Hydrodynamics of the leucon sponge pump

Leuconoid sponges are filter-feeders with a complex system of branching inhalant and exhalant canals leading to and from the close-packed choanocyte chambers. Each of these choanocyte chambers holds many choanocytes that act as pumping units delivering the relatively high pressure rise needed to overcome the system pressure losses in canals and constrictions. Here, we test the hypothesis that, in order to deliver the high pressures observed, each choanocyte operates as a leaky, positive displacement-type pump owing to the interaction between its beating flagellar vane and the collar, open at the base for inflow but sealed above. The leaking backflow is caused by small gaps between the vaned flagellum and the collar. The choanocyte pumps act in parallel, each delivering the same high pressure, because low-pressure and high-pressure zones in the choanocyte chamber are separated by a seal (secondary reticulum). A simple analytical model is derived for the pump characteristic, and by imposing an estimated system characteristic we obtain the back-pressure characteristic that shows good agreement with available experimental data. Computational fluid dynamics is used to verify a simple model for the dependence of leak flow through gaps in a conceptual collar–vane–flagellum system and then applied to models of a choanocyte tailored to the parameters of the freshwater demosponge *Spongilla lacustris* to study its flows in detail. It is found that both the impermeable glyccalyx mesh covering the upper part of the collar and the secondary reticulum are indispensable features for the choanocyte pump to deliver the observed high pressures. Finally, the mechanical pump power expended by the beating flagellum is compared with the useful (reversible) pumping power received by the water flow to arrive at a typical mechanical pump efficiency of about 70%.

General information
State: Published
Organisations: Fluid Mechanics, Coastal and Maritime Engineering, Department of Mechanical Engineering, University of Southern Denmark
Number of pages: 9
Publication date: 2019
Peer-reviewed: Yes

Publication information
Journal: Journal of the Royal Society. Interface
Volume: 16
Issue number: 150
Article number: 20180630
ISSN (Print): 1742-5689
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.89
Web of Science (2017): Impact factor 3.355
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.04
Web of Science (2016): Impact factor 3.579
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.5
Web of Science (2015): Impact factor 3.818
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 3.59
Web of Science (2014): Impact factor 3.917
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 4.88
Web of Science (2013): Impact factor 3.856
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 5.06
Web of Science (2012): Impact factor 4.907
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 4.53
Web of Science (2011): Impact factor 4.402
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Web of Science (2010): Impact factor 4.259
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Original language: English
Keywords: Choanocytes, Flagellar vane, Low Reynolds number flow, Computational fluid dynamics, Positive displacement pump
DOIs: 10.1098/rsif.2018.0630
Research output: Research - peer-review › Journal article – Annual report year: 2019