Hydrodynamic functionality of the lorica in choanoflagellates

Choanoflagellates are unicellular eukaryotes that are ubiquitous in aquatic habitats. They have a single flagellum that creates a flow toward a collar filter composed of filter strands that extend from the cell. In one common group, the loricate choanoflagellates, the cell is suspended in an elaborate basket-like structure, the lorica, the function of which remains unknown. Here, we use Computational Fluid Dynamics to explore the possible hydrodynamic function of the lorica. We use the choanoflagellate Diaphanoeca grandis as a model organism. It has been hypothesized that the function of the lorica is to prevent refiltration (flow recirculation) and to increase the drag and, hence, increase the feeding rate and reduce the swimming speed. We find no support for these hypotheses. On the contrary, motile prey are encountered at a much lower rate by the loricate organism. The presence of the lorica does not affect the average swimming speed, but it suppresses the lateral motion and rotation of the cell. Without the lorica, the cell jiggles from side to side while swimming. The unsteady flow generated by the beating flagellum causes reversed flow through the collar filter that may wash away captured prey while it is being transported to the cell body for engulfment. The lorica substantially decreases such flow, hence it potentially increases the capture efficiency. This may be the main adaptive value of the lorica.
Hydrodynamic functionality of the lorica in choanoflagellates

Choanoflagellates are unicellular microswimmers that are ubiquitous in aquatic habitats. They have a single flagellum that creates a flow toward the collar, the filtration apparatus composed of closely spaced filter strands. Loricate choanoflagellates have evolved a basket-like “skeleton” around the cell, the lorica, the function of which remains unknown. Here, we use Computational Fluid Dynamics (CFD) to explore the possible hydrodynamic function of the lorica by studying the choanoflagellate Diaphanoeca grandis, with and without its lorica. We study the flow rate, the flow recirculation, and the resulting clearance rate for the capture of motile and non-motile prey by the freely swimming choanoflagellate. We find no support for several previous hypotheses regarding the effects of the lorica. Rather, our simulations suggest that the main function of the lorica is to enhance the capture efficiency, but this happens at the cost of lower encounter rate with motile prey.
An analytical model of flagellate hydrodynamics

Flagellates are unicellular microswimmers that propel themselves using one or several beating flagella. We consider a hydrodynamic model of flagellates and explore the effect of flagellar arrangement and beat pattern on swimming kinematics and near-cell flow. The model is based on the analytical solution by Oseen for the low Reynolds number flow due to a point force outside a no-slip sphere. The no-slip sphere represents the cell and the point force a single flagellum. By superposition we are able to model a freely swimming flagellate with several flagella. For biflagellates with left–right symmetric flagellar arrangements we determine the swimming velocity, and we show that transversal forces due to the periodic movements of the flagella can promote swimming. For a model flagellate with both a longitudinal and a transversal flagellum we determine radius and pitch of the helical swimming trajectory. We find that the longitudinal flagellum is responsible for the average translational motion whereas the transversal flagellum governs the rotational motion. Finally, we show that the transversal flagellum can lead to strong feeding currents to localized capture sites on the cell surface.

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BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.84
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 0.64
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BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 0.62
Web of Science (2014): Impact factor 1.126
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 0.61
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ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 0.67
Web of Science (2012): Impact factor 1.032
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 0.85
Computational Fluid Dynamics of Choanoflagellate Filter-Feeding

Choanoflagellates are unicellular aquatic organisms with a single flagellum that drives a feeding current through a funnel-shaped collar filter on which bacteria-sized prey are caught. Using computational fluid dynamics (CFD) we model the beating flagellum and the complex filter flow of the choanoflagellate Diaphanoeca grandis. Our CFD simulations based on the current understanding of the morphology underestimate the experimentally observed clearance rate by more than an order of magnitude: The beating flagellum is simply unable to draw enough water through the fine filter. Our observations motivate us to suggest a radically different filtration mechanism that requires a flagellar vane (sheet), and addition of a wide vane in our CFD model allows us to correctly predict the observed clearance rate.

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Computational Fluid Dynamics of Choanoflagellate Filter-Feeding

Choanoflagellates are unicellular aquatic organisms with a single flagellum that drives a feeding current through a funnel-shaped collar filter on which bacteria-sized prey are caught. Using computational fluid dynamics (CFD) we model the beating flagellum and the complex filter flow of the choanoflagellate Diaphanoeca grandis. Our CFD simulations based on the current understanding of the morphology underestimate the experimentally observed clearance rate by more than an order of magnitude: The beating flagellum is simply unable to draw enough water through the fine filter. Our observations motivate us to suggest a radically different filtration mechanism that requires a flagellar vane (sheet), and addition of a wide vane in our CFD model allows us to correctly predict the observed clearance rate.

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Hydrodynamics of microbial filter feeding

Microbial filter feeders are an important group of grazers, significant to the microbial loop, aquatic food webs, and biogeochemical cycling. Our understanding of microbial filter feeding is poor, and, importantly, it is unknown what force microbial filter feeders must generate to process adequate amounts of water. Also, the trade-off in the filter spacing remains unexplored, despite its simple formulation: A filter too coarse will allow suitably sized prey to pass unintercepted, whereas a filter too fine will cause strong flow resistance. We quantify the feeding flow of the filter-feeding choanoflagellate Diaphanoeca grandis using particle tracking, and demonstrate that the current understanding of microbial filter feeding is inconsistent with computational fluid dynamics (CFD) and analytical estimates. Both approaches underestimate observed filtration rates by more than an order of magnitude; the beating flagellum is simply unable to draw enough water through the fine filter. We find similar discrepancies for other choanoflagellate species, highlighting an apparent paradox. Our observations motivate us to suggest a radically different filtration mechanism that requires a flagellar vane (sheet), something notoriously difficult to visualize but sporadically observed in the related choanocytes (sponges). A CFD model with a flagellar vane correctly predicts the filtration rate of D. grandis, and using a simple model we can account for the filtration rates of other microbial filter feeders. We finally predict how optimum filter mesh size increases with cell size in microbial filter feeders, a prediction that accords very well with observations. We expect our results to be of significance for small-scale biophysics and trait-based ecological modeling.
Swimming and feeding of mixotrophic biflagellates

Many unicellular flagellates are mixotrophic and access resources through both photosynthesis and prey capture. Their fitness depends on those processes as well as on swimming and predator avoidance. How does the flagellar arrangement and beat pattern of the flagellate affect swimming speed, predation risk due to flow-sensing predators, and prey capture? Here, we describe measured flows around two species of mixotrophic, biflagellated haptophytes with qualitatively different flagellar arrangements and beat patterns. We model the near cell flows using two symmetrically arranged point forces with variable position next to a no-slip sphere. Utilizing the observations and the model we find that puller force arrangements favour feeding, whereas equatorial force arrangements favour fast and quiet swimming. We determine the capture rates of both passive and motile prey, and we show that the flow facilitates transport of captured prey along the haptonema structure. We argue that prey capture alone cannot fulfil the energy needs of the observed species, and that the mixotrophic life strategy is essential for survival.
Wake structure and thrust generation of a flapping foil in two-dimensional flow

We present a combined numerical (particle vortex method) and experimental (soap film tunnel) study of a symmetric foil undergoing prescribed oscillations in a two-dimensional free stream. We explore pure pitching and pure heaving, and contrast these two generic types of kinematics. We compare measurements and simulations when the foil is forced with pitching oscillations, and we find a close correspondence between flow visualisations using thickness variations in the soap film and the numerically determined vortex structures. Numerically, we determine wake maps spanned by oscillation frequency and amplitude, and we find qualitatively similar maps for pitching and heaving. We determine the drag–thrust transition for both pitching and heaving numerically, and we discuss it in relation to changes in wake structure. For heaving with low oscillation frequency and high amplitude, we find that the drag–thrust transition occurs in a parameter region with wakes in which two vortex pairs are formed per oscillation period, in contrast to the common transition scenario in regions with inverted von Kármán wakes.

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Scopus rating (2015): CiteScore 2.57 SJR 1.896 SNIP 1.639
Web of Science (2015): Impact factor 2.514
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Scopus rating (2014): CiteScore 2.66 SJR 1.864 SNIP 1.805
Web of Science (2014): Impact factor 2.383
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BFI (2013): BFI-level 2
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Web of Science (2013): Impact factor 2.294
ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.47 SJR 1.678 SNIP 1.86
Web of Science (2012): Impact factor 2.183
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Web of Science (2012): Indexed yes
Bouncing droplets, pilot-waves, and quantum mechanics

Bouncing droplets on a fluid surface have recently been shown to provide a surprising analogy to quantum behaviour. Here we discuss the limitation of this analogy in the context of the double-slit experiment, which our colleagues and we have analysed in a recent paper [Phys. Rev. E 92, 013006 (2015)]. The present paper is based on the talk given by Tomas Bohr at the XX Congreso de la División de Dinámica de Fluidos, Sociedad Mexicana de Física, Centro Mesoamericana de Física Teórica, Tuxtla Gutiérrez, November 2014.

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Contributors: Bohr, T., Andersen, A. P., Lautrup, B.
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Cavitation nuclei in water exposed to transient pressures

A model of skin-stabilized interfacial cavitation nuclei and their response to tensile and compressive stressing is presented. The model is evaluated in relation to experimental tensile strength results for water at rest at the bottom of an open water-filled container at atmospheric pressure and room temperature. These results are obtained by recording the initial growth of cavities generated by a short tensile pulse applied to the bottom of the container. It is found that the cavitation nuclei shift their tensile strength depending on their pressure history. Static pressurization for an extended period of time prior to testing is known to increase the tensile strength of water, but little information is available on how it is affected by compression pulses of short duration. This is addressed by imposing compression pulses of approximately 1 ms duration and a peak intensity of a few bar prior to the tension pulse. The observations are interpreted on the basis of the new model.
In a thought-provoking paper, Couder and Fort [Phys. Rev. Lett. 97, 154101 (2006)] describe a version of the famous double-slit experiment performed with droplets bouncing on a vertically vibrated fluid surface. In the experiment, an interference pattern in the single-particle statistics is found even though it is possible to determine unambiguously which slit the walking droplet passes. Here we argue, however, that the single-particle statistics in such an experiment will be fundamentally different from the single-particle statistics of quantum mechanics. Quantum mechanical interference takes place between different classical paths with precise amplitude and phase relations. In the double-slit experiment with walking droplets, these relations are lost since one of the paths is singled out by the droplet. To support our conclusions,
we have carried out our own double-slit experiment, and our results, in particular the long and variable slit passage times of the droplets, cast strong doubt on the feasibility of the interference claimed by Couder and Fort. To understand theoretically the limitations of wave-driven particle systems as analogs to quantum mechanics, we introduce a Schrödinger equation with a source term originating from a localized particle that generates a wave while being simultaneously guided by it. We show that the ensuing particle-wave dynamics can capture some characteristics of quantum mechanics such as orbital quantization. However, the particle-wave dynamics can not reproduce quantum mechanics in general, and we show that the single-particle statistics for our model in a double-slit experiment with an additional splitter plate differs qualitatively from that of quantum mechanics.
Quiet swimming at low Reynolds number

The stresslet provides a simple model of the flow created by a small, freely swimming and neutrally buoyant aquatic organism and shows that the far field fluid disturbance created by such an organism in general decays as one over distance squared. Here we discuss a quieter swimming mode that eliminates the stresslet component of the flow and leads to a faster spatial decay of the fluid disturbance described by a force quadrupole that decays as one over distance cubed. Motivated by recent experimental results on fluid disturbances due to small aquatic organisms, we demonstrate that a three-Stokeslet model of a swimming organism which uses breast stroke type kinematics is an example of such a quiet swimmer. We show that the fluid disturbance in both the near field and the far field is significantly reduced by appropriately arranging the propulsion apparatus, and we find that the far field power laws are valid surprisingly close to the organism. Finally, we discuss point force models as a general framework for hypothesis generation and experimental exploration of fluid mediated predator-prey interactions in the planktonic world.

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Web of Science (2017): Impact factor 2.284
Web of Science (2017): Indexed yes
Zooplankton Hydrodynamics: An investigation into the physics of aquatic interactions

Zooplankton are hugely abundant organisms found in all aquatic environments and form an important part of the marine ecosystems. Most zooplankton swim in order to find food and mates, and to avoid predators. In spite of its advantages, swimming comes with trade-offs, it costs energy and creates flow disturbances that may attract predators. The first part of this thesis attempts to quantify the trade-offs associated with the swimming behaviour of diverse zooplankton. We measured the swimming kinematics and flow fields around the 'jumping' copepod Acartia tonsa at various stages of its life cycle, and found qualitative differences in flow structures, energy expenditure, and swimming efficiency, between the early and later stages. The spatial decay rate of flow disturbances was faster in the later stages, suggesting that those may be less vulnerable to predation. Broadening the scope, we then measured flows around a wide range of zooplankton
which use a variety of swimming modes such as hovering, cruising, jumping, and breast stroke swimming. We found that the spatial decay rate of the flow velocity is dictated by the swimming mode. The modes used for swimming only, such as jumping and breast stroke swimming, had much faster spatial decay as compared to the other modes, resulting in ‘quiet’ swimming.

This motivated us to examine breast stroke swimming in more detail, for which flow velocity decayed spatially as one over distance cubed. We employed a simple model using three point forces to represent the forces acting on the swimmer. Our analysis showed a configuration-dependent spatial decay of flow velocity. Arranging the propulsive forces close to the equator resulted in changing the far field velocity decay from one over distance squared to one over distance cubed, comparing well with the experimental observations. To further investigate periodic swimming using breast stroke, we measured detailed swimming dynamics and induced flows for the cladoceran Podon intermedius. We estimated the propulsive forces acting on P. intermedius, which showed that the fast spatial decay in the induced flows was not explained by the three point force model. We speculate that this is due to inertial effects in the flow, which seem to play an important role in the swimming of larger zooplankton. We also developed a simple model to mimic the dynamics of periodic swimming, which showed that non-linear drag terms are needed in the model to correctly capture the observed dynamics.

The second part of this thesis examines how size dictates transitions in life strategies, and thus acts as a structuring factor in marine life. To this end, we reviewed data on size-based scaling laws for resource acquisition, motility, sensing, and offspring size for all pelagic marine life, from bacteria to whales. We also reviewed and developed theoretical arguments for the observed scaling laws and for the characteristic sizes at which transitions from one strategy to another take place. Based on our findings, we divided life in the ocean into seven major realms based on trophic strategy, physiology, and life history strategy.

Finally, we delve deeper into size based structuring of sensory strategies in the ocean. Survival in the open ocean requires effective collection of information from the surroundings via the use of various sensory modes. We studied how sensing modes and their respective ranges depend on body size. We investigated the physiological constraints on sense organs, together with the physics of signal generation, transmission, and reception. Our analysis revealed a hierarchy of sensing modes - with increasing size, a larger battery of sensory modes becomes available and the sensing range increases. Our theoretical predictions of lower and upper size limits for various senses aligned well with the size ranges found in the literature. Although the scaling analyses and the size limits are only first order estimates, this work forms the first comprehensive analysis of the size based structuring of sensory modes used by marine life.

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Bathtub physics

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BFI (2017): BFI-level 2
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Web of Science (2017): Impact factor 4.37
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BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.38 SJR 0.726 SNIP 1.172
Web of Science (2016): Impact factor 4.188
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 1.39 SJR 0.733 SNIP 1.6
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 1.64 SJR 1.024 SNIP 1.902
Web of Science (2014): Impact factor 4.859
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 1.99 SJR 1.277 SNIP 1.717
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ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 1.84 SJR 1.631 SNIP 1.789
Web of Science (2012): Impact factor 6.762
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BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 1.46 SJR 1.599 SNIP 1.703
Web of Science (2011): Impact factor 5.648
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 0.918 SNIP 1.499
Web of Science (2010): Impact factor 4.432
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.749 SNIP 1.206
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.991 SNIP 1.73
Scopus rating (2007): SJR 1.192 SNIP 2.362
Scopus rating (2006): SJR 1.303 SNIP 2.385
Scopus rating (2005): SJR 1.333 SNIP 3.23
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Scopus rating (2003): SJR 1.084 SNIP 3.004
Scopus rating (2002): SJR 2.51 SNIP 2.803
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Comment on Y. Couder and E. Fort

General information
From Newton's bucket to rotating polygons: experiments on surface instabilities in swirling flows

We present an experimental study of 'polygons' forming on the free surface of a swirling water flow in a partially filled cylindrical container. In our set-up, we rotate the bottom plate and the cylinder wall with separate motors. We thereby vary rotation rate and shear strength independently and move from a rigidly rotating 'Newton's bucket' flow to one where bottom and cylinder wall are rotating oppositely and the surface is strongly turbulent but flat on average. Between those two extremes, we find polygonal states for which the rotational symmetry is spontaneously broken. We investigate the
phase diagram spanned by the two rotational frequencies at a given water filling height and find polygons in a regime, where the two frequencies are sufficiently different and, predominantly, when they have opposite signs. In addition to the extension of the family of polygons found with the stationary cylinder, we find a new family of smaller polygons for larger rotation rates of the cylinder, opposite to that of the bottom plate. Further, we find a ‘monogon’, a figure with one corner, roughly an eccentric circle rotating in the same sense as the cylinder. The case where only the bottom plate is rotating is compared with the results of Jansson et al. (Phys. Rev. Lett., vol. 96, 2006, art. 174502), where the same size of cylinder was used, and although the overall structure of the phase diagram spanned by water height and rotational frequency is the same, many details are different. To test the effect of small experimental defects, such as misalignment of the bottom plate, we investigate whether the rotating polygons are phase locked with the bottom plate, and although we find cases where the frequency ratio of figure and bottom plate is nearly rational, we do not find phase locking. Finally, we show that the system has a surprising multistability and excitability, and we note that this can cause quantitative differences between the phase diagrams obtained in comparable experiments.

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Web of Science (2015): Impact factor 2.514
Web of Science (2015): Indexed yes
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Scopus rating (2014): CiteScore 2.66 SJR 1.864 SNIP 1.805
Web of Science (2014): Impact factor 2.383
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BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.71 SJR 1.853 SNIP 1.88
Web of Science (2013): Impact factor 2.294
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.47 SJR 1.678 SNIP 1.86
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BFI (2011): BFI-level 2
Hydrodynamics and energetics of jumping copepod nauplii and copepodids

Within its life cycle, a copepod goes through drastic changes in size, shape and swimming mode. In particular, there is a stark difference between the early (nauplius) and later (copepodid) stages. Copepods inhabit an intermediate Reynolds number regime (between similar to 1 and 100) where both viscosity and inertia are potentially important, and the Reynolds number changes by an order of magnitude during growth. Thus we expect the life stage related changes experienced by a copepod to result in hydrodynamic and energetic differences, ultimately affecting the fitness. To quantify these differences, we measured the swimming kinematics and fluid flow around jumping Acartia tonsa at different stages of its life cycle, using particle image velocimetry and particle tracking velocimetry. We found that the flow structures around nauplii and copepodids are topologically different, with one and two vortex rings, respectively. Our measurements suggest that copepodids cover a larger distance compared to their body size in each jump and are also hydrodynamically quieter, as the flow disturbance they create attenuates faster with distance. Also, copepodids are energetically more efficient than nauplii, presumably due to the change in hydrodynamic regime accompanied with a well-adapted body form and swimming stroke.
Polygon formation and surface flow on a rotating fluid surface - ERRATUM

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Scopus rating (2015): CiteScore 2.57 SJR 1.896 SNIP 1.639
Web of Science (2015): Impact factor 2.514
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.66 SJR 1.864 SNIP 1.805
Web of Science (2014): Impact factor 2.383
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Tensile Strength of Water Exposed to Pressure Pulses

It is well known that pressurization for an extended period of time increases the tensile strength of water, but little information is available on the effect of pressure pulses of short duration. This is addressed in the present paper where we first measure the tensile strength of water at an extended water-solid interface by imposing a tensile stress pulse which easily causes cavitation. Next, a compressive pulse of duration ~1 ms and a peak intensity of a few bar is imposed prior to the tensile stress pulse. A dramatic increase of the tensile strength is observed immediately after the compressive pulse, but the effect is shortlived. We presume that diffusion of non-condensable gas from the cavitation nuclei into the liquid at compression, and back again later, is responsible for the changes of tensile strength.
**Exotic wakes of flapping fins**

We present, in 8 chapters, experiments on and numerical simulations of bodies flapping in a fluid. Focus is predominantly on a rigid foil, a model fish, that performs prescribed pitching oscillations where the foil rotates around its leading edge. In a flowing soap film is measured, with unprecedented accuracy, the vortex wake structure behind the flapping foil in the space spanned by dimensionless flapping frequency $0 < St_D < 0.3$ and amplitude $0 < A_D < 2$. We measure not only the ubiquitous von Kármán wake, but also wakes where up to sixteen vortices are shed each oscillation period. The wake measurements are supplemented with numerical simulations of the flow and fluid forces, in settings relevant for the experiments. It is shown that wake transitions and average fluid forces are described by a single parameter, the Strouhal number, which is a measure of both the dimensionless foil tip-speed and the strength ratio of the vortices formed at the foil’s leading and trailing edge. The simulated vortex particles and measured thickness variations in the soap film show similar behaviour which indicates that the soap film provides a good approximation the flow of a two-dimensional incompressible and Newtonian fluid. Also, measurements of the swimming speed of a pitching foil in a water tank are presented. Finally, an experimental study of the surprisingly strong fluid-mediated interaction of two tandem flappers is presented. It is shown that a passively flapping flag in general is affected by its downstream neighbour. When this neighbour is a second flag close by, they synchronise in frequency and the leader experiences a reduced drag compared to that on the lone flag. In case the follower is replaced by a flapping plate, upstream synchronisation and drag reduction is again found over a wide range of frequencies. Drag reductions up to a factor 3 are measured. Many results presented are obtained through flow visualisations. A great effort is made to produce visualisations of primarily high scientific quality, but often also with a certain aesthetic appeal.
Polygon formation and surface flow on a rotating fluid surface

We present a study of polygons forming on the free surface of a water flow confined to a stationary cylinder and driven by a rotating bottom plate as described by Jansson et al. (Phys. Rev. Lett., vol. 96, 2006, 174502). In particular, we study the case of a triangular structure, either completely ‘wet’ or with a ‘dry’ centre. For the dry structures, we present measurements of the surface shapes and the process of formation. We show experimental evidence that the formation can take place as a two-stage process: first the system approaches an almost stable rotationally symmetric state and from there the symmetry breaking proceeds like a low-dimensional linear instability. We show that the circular state and the unstable manifold connecting it with the polygon solution are universal in the sense that very different initial conditions lead to the same circular state and unstable manifold. For a wet triangle, we measure the surface flows by particle image velocimetry (PIV) and show that there are three vortices present, but that the strength of these vortices is far too weak to account for the rotation velocity of the polygon. We show that partial blocking of the surface flow destroys the polygons and re-establishes the rotational symmetry. For the rotationally symmetric state our theoretical analysis of the surface flow shows that it consists of two distinct regions: an inner, rigidly rotating centre and an outer annulus, where the surface flow is that of a point vortex with a weak secondary flow. This prediction is consistent with the experimentally determined surface flow.

General information
State: Published
Organisations: Department of Physics, Biophysics and Fluids, Center for Fluid Dynamics, University of Twente, University Paris Diderot - Paris 7
Pages: 415-431
Publication date: 2011
Peer-reviewed: Yes
Japanese fan flow

General information
State: Published
Organisations: Biophysics and Fluids, Department of Physics, Center for Fluid Dynamics
Contributors: Schnipper, T., Tophøj, L. E. H., Andersen, A. P., Bohr, T.
Pages: 091102
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Physics of Fluids
Volume: 22
Issue number: 9
ISSN (Print): 1070-6631
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 2.51 SJR 1.19 SNIP 1.278
Web of Science (2017): Impact factor 2.279
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.16 SJR 1.331 SNIP 1.356
Web of Science (2016): Impact factor 2.232
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.35 SNIP 1.282
Web of Science (2015): Impact factor 2.017
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.375 SNIP 1.414
Web of Science (2014): Impact factor 2.031
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.419 SNIP 1.471
Web of Science (2013): Impact factor 2.04
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.202 SNIP 1.44
Web of Science (2012): Impact factor 1.942
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.381 SNIP 1.485
Web of Science (2011): Impact factor 1.926
ISI indexed (2011): ISI indexed yes
Separation vortices and pattern formation

In this paper examples are given of the importance of flow separation for fluid patterns at moderate Reynolds numbers—both in the stationary and in the time-dependent domain. In the case of circular hydraulic jumps, it has been shown recently that it is possible to generalise the Prandtl–Kármán–Pohlhausen approach to stationary boundary layers with free surfaces going through separation, and thus obtain a quantitative theory of the simplest type of hydraulic jump, where a single separation vortex is present outside the jump. A second type of jump, where an additional roller appears at the surface, cannot be captured by this approach and has not been given an adequate theoretical description. Such a model is needed to describe “polygonal” hydraulic jumps, which occur by spontaneous symmetry breaking of the latter state. Time-dependent separation is of importance in the formation of sand ripples under oscillatory flow, where the separation vortices become very strong. In this case no simple theory exists for the determination of the location and strengths of separation vortices over a wavy bottom of arbitrary profile. We have, however, recently suggested an amplitude equation describing the long-time evolution of the sand ripple pattern, which has the surprising features that it breaks the local sand conservation and has long-range interaction, features that can be underpinned by experiments. Very similar vortex dynamics takes place around oscillating structures such as wings and fins. Here, we present results for the vortex patterns behind a flapping foil in a flowing soap film, which shows the interaction and competition between the vortices shed from the round leading edge (like the von Kármán vortex street) and those created at the sharp trailing edge.

General information
State: Published
Organisations: Department of Physics, Center for Fluid Dynamics
Contributors: Andersen, A. P., Bohr, T., Schnipper, T.
Pages: 329-334
Structure of a steady drain-hole vortex in a viscous fluid

We use direct numerical simulations to study a steady bathtub vortex in a cylindrical tank with a central drain-hole, a flat stress-free surface and velocity prescribed at the inlet. We find that the qualitative structure of the meridional flow does not depend on the radial Reynolds number, whereas we observe a weak overall rotation at a low radial Reynolds number and a concentrated vortex above the drain-hole at a high radial Reynolds number. We introduce a simple analytically integrable model that shows the same qualitative dependence on the radial Reynolds number as the simulations and compares favourably with the results for the radial velocity and the azimuthal velocity at the surface. Finally, we describe the height dependence of the radius of the vortex core and the maximum of the azimuthal velocity at the surface. We show that the data on the radius of the vortex core and the maximum of the azimuthal velocity as functions of height collapse on single curves by appropriate scaling.
Swimming behavior and prey retention of the polychaete larvae *Polydora ciliata* (Johnston)
The behavior of the ubiquitous estuarine planktotrophic spionid polychaete larvae *Polydora ciliata* was studied. We describe ontogenetic changes in morphology, swimming speed and feeding rates and have developed a simple swimming model using low Reynolds number hydrodynamics. In the model we assumed that the ciliary swimming apparatus is primarily composed of the prototroch and secondarily by the telotroch. The model predicted swimming speeds and feeding rates that corresponded well with the measured speeds and rates. Applying empirical data to the model, we were able to explain the profound decrease in specific feeding rates and the observed increase in the difference between upward and downward swimming speeds with larval size. We estimated a critical larval length above which the buoyancy-corrected weight of the larva exceeds the propulsion force generated by the ciliary swimming apparatus and thus forces the larva to the bottom. This modeled critical larval length corresponded to approximately 1 mm, at which, according to the literature, competence for metamorphosis and no more length increase is observed. These findings may have general implications...
for all planktivorous polychaete larvae that feed without trailing threads. We observed bell shaped particle retention spectra with a minimum prey size of approximately 4 m equivalent spherical diameter, and we found that an ontogenetic increase in maximum prey size add to a reduction in intra-specific food competition in the various larval stages. In a grazing experiment using natural seawater, ciliates were cleared approximately 50% more efficiently than similar sized dinoflagellates. The prey sizes retainable for P. ciliata larvae covers the microplankton fraction and includes non-motile as well as motile prey items, which is why the larvae are trophically positioned among the copepods and dinoflagellates. Not only do larval morphology and behavior govern larval feeding, prey behavior also influences the feeding efficiency of Polydora ciliata.

**General information**
State: Published
Organisations: Section for Ocean Ecology and Climate, National Institute of Aquatic Resources, Department of Physics, Biophysics and Fluids
Contributors: Hansen, B., Jakobsen, H. H., Andersen, A. P., Almeda, R., Pedersen, T., Christensen, A., Nilsson, B.
Pages: 3237-3246
Publication date: 2010
Peer-reviewed: Yes

**Publication information**
Journal: Journal of Experimental Biology
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Issue number: 18
ISSN (Print): 0022-0949
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 2.6 SJR 1.611 SNIP 1.306
Web of Science (2017): Impact factor 3.179
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.62 SJR 1.824 SNIP 1.27
Web of Science (2016): Impact factor 3.32
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.4 SJR 1.821 SNIP 1.211
Web of Science (2015): Impact factor 2.914
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.51 SJR 1.742 SNIP 1.315
Web of Science (2014): Impact factor 2.897
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.75 SJR 1.733 SNIP 1.314
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.91 SJR 1.627 SNIP 1.372
Web of Science (2012): Impact factor 3.236
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.77 SJR 1.553 SNIP 1.321
Web of Science (2011): Impact factor 2.996
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Unsteady motion: escape jumps in planktonic copepods, their kinematics and energetics

We describe the kinematics of escape jumps in three species of 0.3–3.0 mm-sized planktonic copepods. We find similar kinematics between species with periodically alternating power strokes and passive coasting and a resulting highly fluctuating escape velocity. By direct numerical simulations, we estimate the force and power output needed to accelerate and overcome drag. Both are very high compared with those of other organisms, as are the escape velocities in comparison to startle velocities of other aquatic animals. Thus, the maximum weight-specific force, which for muscle motors of other animals has been found to be near constant at 57 N (kg muscle)−1, is more than an order of magnitude higher for the escaping copepods. We argue that this is feasible because most copepods have different systems for steady propulsion (feeding appendages) and intensive escapes (swimming legs), with the muscular arrangement of the latter probably adapted for high force production during short-lasting bursts. The resulting escape velocities scale with body length to power 0.65, different from the size-scaling of both similar sized and larger animals moving at constant velocity, but similar to that found for startle velocities in other aquatic organisms. The relative duration of the pauses between power strokes was observed to increase with organism size. We demonstrate that this is an inherent property of swimming by alternating power strokes and pauses. We finally show that the Strouhal number is in the range of peak propulsion efficiency, again suggesting that copepods are optimally designed for rapid escape jumps.

General information
State: Published
Organisations: Section for Ocean Ecology and Climate, National Institute of Aquatic Resources, Biophysics and Fluids, Department of Physics
Contributors: Kiørboe, T., Andersen, A. P., Langlois, V. J., Jakobsen, H. H.
Pages: 1591-1602
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Journal of the Royal Society Interface
A lightning stab in the dark: fluid dynamics of attack jumps of ambush feeding copepods

General information
State: Published
Organisations: Biophysics and Fluids, Department of Physics, Section for Ocean Ecology and Climate, National Institute of Aquatic Resources
Bubble Pinch-Off in a Rotating Flow

We create air bubbles at the tip of a "bathtub vortex" which reaches to a finite depth. The bathtub vortex is formed by letting water drain through a small hole at the bottom of a rotating cylindrical container. The tip of the needlelike surface dip is unstable at high rotation rates and releases bubbles which are carried down by the flow. Using high-speed imaging we find that the minimal neck radius of the unstable tip decreases in time as a power law with an exponent close to 1/3. This exponent was found by Gordillo et al. [Phys. Rev. Lett. 95, 194501 (2005)] to govern gas flow driven pinch-off, and indeed we find that the volume oscillations of the tip creates a considerable air flow through the neck. We argue that the Bernoulli pressure reduction caused by this air flow can become sufficient to overcome the centrifugal forces and cause the final pinch-off.

General information
State: Published
Organisations: Department of Physics, Biophysics and Fluids, University of Twente
Contributors: Bergmann, R., Andersen, A. P., van der Meer, D., Bohr, T.
Pages: 204501
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Physical Review Letters
Volume: 102
Issue number: 20
ISSN (Print): 0031-9007
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 7.58 SJR 3.622 SNIP 2.464
Web of Science (2017): Impact factor 8.839
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 6.33 SJR 4.196 SNIP 2.61
Web of Science (2016): Impact factor 8.462
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.76 SJR 4.656 SNIP 2.538
Web of Science (2015): Impact factor 7.645
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 6.62 SJR 5.232 SNIP 2.71
Web of Science (2014): Impact factor 7.512
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 7.46 SJR 5.675 SNIP 2.781
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 7.19 SJR 6.292 SNIP 2.867
ISI indexed (2012): ISI indexed yes
Fluid Forces and Vortex Wakes of a Flapping Foil

General information
State: Published
Organisations: Biophysics and Fluids, Department of Physics, Fluid Mechanics, Department of Mechanical Engineering, Center for Fluid Dynamics
Contributors: Schnipper, T., Andersen, A. P., Bohr, T., Walther, J. H.
Publication date: 2009
Peer-reviewed: Yes
Event: Abstract from 62nd APS Division of Fluid Dynamics, Minneapolis, MN, United States.
Source: orbit
Hydraulic jumps in a channel
We present a study of hydraulic jumps with flow predominantly in one direction, created either by confining the flow to a narrow channel with parallel walls or by providing an inflow in the form of a narrow sheet. In the channel flow, we find a linear height profile upstream of the jump as expected for a supercritical one-dimensional boundary layer flow, but we find that the surface slope is up to an order of magnitude larger than expected and independent of flow rate. We explain this as an effect of turbulent fluctuations creating an enhanced eddy viscosity, and we model the results in terms of Prandtl's mixing-length theory with a mixing length that is proportional to the height of the fluid layer. Using averaged boundary-layer equations, taking into account the friction with the channel walls and the eddy viscosity, the flow both upstream and downstream of the jump can be understood. For the downstream subcritical flow, we assume that the critical height is attained close to the channel outlet. We use mass and momentum conservation to determine the position of the jump and obtain an estimate which is in rough agreement with our experiment. We show that the averaging method with a varying velocity profile allows for computation of the flow-structure through the jump and predicts a separation vortex behind the jump, something which is not clearly seen experimentally, probably owing to turbulence. In the sheet flow, we find that the jump has the shape of a rhombus with sharply defined oblique shocks. The experiment shows that the variation of the opening angle of the rhombus with flow rate is determined by the condition that the normal velocity at the jump is constant.

General information
State: Published
Organisations: Biophysics and Fluids, Department of Physics, Center for Fluid Dynamics
Contributors: Bonn, D., Andersen, A. P., Bohr, T.
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Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Journal of Fluid Mechanics
Volume: 618
ISSN (Print): 0022-1120
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.33 SJR 1.591 SNIP 1.702
Web of Science (2017): Impact factor 2.893
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.82 SJR 1.744 SNIP 1.671
Web of Science (2016): Impact factor 2.821
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.57 SJR 1.896 SNIP 1.639
Web of Science (2015): Impact factor 2.514
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.66 SJR 1.864 SNIP 1.805
Web of Science (2014): Impact factor 2.383
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.71 SJR 1.853 SNIP 1.88
Web of Science (2013): Impact factor 2.294
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.47 SJR 1.678 SNIP 1.86
Mechanisms and feasibility of prey capture in ambush-feeding zooplankton

Many marine zooplankters, particularly among copepods, are "ambush feeders" that passively wait for their prey and capture them by fast surprise attacks. This strategy must be very demanding in terms of muscle power and sensing capabilities, but the detailed mechanisms of the attacks are unknown. Using high-speed video we describe how copepods perform spectacular attacks by precision maneuvering during a rapid jump. We show that the flow created by the attacking copepod is so small that the prey is not pushed away, and that the attacks are feasible because of their high velocity (approximate to 100 mm.s\(^{-1}\)) and short duration (few ms), which leaves the prey no time for escape. Simulations and analytical estimates show that the viscous boundary layer that develops around the attacking copepod is thin at the time of prey capture and that the flow around the prey is small and remains potential flow. Although ambush feeding is highly successful as a feeding strategy in the plankton, we argue that power requirements for acceleration and the hydrodynamic constraints restrict the strategy to larger (> 0.25 mm), muscular forms with well-developed prey perception capabilities. The smallest of the examined species is close to this size limit and, in contrast to the larger species, uses its largest possible jump velocity for such attacks. The special requirements to ambush feeders with such attacks may explain why this strategy has evolved to perfection only a few times among planktonic suspension feeders (few copepod families and chaetognaths).
Significance of swimming and feeding currents for nutrient uptake in osmotrophic and interception feeding flagellates

General information
State: Published
Organisations: Department of Physics, Biophysics and Fluids, National Institute of Aquatic Resources, Section for Ocean Ecology and Climate, Center for Fluid Dynamics
Contributors: Langlois, V., Andersen, A. P., Bohr, T., Visser, A., Kiørboe, T.
Pages: 35-44
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Aquatic Microbial Ecology
Volume: 54
Issue number: 1
ISSN (Print): 0948-3055
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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 2.13 SJR 0.962 SNIP 0.707
Web of Science (2017): Impact factor 2.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.77 SJR 0.852 SNIP 0.587
Web of Science (2016): Impact factor 1.633
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.21 SJR 1.148 SNIP 0.781
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.88 SJR 0.907 SNIP 0.706
Web of Science (2014): Impact factor 1.967
Vortex wakes of a flapping foil
We present an experimental study of a symmetric foil performing pitching oscillations in a vertically flowing soap film. By varying the frequency and amplitude of the oscillation we visualize a variety of wakes with up to 46 vortices per oscillation period, including von Karman vortex street, inverted von Karman vortex street, 2P wake, 2P+2S wake and novel wakes ranging from 4P to 8P. We map out the wake types in a phase diagram spanned by the width-based Strouhal number and the dimensionless amplitude. We follow the time evolution of the vortex formation near the round leading edge and the shedding process at the sharp trailing edge in detail. This allows us to identify the origins of the vortices in the 2P wake, to understand that two distinct 2P regions are present in the phase diagram due to the timing of the vortex shedding at the leading edge and the trailing edge and to propose a simple model for the vorticity generation. We use the model to describe the transition from 2P wake to 2S wake with increasing oscillation frequency and the transition from the von Karman wake, typically associated with drag, to the inverted von Karman wake, typically associated with thrust generation.
Swimming in a soap film

General information
State: Published
Organisations: Biophysics and Fluids, Department of Physics, Center for Fluid Dynamics
Contributors: Schnipper, T., Andersen, A. P., Bohr, T.
Publication date: 2008
Peer-reviewed: No
Event: Poster session presented at 61st Annual Meeting of the APS Division of Fluid Dynamics, San Antonio, United States.
Source: orbit
Source-ID: 251719
Research output: Research - peer-review › Journal article – Annual report year: 2009

Vortex wakes of a flapping foil in a flowing soap film

We present an experimental study of an oscillating, symmetric foil in a vertically flowing soap film. By varying frequency and amplitude of the oscillation we explore and visualize a variety of wake structures, including von K`arm`an wake, reverse von K`arm`an wake, 2P wake, and 2P+2S wake. We characterize the transition from the von K`arm`an wake (drag) to the reverse von K`arm`an wake (thrust) and discuss the results in relation to fish swimming. We visualize the time evolution of the vortex shedding in detail, identify the origins of the vortices comprising the wake, and propose a simple model to account for the transition from von K`arm`an like wakes to more exotic wake structures.

General information
State: Published
Organisations: Biophysics and Fluids, Department of Physics, Center for Fluid Dynamics
Contributors: Schnipper, T., Andersen, A. P., Bohr, T.
Publication date: 2008

Event Information
Event: APS Division of Fluid Dynamics
Location: San Antonio, USA
**Airflow driven pinch-off of a bubble in a rotating liquid**

**General information**
State: Published
Organisations: Department of Physics, Center for Fluid Dynamics
Contributors: Bergmann, R., Andersen, A. P., Bohr, T., van der Meer, D.
Publication date: 2007

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Title of host publication: Bull. American Phys. Soc., Salt Lake City
Source: orbit
Source-ID: 211714
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

**Hydraulic jumps in a narrow channel**

**General information**
State: Published
Organisations: Department of Physics, Center for Fluid Dynamics
Contributors: Andersen, A. P., Bohr, T., Bonn, D., Bouamrire, F.
Publication date: 2007

**Host publication information**
Title of host publication: Bull. American Phys. Soc., Salt Lake City
Source: orbit
Source-ID: 211712
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

**The bathtub vortex in a rotating container**

We study the time-independent free-surface flow which forms when a fluid drains out of a container, a so-called bathtub vortex. We focus on the bathtub vortex in a rotating container and describe the free-surface shape and the complex flow structure using photographs of the free surface, flow visualizations, and velocity measurements. We find that the velocity field in the bulk of the fluid agrees with predictions from linear Ekman theory for the boundary layer at the bottom, and we discuss the limitations of linear Ekman theory for the source–sink flow in the experiment. We introduce a radial expansion approximation of the central vortex core and reduce the model to a single first-order equation. We solve the equation numerically and find that the axial velocity depends linearly on height whereas the azimuthal velocity is almost independent of height. We discuss the model of the bathtub vortex introduced by Lundgren (J. Fluid Mech. vol. 155, 1985, p. 381) and compare it with our experiment. We find that the measured velocities and surface profiles are described well by the model when Ekman upflow and surface tension effects are included.

**General information**
State: Published
Organisations: Department of Physics
Contributors: Andersen, A. P., Bohr, T., Stenum, B., Rasmussen, J. J., Lautrup, B.
Pages: 121-146
Publication date: 2006
Peer-reviewed: Yes

**Publication information**
Journal: Journal of Fluid Mechanics
Volume: 556
ISSN (Print): 0022-1120
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Anatomy of a Bathtub Vortex

We present experiments and theory for the "bathtub vortex," which forms when a fluid drains out of a rotating cylindrical container through a small drain hole. The fast down-flow is found to be confined to a narrow and rapidly rotating "drainpipe" from the free surface down to the drain hole. Surrounding this drainpipe is a region with slow upward flow generated by the Ekman layer at the bottom of the container. This flow structure leads us to a theoretical model similar to one obtained earlier by Lundgren [J. Fluid Mech. 155, 381 (1985)], but here including surface tension and Ekman upwelling, comparing favorably with our measurements. At the tip of the needlelike surface depression, we observe a bubble-forming instability at high rotation rates.

General information

State: Published
Organisations: Biophysics and Fluids, Department of Physics, Risø National Laboratory for Sustainable Energy, Plasma Physics and Technology Programme, Niels Bohr Institute
Contributors: Andersen, A. P., Bohr, T., Stenum, B., Juul Rasmussen, J., Lautrup, B.
Number of pages: 4
Pages: 104502
Publication date: 2003
Peer-reviewed: Yes

Publication information

Journal: Physical Review Letters
Volume: 91
Issue number: 10
ISSN (Print): 0031-9007
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 7.58 SJR 3.622 SNIP 2.464
Web of Science (2017): Impact factor 8.839
An averaging method for nonlinear laminar Ekman layers

We study steady laminar Ekman boundary layers in rotating systems using an averaging method similar to the technique of von Karman and Pohlhausen. The method allows us to explore nonlinear corrections to the standard Ekman theory even at large Rossby numbers. We consider both the standard self-similar ansatz for the velocity profile, which assumes that a single length scale describes the boundary layer structure, and a new non-self-similar ansatz in which the decay and the oscillations of the boundary layer are described by two different length scales. For both profiles we calculate the up-flow in a vortex core in solid-body rotation analytically. We compare the quantitative predictions of the model with the family of exact similarity solutions due to von Karman and find that the results for the non-self-similar profile are in almost perfect quantitative agreement with the exact solutions and that it performs markedly better than the self-similar profile.
Random matrix theory and acoustic resonances in plates with an approximate symmetry

We discuss a random matrix model of systems with an approximate symmetry and present the spectral fluctuation statistics and eigenvector characteristics for the model. An acoustic resonator like, e.g., an aluminum plate may have an approximate symmetry. We have measured the frequency spectrum and the widths for acoustic resonances in thin aluminum plates, cut in the shape of the so-called three-leaf clover. Due to the mirror symmetry through the middle plane of the plate, each resonance of the plate belongs to one of two mode classes and we show how to separate the modes into these two classes using their measured widths. We compare the spectral statistics of each mode class with results for the Gaussian orthogonal ensemble. By cutting a slit of increasing depth on one face of the plate, we gradually break the mirror symmetry and study the transition that takes place as the two classes are mixed. Presenting the spectral fluctuation statistics and the distribution of widths for the resonances, we find that this transition is well described by the random matrix model.
Vortex dynamics around a solid ripple in an oscillatory flow

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Physics, Biophysics and Fluids
Contributors: Thomassen, J., Jespersen, T., Andersen, A. P., Bohr, T.
Publication date: 2001
Peer-reviewed: No
Event: Abstract from Workshop: Discussions on the formation and dynamics of ripples, dunes and related systems, Paris (FR), 2-5 May,
Source: orbit
Source-ID: 303550
Research output: Research › Conference abstract for conference – Annual report year: 2001

Projects:

Predation in a Microbial World
Suzuki, S., PhD Student, National Institute of Aquatic Resources
Kiørboe, T., Main Supervisor, National Institute of Aquatic Resources
Andersen, A. P., Supervisor, Department of Physics
01/01/2019 → 31/12/2021
Project: PhD

Physics of Microbial Feeding
Rode, M. B., PhD Student, Department of Physics
Andersen, A. P., Main Supervisor, Department of Physics
Kiørboe, T., Supervisor, National Institute of Aquatic Resources
Samfinansieret - Andet
01/09/2018 → 31/08/2021
Award relations: Physics of Microbial Feeding
Project: PhD

Hydrodynamics of small Marine Organisms
Dölger, J., PhD Student, Department of Physics
Andersen, A. P., Main Supervisor, Department of Physics
Bohr, T., Supervisor, Department of Physics
Kiørboe, T., Supervisor
Jensen, K. H., Examiner, Department of Physics
Koehl, M. A. R., Examiner
Lauga, E., Examiner
Samfinansieret - Andet
15/12/2014 → 11/04/2018
Award relations: Hydrodynamics of small Marine Organisms
Project: PhD

Zooplankton Fluid Dynamics
Wadhwa, N., PhD Student, Department of Physics
Andersen, A. P., Main Supervisor, Department of Physics
Bohr, T., Supervisor, Department of Physics
Kærøe, T., Supervisor
Rasmussen, J. J., Examiner, Department of Physics
Humphries, S., Examiner
Zhang, J., Examiner
Institut, samfinansiering
01/08/2012 → 19/11/2015
Award relations: Zooplankton Fluid Dynamics
Project: PhD

Vortex flows with a free surface and random matrix theory and acoustic resonances
Andersen, A. P., PhD Student, Department of Physics
Bohr, T., Main Supervisor, Department of Physics
Rasmussen, J. J., Supervisor, Department of Physics
Serensen, J. N., Examiner, Department of Wind Energy
Lundgren, T. S., Examiner
Wang, J., Examiner
Institut, samfinansiering
01/06/1999 → 16/10/2002
Award relations: Vortex flows with a free surface and random matrix theory and acoustic resonances
Project: PhD

Fluid Dynamics of Animal Locomotion
Schnipper, T., PhD Student, Department of Physics
Andersen, A. P., Main Supervisor, Department of Physics
Aref, H., Supervisor, Department of Physics
Bohr, T., Supervisor, Department of Physics
Serensen, J. N., Supervisor
Brøns, M., Examiner
Water, W. V. D., Examiner
Williamson, C. H. K., Examiner
DTU, Samfinansiering
15/08/2007 → 02/02/2011
Award relations: Fluid Dynamics of Animal Locomotion
Project: PhD

Global Modelling of Turbulence and Transport in Magnetically Confined Plasma
Magnussen, M. L., PhD Student, Department of Physics
Rasmussen, J. J., Main Supervisor, Department of Physics
Madsen, J., Supervisor, Department of Physics
Naulin, V., Supervisor, Department of Physics
Andersen, A. P., Examiner, Department of Physics
Hnat, B., Examiner
Kendl, A., Examiner
Institut stipendie (DTU) Samf.
01/09/2013 → 14/06/2017
Award relations: Global Modelling of Turbulence and Transport in Magnetically Confined Plasma
Project: PhD

Mathematical modeling of wetting properties of micro and nano structured polymer surfaces
Wind-Willassen, Ø., PhD Student, Department of Applied Mathematics and Computer Science
Serensen, M. P., Main Supervisor, Department of Applied Mathematics and Computer Science
Johansson, A. C., Supervisor, Department of Micro- and Nanotechnology
Activities:

Complex Motion in Fluids Summer School
Period: 24 Sep 2017 → 29 Sep 2017
Seyed Saeed Asadzadeh (Participant)
Jens Honore Walther (Participant)
Lasse Tor Nielsen (Participant)
Julia Dölger (Participant)
Thomas Kjørboe (Participant)
Anders Peter Andersen (Participant)
Department of Mechanical Engineering
Fluid Mechanics, Coastal and Maritime Engineering
National Institute of Aquatic Resources
Centre for Ocean Life
Department of Physics
Biophysics and Fluids

Description
The school will consist of 16 lectures in total, given by 8 speakers (90' + 60' each), contributed talks, poster sessions and other activities.
Degree of recognition: International
Documents:
Asadzadeh

Related event

Complex Motion in Fluids Summer School
24/09/2017 → 30/09/2017
Cambridge, United Kingdom
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Hydrodynamics of Microbial Filter-Feeding
Period: 21 Nov 2016
Anders Peter Andersen (Lecturer)
Department of Physics
Biophysics and Fluids
Links:
http://meetings.aps.org/Meeting/DFD16/Session/H39.7

Related external organisation

Unknown external organisation
Activity: Talks and presentations › Conference presentations
Quiet swimming at low Reynolds number
Period: 23 Nov 2015
Anders Peter Andersen (Lecturer)
Department of Physics
Biophysics and Fluids
Links:
http://meetings.aps.org/Meeting/DFD15/Session/H25.3

Related external organisation
Unknown external organisation
Activity: Talks and presentations › Conference presentations

Hydrodynamics of Choanoflagellate Feeding
Period: 24 Nov 2013
Anders Peter Andersen (Lecturer)
Department of Physics
Biophysics and Fluids
Links:
http://meetings.aps.org/Meeting/DFD13/Session/D18.5

Related external organisation
Unknown external organisation
Activity: Talks and presentations › Conference presentations

Press clippings:

Farvel til en gammel drøm
Anders Peter Andersen
17/07/2015
Biophysics and Fluids, Department of Physics

Media contribution (1)

Farvel til en gammel drøm
17/07/2015
Weekendavisen, Print
Henrik Prætorius
Anders Peter Andersen
Department of Physics, Biophysics and Fluids
Press/Media: Press / Media