers. Can you explain what could be the cause of the drop in rpm when the length of the fins gets larger than 0.6 mm? It seems counterintuitive since longer fins should mean more surface area in contact with the flow which would imply that there is more energy transfer between the impeller and the flow.

2. How does the design of the flow powering module, in particular the fin geometry and housing opening ratio (Figure 2), optimize the balance between fluid intake and impeller drag, and what constraints limit the scaling of this design to smaller flow channels? Can the robot handle pulsatile flows? Would the robot operate if the direction of flow reversed? Could cambered or airfoil-shaped fins enhance flow-to-torque conversion? Given that flow direction is reversed by the magnetic gate, such fins may increase efficiency in one direction while reducing it in the other. Could a camber profile be optimized to prioritize improved performance against flow while accepting some trade-off in the with-flow direction?

3. Simulation results deviate from experimental data under high load conditions (Figure 2Fii). What assumptions in the modeling of friction, flow field, or other behavior might explain this, and how could the computational model be refined?

4. The robot's movement can be controlled using either an external magnetic field or an onboard mechanical regulator, allowing it to move with or against the flow, or to pause. Can you elaborate on how the external magnetic field and the onboard mechanical regulator function to control the robot's motion? What are the advantages and limitations of each control method ?

5. Figure 4A(iii) shows that for a given pipe, there is a lower flow threshold below which the robot stalls and an upper threshold above which the wheels slip. What mechanistic factors set these limits, and how might you extend the robot’s operating flow range for slippery or high-flow pipelines (e.g. oil lines) without compromising its mobility? In Fig 5.B, a two gates system is implemented to make the robot able to stop. Do you think that it would be possible to achieve the same result with one gate having three resting positions (one blocking the left side, one blocking the right side and the third position in the middle at equilibrium blocking neither side?

6. Authors say that they tried both a highly soft solid wheel and the final picked Kirigami wheel, but they retained Kirigami wheel instead of the solid one due to the buckling risk of the wheel under large compression. First, why are Kirigami wheels not subjected to the same buckling risk under the same load? Can you explain how the kirigami wheel structure prevents buckling for rotation under large compression? Materials used to build the wheels are limited since the wheels should provide enough friction to avoid slippage. Since the simulation on Figure 3b shows that the maximum constraint inside the wheel during compression is around 0.35MPa, and that it is located on the rings, how do they ensure that no plastic deformation occurs inside the wheels?