Laminar and Turbulent Fronts

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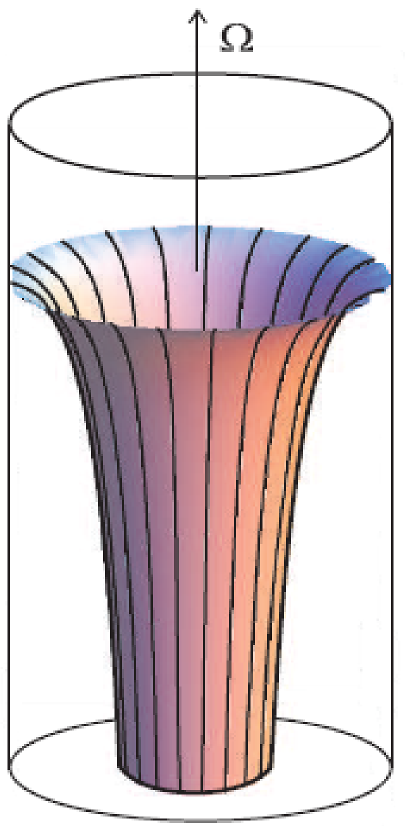
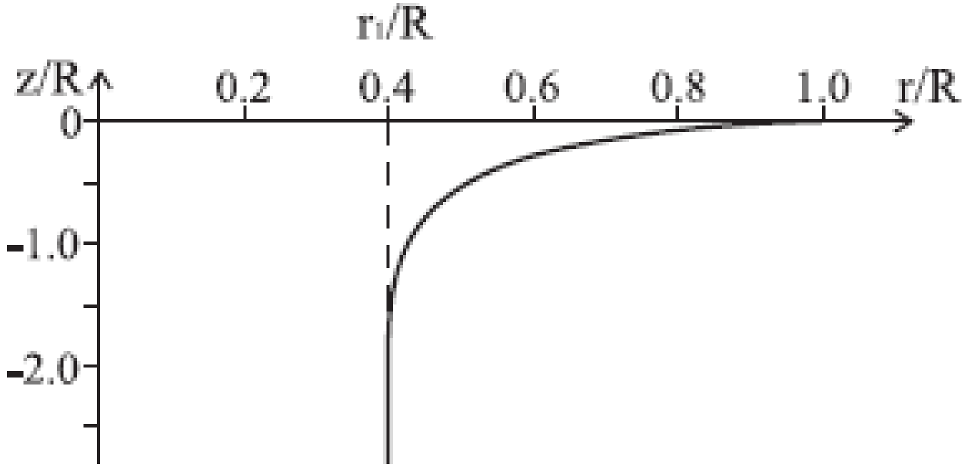
One layer case

$$\frac{\delta}{\delta z(r)}\{\rho_s \frac{(N\kappa)^2}{4\pi}\int_{r_1}^{R} z(r)\frac{dr}{r} + \rho_s \frac{N\kappa^2}{4\pi}\int_{r_1}^{R} \ln\frac{b}{r_c}\sqrt{1+\left[\frac{dz(r)}{dr}\right]^2}dr$$

$$-\boldsymbol{\Omega}\rho_s N\kappa \int_{r_1}^{R} z(r) r\, dr\} = 0$$





Two layers case

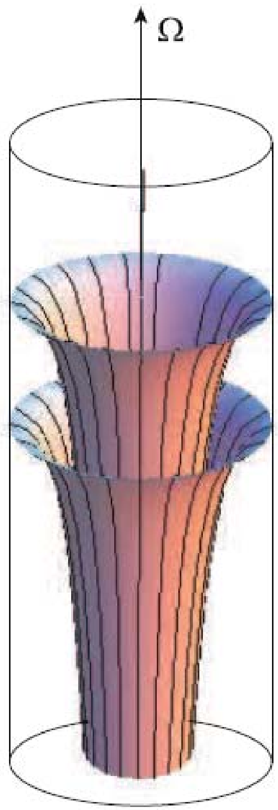
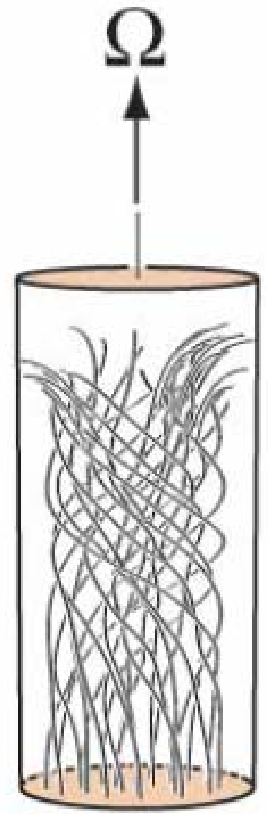


FIG. 4. (Color online) Hypothetical picture of two vortex sheets terminating on the lateral wall. But no state of solid-body rotation of two sheets with the same angular velocity was found.

Turbulent case



vortex front
and
twisted state

Propagation of the Turbulent Front. I

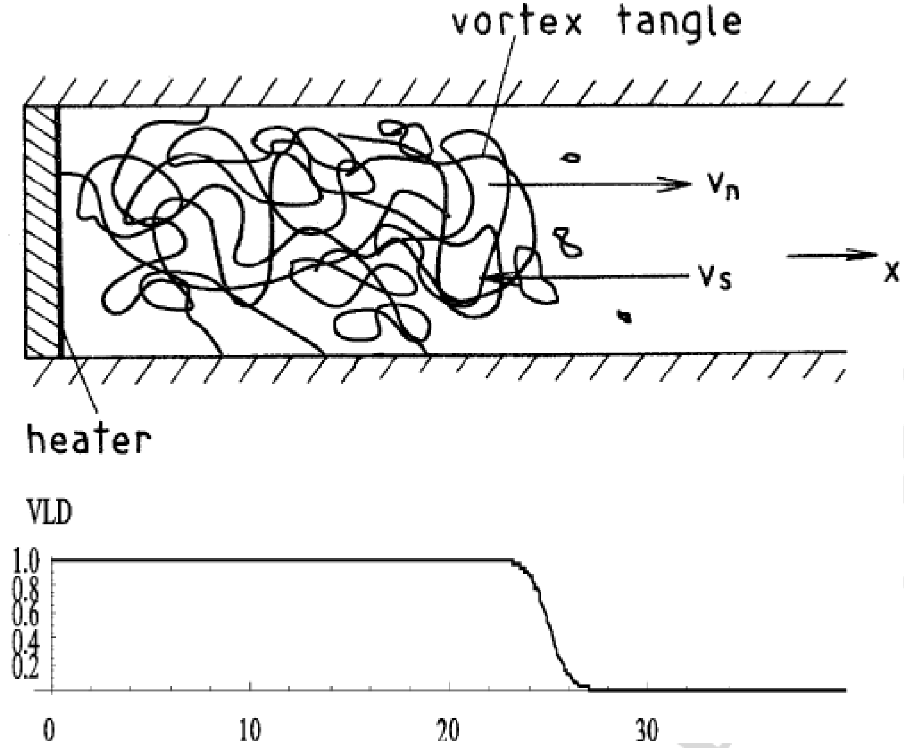


Fig. 1 (Color online) Schematic illustration of the statement of the problem. In the *upper picture* the propagating superfluid turbulent front is depicted. It propagates in the direction of the heat flux, which is created by the heater. In the *lower picture* the schematic distribution of the vortex line density is depicted. The units for both the VLD and the *x* axis are arbitrary

Propagation of the Turbulent Front.II

We propose that the propagation of the front is due to the following factors: a) the diffusion-like spread of the vortex tangle, b) the intensive production of the vortices behind the front, and c). the drift motion of the vortex tangles as a whole due to polarization of vortex loops. In the one-dimensional case (when the front propagates along the x axis) equation for the vortex line density is

$$\frac{\partial \mathcal{L}(t,x)}{\partial t} + \frac{\partial \mathcal{L}(t,x) V_L}{\partial x} = D \frac{\partial^2 \mathcal{L}(t,x)}{\partial x^2} + F(\mathcal{L}(t,x)) \tag{1}$$

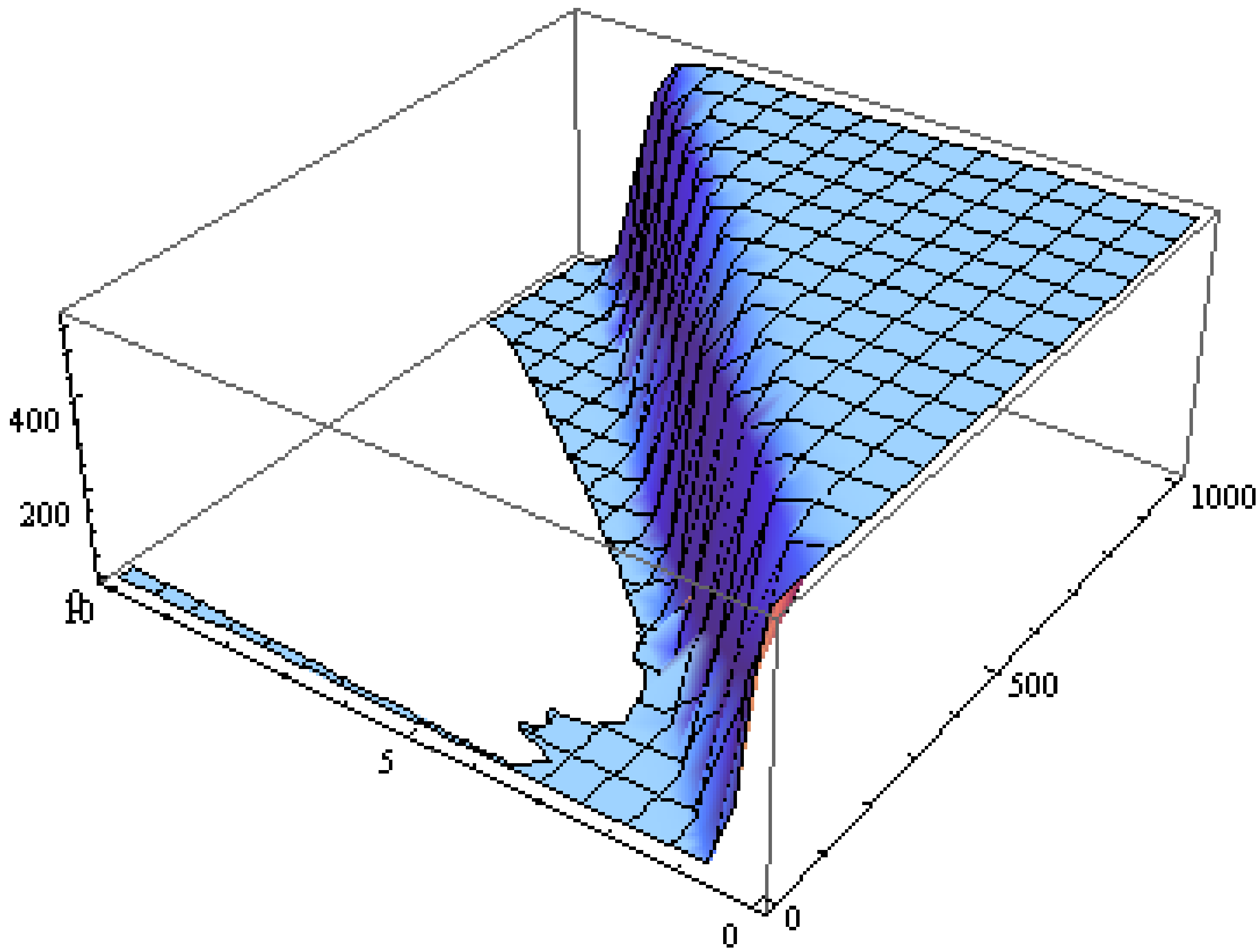
In the case of the counterflowing turbulence, the source term is just the rhs of the Vinen equation.

$$F_{Vi}(\mathcal{L}) = \alpha_{Vi} \left| \mathbf{v}_{ns} \right| \mathcal{L}^{3/2} - \beta_{Vi} \mathcal{L}^2. \tag{2}$$

$$V \approx 0.8 \sqrt{D/\tau} \approx 0.8 v_{ns} \sqrt{D \frac{\alpha_{Vi}^2}{\beta_{Vi}}}. \tag{3}$$

Numerical example $V_{fr} \approx 9 * 10^{-3}\ cm/s \approx 3 \times 10^{-2} \Omega r$

$D = 10^{-3},\ \alpha_{Vi} = 0.016,\ \beta_{Vi} = 2 * 10^{-4}$



The first observation of fronts was made by Mendelssohn (1958).Then Peshkov and Tkachenko (1961) and Bhagat et al. (1964) studied the kinetics of formation of the superfluid turbulence (ST) in long (up to 8 m) capillaries under the influence of small heat fluxes. Van Sciver (1979) studied a similar problem but for much larger heat fluxes of the order of 1 W/cm.

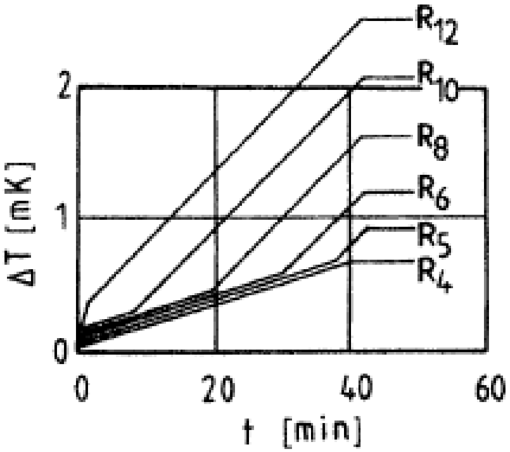


Fig. 2 (Color online) Time dependence of temperatures measured along the capillary for a thermal current ($Q = 4.4 \cdot 10^{-2}$ W/cm^2, $T = 1.34$ K), Peshkov and Tkachenko [1]

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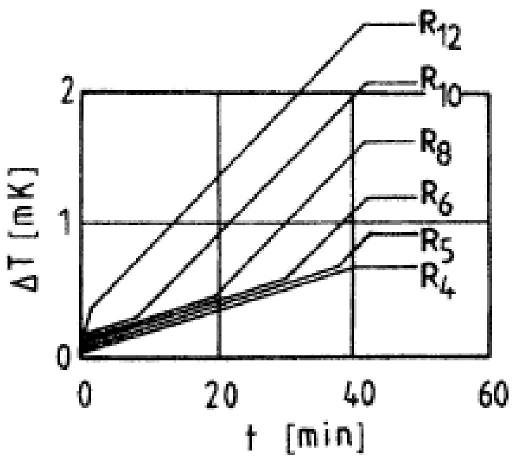
Vexp≈0.27 cm/s

Vtheor≈0.23 cm/s



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Summary

Probably we are in position to state two points.

1. Preliminary analytical studies leads to conclusion, that the penetration of a vortex bundle into an originally vortex-free rotating container filled with a superfluid is fulfilled with the turbulent front.

2 Investigation of the counterflowing turbulence had demonstrated the existence of a turbulent front, and explained the previous experiments.