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Editorial

Symmetry and Symmetry-Breaking in Fluid Dynamics

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It may seem that the heading of this Special Issue of *Symmetry*—though narrower than the famous all-inclusive title of an essay by Jean-Paul Sartre, *Being and Nothingness*—encompasses most, if not all, fluid phenomena. While we did endeavor to represent a broad range of flows, the primary aim was to provoke new questions and insights to those wherein the role of symmetry, a lack thereof, or transition away or toward symmetry are key to understanding them.

We thus anticipated attracting contributions spanning different scales and levels of complexity, in either two or three dimensions, including symmetry-breaking instabilities, symmetry-imposing boundary conditions, and flows that are symmetric partially, locally, or intermittently. Our hope was that a collection of such varied topics and results may suggest new approaches to fluid phenomena, whether well studied already or less familiar.

The eleven papers collected in this Special Issue are indeed diverse: in two or three dimensions, fundamental and applied, at macro and micro scales, elucidating flows that are symmetric, symmetry-breaking, and intermittently symmetric, and in uniform and stratified fluids. The phenomena addressed include single-drop dynamics, hydrodynamic lattices, viscous flows, interfacial instability, magneto-hydrodynamics, turbulence, swimming dynamics, sedimentation, and diffusion flames.

Several papers—contributions on spreading and rotating drops, viscous jets, the dynamo problem, and diffusion flames—illustrate phenomena wherein a flow ceases to be symmetrical when it transitions from one regime to another, an indication of the non-linear nature of the Navier–Stokes equations. The solutions can jump from symmetric to non-symmetric only when the balance of forces (viscous, inertial, surface tension) is broken, leading to a new state.

The collection opens with three papers [1–3] concerning drops but in highly diverse settings. The contribution from the research group of Sunghwan (Sunny) Jung [1] at Cornell University presents new experiments exploring the spreading of a water droplet on a bath of glycerol–water solutions. In this scenario, the outward buoyancy competes with the inward forcing due to Marangoni and viscous effects and a quasi-symmetric fingering pattern develops. A paper by Roach and Huppert [2] from the University of Cambridge takes up the problem of axisymmetric drop expanding between two rotating discs at low Reynolds numbers, and also the effect of squeezing the droplet, which has a similar solution. In the latter case, critical parameters are determined when the system breaks symmetry. The third contribution in this trio, by John Bush and his collaborators at MIT [3], considers the stability of a two-dimensional lattices, square and triangular, of oil droplets bouncing in synchrony on the surface of the same liquid.

The next paper, by Sznajder, Cichocki and Ekiel-Jeżewska [4] from the Polish Academy of Science and the University of Warsaw, analyzes the sedimentation of particles in the vanishing Reynolds number limit. Their results, based on BBGKY hierarchy derived from the Liouville equation, suggest the breaking of translational symmetry of the system due to plasma-like screening.

The next two papers [5,6] concern viscous jets falling on a moving substrate, symmetry-breaking extensions of the classical, axis-symmetric coiling instability. The first of these

Citation: Herczyński, A.; Zenit, R. Symmetry and Symmetry-Breaking in Fluid Dynamics. *Symmetry* **2024**, *16*, 621. https://doi.org/10.3390/sym16050621

Received: 7 May 2024
Accepted: 11 May 2024
Published: 17 May 2024

contributions, by Neil Ribe from CNRS and collaborators [5], revisits the version of the problem wherein the substrate is a translating belt, the so-called fluid mechanical sewing machine. As the name suggests, a rich variety of trace patterns can be obtained depending on the relative speed of the belt and the fluid at the contact point, such as overlapping loops, separated loops, meanders, figures of eight, and other forms. In the second, experimental contribution from Lisicki, Adamowicz, Herczyński, and Moffatt [6], the jet falls on a spinning surface at various radial distances. Similar patterns emerge in this case, but their center-line symmetry is subtly broken by centrifugal effects.

Three papers [7–9] bring the lens of symmetry/symmetry-breaking to somewhat more specialized problems. The magnetohydrodynamic turbulence in the Earth's core, the dynamo problem, is the subject of a paper by Krzysztof Mizerski [7] from the Polish Academy of Science. The focus here is on the asymmetric flow due to turbulent wave fields. The role of both symmetric and asymmetric edge flames in stabilizing diffusion flames is analyzed in a paper by Lu and Matalon [8]. The asymmetry is caused not by the geometry of the mixing zone, but by the unequal fuel and oxidizer Lewis numbers. The third paper in this group, a review article by Yuli Chashechkin [9] from the Russian Academy of Science, concerns stratified flow past a sphere, which has been visualized using the schlieren method. The images reveal the presence of very fine ligaments that, at higher velocities, introduce asymmetric features to the flow in the wake.

The last two papers [10,11] address propulsion in water, but in very different contexts: the first is a fundamental investigation of a surprising swimming mechanism; the second, an engineering design for reducing drag in high-speed vessels. Jean-Luc Thiffeault from the University of Wisconsin-Madison offers [10] a simple mechanical "toy" model for a micro swimmer, which shakes from side to side but nevertheless moves forward. The effect depends on forcing that also exerts a torque and, crucially, on some form of friction. A numerical investigation of a drag-reducing mechanism for a surface ship is carried out in the concluding paper by a group of researchers from Harbin Engineering University led by Hai An [11]. The paper proposes a novel design of a partially submerged strut attached to the vehicle, with the air intake above the water line and air outlet below, producing a bubbly flow, which reduces skin friction.

It is our hope that this small collection of papers may serve to illustrate a remarkably wide range of fluid dynamical phenomena wherein consideration of symmetry proves worthwhile, and perhaps also to encourage such considerations. After all, as Blaise Pascal remarked in his *Pensée*, "symmetry is what we see at a glance".

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hooshanginejad, A.; Jung, S. Buoyancy-Marangoni Fingering of a Miscible Spreading Drop. *Symmetry* **2022**, *14*, 425. [CrossRef]
2. Roach, M.G.; Huppert, H.E. Spreading and Contraction of an Axisymmetric Viscous Drop between Two Plates in a Rapidly Rotating Frame. *Symmetry* **2022**, *14*, 2488. [CrossRef]
3. Couchman, M.M.; Evans, D.J.; Bush, J.W. The stability of a Hydrodynamic Bravais Lattice. *Symmetry* **2022**, *14*, 1524. [CrossRef]
4. Sznajder, P.; Cichocki, B.; Ekiel-Jeżewska, M. Lack of Plasma-like Screening Mechanism in Sedimentation of a Non-Brownian Suspension. *Symmetry* **2022**, *14*, 63. [CrossRef]
5. Ribe, N.M.; Brun, P.T.; Audoly, B. Symmetry and asymmetry in the fluid mechanical sewing machine. *Symmetry* **2022**, *14*, 772. [CrossRef]
6. Lisicki, M.; Adamowicz, Ł.; Herczyński, A.; Moffatt, H.K. Viscous thread falling on a spinning surface. *Symmetry* **2022**, *14*, 1550. [CrossRef]
7. Mizerski, K.A. Possible Role of Non-Stationarity of Magnetohydrodynamic Turbulence in Understanding of Geomagnetic Excursions. *Symmetry* **2021**, *13*, 1881. [CrossRef]
8. Lu, Z.; Matalon, M. Anchored and Lifted Diffusion Flames Supported by Symmetric and Asymmetric Edge Flames. *Symmetry* **2023**, *15*, 1547. [CrossRef]
9. Chashechkin, Y.D. Discrete and Continuous Symmetries of Stratified Flows Past a Sphere. *Symmetry* **2022**, *14*, 1278. [CrossRef]

10. Thiffeault, J.L. Moving Forward by Shaking Sideways. *Symmetry* **2022**, *14*, 620. [CrossRef]
11. An, H.; Hu, Z.; Pan, H.; Yang, P. Numerical Investigation of the Automatic Air Intake Drag Reduction Strut Base on the Venturi Effect. *Symmetry* **2022**, *14*, 367. [CrossRef]