

OIST-Keio Showcase talk Series 8

Science meets Society: Twist, Flow, and Instability

Posters

Mr. Soratsugu Sakazume	Keio	<b>PIV-based validation of friction drag reduction by streamwise traveling wave-like wall deformation in turbulent channel flow</b>
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This study experimentally investigates the friction drag reduction effect of streamwise traveling wave-like wall deformation driven by a single actuator in turbulent channel flow. Wind tunnel experiment was conducted to validate the control concept in which a thin silicone rubber wall is oscillated by a voice coil motor to generate a traveling wave-like deformation along the streamwise direction. The velocity field within the test section was measured using particle image velocimetry (PIV) under both controlled and uncontrolled conditions. As a result, the bulk mean velocity increased by 13.6%, corresponding to a friction drag reduction rate of 22.6%. However, due to the large power consumption of the actuator, a net energy saving effect was not achieved. However, it was found that the flow was not in a fully developed turbulent state due to insufficient test section length, which limited the accuracy of the friction drag reduction.

Ms. Morie Koseki	OIST	<b>The effects of wall flexibility in turbulent channel flow over a deformable wall</b>
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When fluids flow over deformable walls, the flow field is modified by the fluid-wall interactions. The complex coupling can be described by a combination of many undistinguished effects, e.g., roughness effects (due to the wall deformation by the hydrodynamic force), non-zero wall-normal fluctuations (coming from the wall movement), and wall motion (owing to the wave propagation on the surface and inside materials). This study aims to disentangle the effects of fluid-structure interaction and wall shape/undulations individually in a turbulent flow. We conduct direct numerical simulations of turbulent channel flows over deformable and statistically equivalent rough walls. Turbulent flows over relatively rigid compliant walls share similar features to those over rough walls; however, as wall flexibility increases, distinct effects are observed that are specific to the mutual fluid-structure interaction.

Mr. Nobuaki Ikeda	Keio	<b>A pressure drop-based method for rheological characterization of food fluids: From methodology to device development</b>
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This study focuses on developing a novel pressure-driven rheometric method and clarifying its differences from conventional rotational viscometry. The rotational viscometer determines shear stress from torque in a narrow gap and continuously accumulates shear deformation during measurement. In contrast, the pressure-driven rheometer estimates wall shear stress and shear rate from the pressure drop and flow rate within a pipe, enabling measurements under constant shear deformation based on the Herschel-Bulkley model. To evaluate its performance, measurements were conducted using tamarind seed gum and xanthan gum aqueous solutions, as well as low-oil-type mayonnaise. The flow curves obtained by both methods showed good agreement for tamarind seed gum aqueous solution, whereas deviations increased for xanthan gum aqueous solution and low-oil-type mayonnaise,

Dr. Simon Haward	OIST	<b>Exploring multi-stability in three-dimensional viscoelastic flow around a free stagnation point</b>
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Fluid elements passing near a stagnation point experience finite strain rates over long persistence times, and thus accumulate large strains. By the numerical optimization of a microfluidic 6-arm cross-slot geometry, recent works have harnessed this flow type as a tool for performing uniaxial and biaxial extensional rheometry [Haward et al. J. Rheol. 67 (2023) 995-1009; Haward et al. J. Rheol. 67 (2023) 1011-1030]. Here we use the microfluidic 'Optimized-shape Uniaxial and Biaxial Extensional Rheometer' (OUBER) geometry to probe an elastic flow instability which is sensitive to the alignment of the extensional flow. A three-dimensional symmetry-breaking instability occurring for flow of a dilute polymer solution in the OUBER geometry is studied experimentally by leveraging tomographic particle image velocimetry. Above a critical Weissenberg number, flow in uniaxial extension undergoes a supercritical pitchfork bifurcation to a multi-stable state. However, for biaxial extension (which is simply the kinematic inverse of uniaxial extension) the instability is strongly suppressed. In uniaxial extension, the multiple stable states align in an apparently random orientation as flow joining from four neighboring inlet channels passes to one of the two opposing outlets; thus forming a mirrored asymmetry about the stagnation point. We relate the suppression of the instability in biaxial extension to the kinematic history of flow under the context of breaking the time-reversibility assumption.

Dr. Masafumi Watanabe	Keio	<b>Femtoliter-sample injection by highly-integrated nanofluidic valves and its application to nanochannel chromatography</b>
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The development of micro/nanofluidics has enabled reaction times to be shortened and reagent volumes to be reduced. To realize complex chemical processing, we previously developed nanofluidic open/close valves based on the nanoscale elastic deformation of glass using piezoelectric actuators, while integrating the valves at intervals of several hundred micrometers remains challenging. Therefore, in the present study, we aim to develop a water pressure-driven valve and integrate the valves on a nanofluidic device to achieve femtoliter (fL) sample injection. In the valve system, a microchannel for applying water pressure and a thin glass deformation part were placed above the valve chamber to switch the valves between open and closed states. To perform fL sample injection, we highly integrated four valves, whose response time and open/close ratio were approximately 0.9 s, with a minimum spacing of 700 μm on a nanofluidic device, enabling fL-scale fluid manipulation of a mixture of fluorescent molecules (=567 fL) by switching the valves sequentially. This mixture was then introduced into the nanochannel for chromatography, resulting in the successful separation of the fluorescent molecules at the detection point. We believe that the developed fL sample injection system can be applied to various chemical analyses in the future.

Mr. Hanley Andean	OIST	<b>Towards new conceptual understanding of the decay of landfalling typhoons</b>
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When a typhoon makes landfall, its intensity sharply decays. The decay is conceptually understood by treating the typhoon as a vortex that decays due to friction underneath. The conceptual picture is based on a spin-down vortex theory that describes a vortex that is much simpler than a typhoon. We test the decay prediction from the spin-down model with the results from idealized landfall of a typhoon and examine the core idea of the spin-down model. We show that the model's prediction highly overestimates the decay rate of a typhoon and fitting data to the model may misguide our understanding. Finally, we propose that a new model must contain a key thermodynamic element in addition to friction and present a thermodynamic effect past landfall.

Dr. Nobumasa Komori	Keio	<b>Deep ocean inertia-gravity waves simulated in a global coupled atmosphere-ocean general circulation model</b>
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In order to investigate the deep ocean inertia-gravity waves, a global coupled atmosphere-ocean simulation is carried out with a coupling interval of 20 minutes. Large ( $\sim 10^{-3} \text{ m s}^{-1}$ ) root-mean-square variability of vertical velocity is found in middepths (2000-4000 m), which is not reported in previous studies using realistic ocean simulations. Horizontal distribution of the large variability roughly corresponds to the wintertime atmospheric storm tracks and is stretched equatorward due to  $\beta$ -dispersion in open ocean with some "shadow regions" behind the obstacles. Frequency spectrum of vertical velocity has strong peaks at around  $f$  and  $2f$  ( $f$  is the local inertial period) in midlatitudes, and has additional peak at around  $(3/2)f$  or  $3f$  at some points. These results