Electronic Supplementary Materials

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Simulation and experiment of a remotely operated underwater vehicle with cavitation jet technology

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Method S1 Principle of hydrodynamic cavitation

The submerged jet structure is shown in Fig. S1a. It includes the initial section of the jet, its basic section, and core area, the nozzle, inner boundary, 0 summit and exterior boundary.

At the outlet of the nozzle, the velocity of the jet is steady, and once it leaves the nozzle, it will suck the surrounding water, so that the velocity is reduced, and the jet boundary is wider. The boundary where the velocity is zero is called the outer jet boundary, and the boundary where the jet velocity maintains the initial velocity is the inner boundary. Both the inner and outer boundaries are straight lines, and the area between the inner and outer boundaries is a boundary layer.

The distance from the nozzle outlet to the turning section is the initial section of jet, and within the initial section, there is a core area in which the velocity remains unchanged. It is a cone with the initial section length as the height based on the section at the outlet of the nozzle.

When the local absolute pressure of the liquid is reduced to the saturated vapor pressure below local temperature, it turns out that there are very small bubbles (gas core) in the liquid and these will expand rapidly, so that bubbles containing water vapor or other gases exist in the liquid,. Thus the phenomenon of cavitation appears. As shown in Fig. S1b, in terms of water flow in a contracted pipe, the upstream pressure is P_1, the downstream pressure is P_2 and the pressure in the contracted section is P_c. When the absolute pressure P_c is reduced to a pressure equal to or less than the saturated vapor pressure of the local water, cavitation will occur in the contracted section. The cavitation liquid in the low-pressure area carries a large number of bubbles, and “two-phase flow” is produced, so that the continuity of liquid flow in the entire pipe is destroyed. Cavitation bubbles first emerge in the boundary layer of the contracted section, and enlarge in the low-pressure area, and then move to the pressure rise area with the mainstream. As a result, cavitation bubbles then contract and collapse. Therefore, the whole process of cavitation should consist of three stages: gestation and birth, development and growth, contraction and collapse. Each stage of the whole process depends on the change of flowing water pressure in the system. The collapse of cavitation bubbles results in a strong micro jet impact. ‘Cavitation jet’ refers to artificially creating high-density cavitation bubbles in the water jet. The strong micro jet impact caused by the collapse of a large number of cavitation bubbles in the local tiny area on the surface of the object is used to clean hard dirt and deposits.

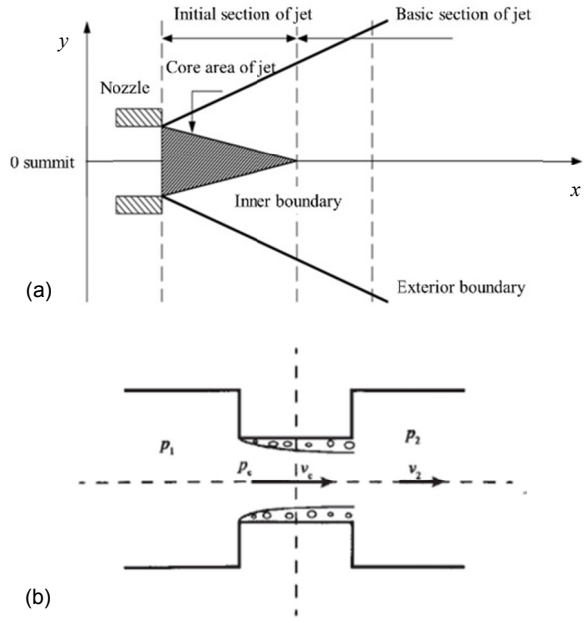

Fig. S1 Schematics of the submerged jet structure (a) and cavitation jet principle (b)