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Presentation Type:	Oral
Select your Sorting Category:	34. Surface Tension Effects
Select your Sub-Category	17.6 General Fluid Dynamics: Mathematical Methods
Abstract Title:	**Surface tension and energy conservation in a moving fluid**
Abstract Body:	In what sense do the surface tension forces in a fluid surface contribute to the energy budget, and what are the correct boundary conditions at a free surface of a moving viscous liquid? In two recent papers (Bhagat et al. *J. Fluid Mech.* (2018), **851**, R5 and Bhagat & Linden, *J. Fluid Mech.* (2020), **896**, A25) it has been claimed that surface tension forces, ***F***, give a power term ***F·v***, where ***v*** is the fluid velocity at the surface, and that this energy, for a stationary flow is balanced by viscous dissipation at the surface, thereby changing the standard dynamic free surface boundary condition into a balance between surface tension and viscosity. In this work we show that this is not correct: the velocity ***v*** determining the power is not the velocity of the liquid, but the velocity of the control surface. For a static control volume, all surface energy contributions from surface tension thus disappear, except the terms coming from the Laplace pressure. We show this by deriving a simple conservation equation for the surface area of a part of a moving liquid, which clearly reveals the contribution of the Laplace pressure at the free surface and the tangential surface tension forces at its boundary.
Category Type:	Theoretical
Publications Reference:	T. Bohr and B. Scheichl, Phys. Rev. Fluids (2021), 6, L052001
Newsworthy Research?	Yes, I would like to consider highlighting my abstract in its outreach to journalists.
Media Summary:	In this talk it is explained how to include surface tension effects correctly into the energy budget of a moving liquid. It might seem surprising that one can say anything new about this in 2021, when the subject has been investigated thoroughly for at least 150 years pioneered by prominent scientists like Lord Rayleigh and G. I. Taylor. However, in recent investigations on "hydraulic jumps", it was claimed that the surface energy budget and the boundary conditions at a free surface of a moving viscous liquid was hitherto treated in a wrong way. The reason is very simple. Surface tension forces, acting in the tangential plane of the surface should give rise to a power F·v, the inner product of the force and the fluid velocity at the surface – and this power could be balanced by viscous dissipation. This is, however, not correct. The surface energy is simply proportional to the magnitude of the liquid surface-area, the proportionality factor being the surface tension coefficient. There is no kinetic energy term for the surface energy. In the mathematical description, the reason for this is that the surface is infinitely thin and therefore has no mass. The physical reason is that surface tension forces are strong, in the sense that they are of the same order of magnitude as the adhesion forces between the molecules in the liquid, whereas the kinetic energy of organized (average) motion of the liquid is around 100.000 times smaller and can therefore be neglected. In the bulk of the liquid this is not so, because the strong adhesion forces usually do not show up since the distances between the molecules remain essentially constant. Thus, free surface flows are unique in their ability to show effects of molecular adhesion, even at velocities well below the speed of sound. The other important feature of surface energy is its reversibility: changes in surface energy come from the breaking of bonds, which is a reversible process. It cannot, therefore, be balanced by viscous dissipation, which is caused by irreversible processes.

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