

Hydrodynamics of high-speed robots driven by the combustion-enabled transient driving method

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Relating literatures:

He ZG, Yang Y, Jiao PC, et al., 2021. Copebot: Underwater soft robot with copepod-like locomotion. *Soft Robotics*, 0158:1-13.

<https://doi.org/10.1089/soro.2021.0158>

Yang Y, Hou BZ, Chen JY, et al., 2020. High-speed soft actuators based on combustion-enabled transient driving method (TDM). *Extreme Mechanics Letters*, 37:100731.

<https://doi.org/10.1016/j.eml.2020.100731>

Yang Y, He ZG, Lin GZ, et al., 2022. Large deformation mechanics of the thrust performances generated by combustion-enabled soft actuators. *International Journal of Mechanical Sciences*, 299(1): 1-15.

<https://doi.org/10.1016/j.ijmecsci.2022.107513>

Transient Driving Method- Soft Robot

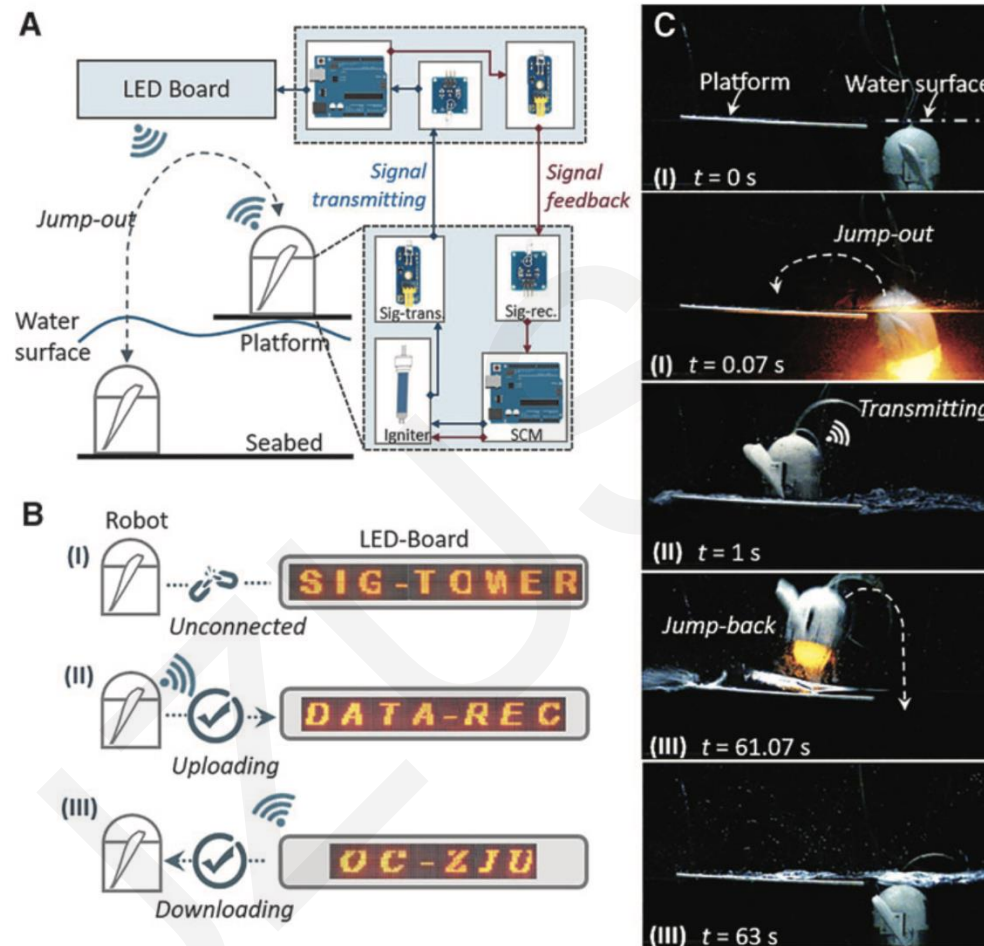


Fig. 1. Illustration of the transient driving method enabled soft robot that can transmit signals from underwater to on-land receiver.

Numerical Setup of the CFD model

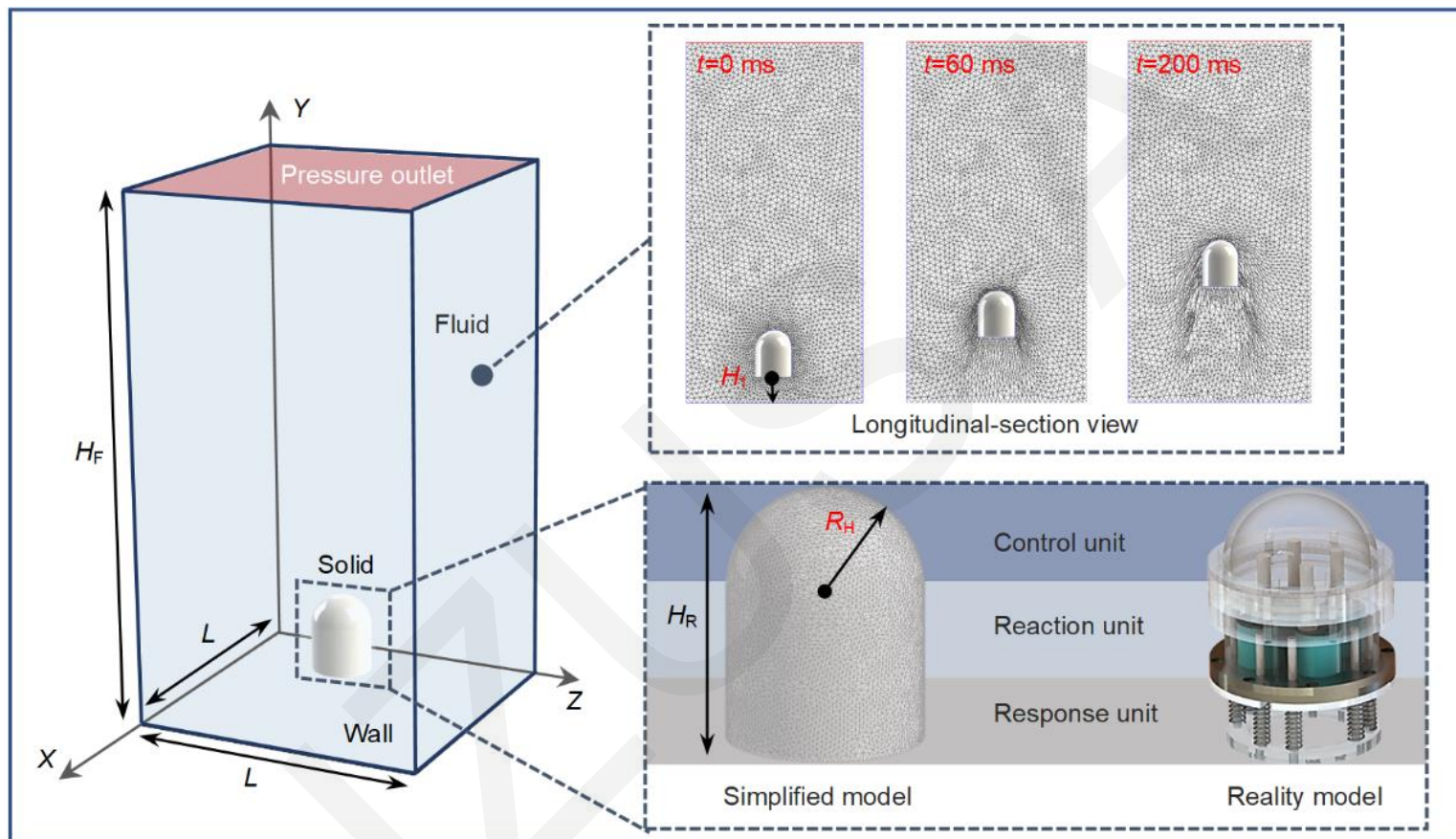


Fig. 2. Setup for the numerical simulation of a fluid field disturbed by robots driven by combustion, including the system coupling, the dynamic mesh, and the design principle of the robots. t is the time

Flow Velocity Distribution

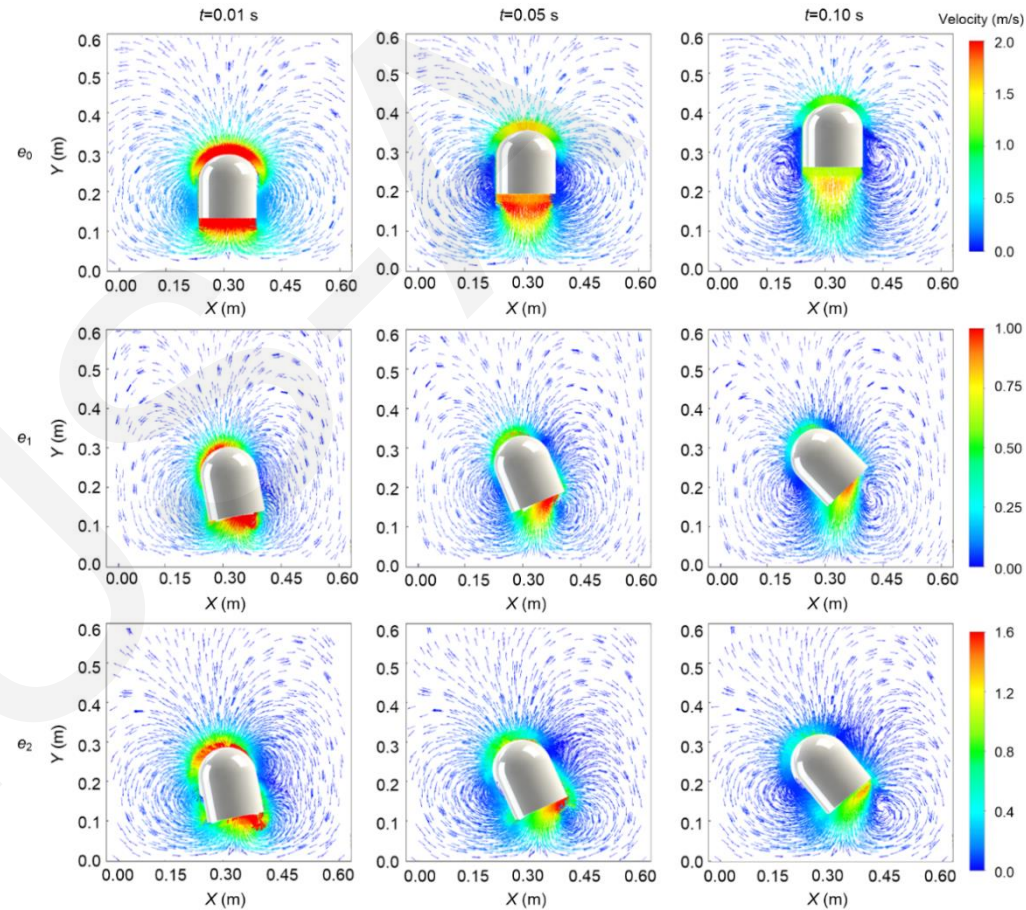
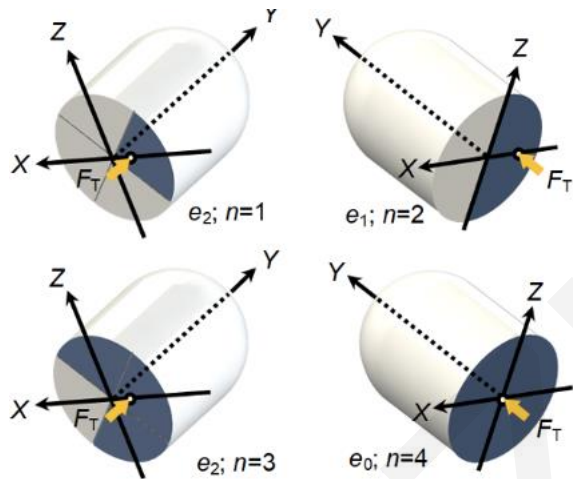


Fig. 3. Illustration of the applied thrust force in the numerical simulations

Fig. 4. Velocity distributions of cases 4–6 at $t=0.01, 0.05,$ and 0.10 s

Pressure & Turbulence Distribution

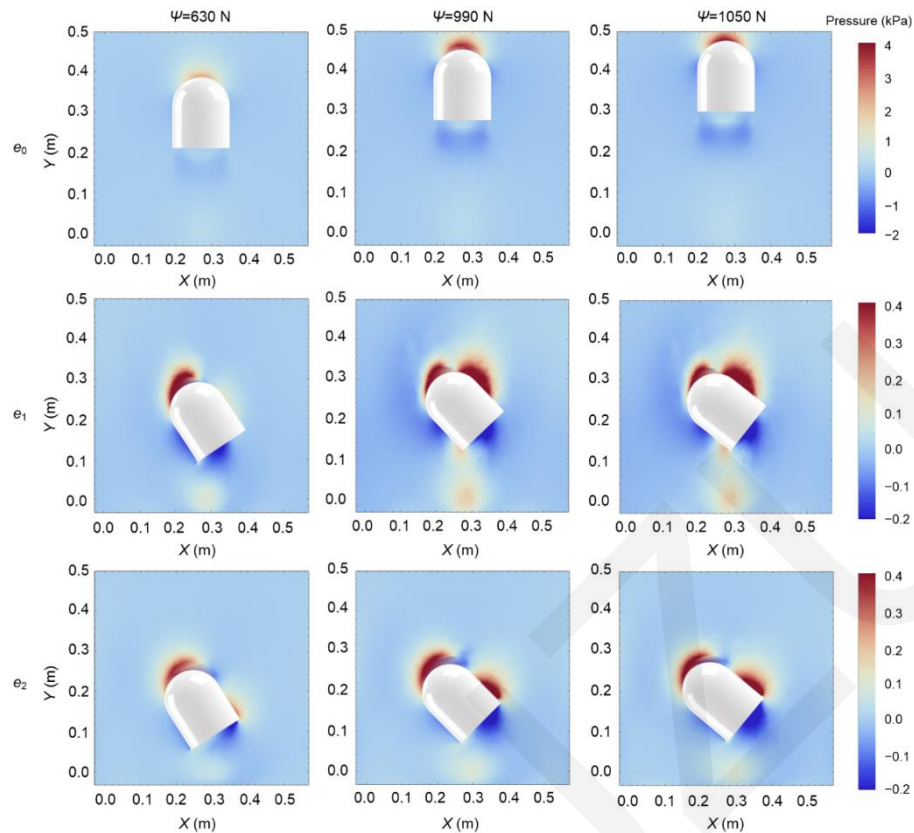


Fig. 5. Pressure distributions of cases 1–3 and 10–15 at $t=0.1$ s

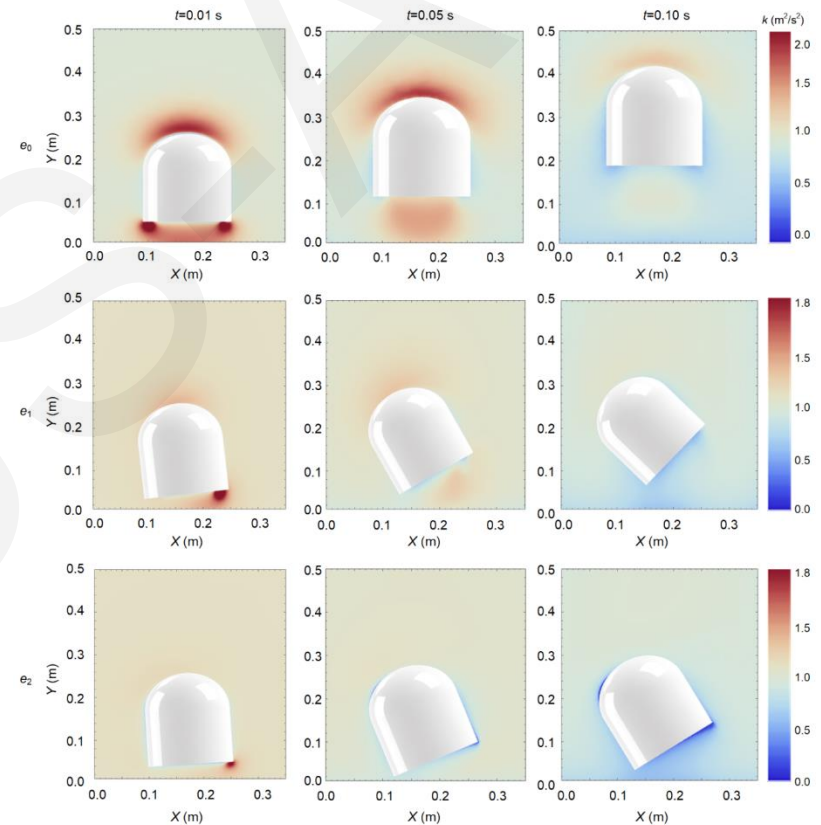


Fig. 6. Turbulence kinematic energy (k) distributions of cases 4–6 at $t=0.01$, 0.05 , and 0.10 s

Conclusions

- The present study numerically investigated the hydrodynamics of robots driven by TDM.
- Focusing on the dependence of robot dynamics on thrust force and eccentricity, we obtained typical structures of turbulence fields around the robots to quantitatively analyze velocity distribution, vortex structures, pressure, and turbulence properties.
- The results demonstrate high-speed regions at both the heads and tails of robots due to sudden acceleration. They also uncover vortex systems at the corner on the side with higher thrust force, and indicate a negative relationship between the maximum fluid velocity and eccentricity. The maximum pressure on robot surfaces is shown to have a positive relationship with thrust force and a negative relationship with eccentricity.
- The model also provides the distribution of the turbulence kinetic energy and turbulence dissipation rate of the fluid field disturbed by robots, revealing the centripetal transference of the high- k regions at the robots' tails and the existence of low- k regions around their bodies due to boundary layer effects. Furthermore, the results concerning asymmetrical thrust force suggest that rotation of the robots, while it tends to increase turbulence, will decrease both k and ε at the head by moderating fluid compression.