Once a Hull Planes, Its Drag Almost Stops Growing with Speed, Because Lift Has Taken Over from Buoyancy

— The friction drag of a boat floating as it moves grows almost as the square of the speed (exponent **1.815296** to **1.832310**) — the separator is whether the weight is carried by buoyancy or by lift — [Paper 651]

Yuuki YAMAGISHI (山岸 勇輝)
Yamagishi Complexity Torus Lab, Japan
September 2026

— *From thinking to syncing.* —

Abstract

A boat floating as it moves carries its weight by buoyancy. A fast small boat, beyond some speed, lifts its bow and runs as if sliding on the water. What then carries the weight is not buoyancy but lift, made by pushing water downward.That when the support changes, the way drag answers to speed changes, is counted by the exponent of friction drag.No new theorem or law is claimed. First, there is a speed at which the wave speed is set by the boat's length——from the speed of waves in deep water, the Froude number of a wave whose length equals the boat's length is 0.398942 ($= 1/\sqrt{2\pi}$), 5.9485 knots for a boat 6 m long (Section 2). **Second, floating, friction drag grows almost as the square of the speed——with a fixed wetted area of 12 m^2 and the ITTC 1957 friction coefficient, the exponent of drag (the proportional rise in drag for a proportional rise in speed) was 1.815296 at 1 m/s and 1.832310 at 3 m/s** (Section 3). **Third, and this is the core.When lift carries the weight and the boat planes, drag hardly grows with speed——the wetted area shrinks so that lift balances the weight, to 1.9135 m^2 at 10 m/s and 0.4784 m^2 at 20 m/s. The drag went from 991.4226 N to 1032.7001 N, with exponents of 0.054595 to 0.063380** (Section 4). **Fourth, the separator is whether the weight is carried by buoyancy or by lift——with buoyancy the wetted area does not depend on speed, and friction acts as the square of the speed. With lift the wetted area shrinks with the inverse square of the speed, and the two cancel** (Section 5). **Keywords**: planing hull, Froude number, frictional resistance, lift, hull.

Scope of this paper (scope note): No new theorem or law is claimed——the speed of waves in deep water, the friction coefficient of ships (ITTC 1957), and the treatment of lift and drag of planing hulls (Savitsky 1964) are all known.Wave-making drag is not computed——the wave-making drag of a floating boat and the hump in drag before planing are not in the model. What is counted is friction and, when planing, the drag from the trim angle.This is an example——a length of 6 m, beam of 2 m, mass of 1000 kg, floating wetted area of 12 m^2, planing trim of 4 degrees and a lift coefficient of 0.10 per wetted area are set as an example. In real planing the trim and lift coefficient move with speed.Relation to earlier papers: Paper 390 showed that a sailing craft can outrun the wind, and stated that wave-making drag, planing and sea state were not its subject——this paper takes that seat for planing.Paper 256 showed that a model scaled by the Froude number cannot match friction, so ships split their resistance into wave-making and friction——here the friction side is counted as changing its exponent in speed when the support changes.What is added is deriving from the wave equation the speed at which the wave length equals the boat length, setting the exponents of drag for floating and planing side by side, and placing the separator on what carries the weight.

1. Notation and the Question

Setting: a boat of weight W is carried by buoyancy or by lift. Friction drag is written with the wetted area S and friction coefficient C_f as

$$D_f = \tfrac{1}{2}\rho V^2 S C_f, \qquad C_f = \frac{0.075}{(\log_{10}\mathrm{Re} - 2)^2}$$

(the right is the ITTC 1957 friction coefficient, with Re the Reynolds number on the wetted length).When floating, the wetted area is taken as $S_0 = 12\ \mathrm{m}^2$ regardless of speed. When planing, the wetted area S_w is set so that the lift $\tfrac{1}{2}\rho V^2 S_w C_L$ balances the weight, and a drag $W\tan\tau$ from the trim angle τ is added.The premises are seawater with $\rho = 1025\ \mathrm{kg/m}^3$ and kinematic viscosity $1.19 \times 10^{-6}\ \mathrm{m}^2/\mathrm{s}$, length 6 m, beam 2 m, mass 1000 kg, $\tau = 4$ degrees and $C_L = 0.10$.

Exponent: how drag grows with speed is measured by $d\ln D / d\ln V$.

Question: when what carries the weight changes, how does the way drag answers to speed change?

2. Waves and the Boat's Length

Computation 2.1: a wave of length λ in deep water travels at $\sqrt{g\lambda/2\pi}$. A wave whose length equals the boat's length L travels at $\sqrt{gL/2\pi}$, which as a Froude number $V/\sqrt{gL}$ is 0.398942. For a length of 6 m this is 3.0602 m/s, or 5.9485 knots.

Observation 2.2

a floating boat is surrounded by the waves it makes.When the spacing of the bow and stern wave crests reaches the boat's length, going faster means climbing its own bow wave. Wave-making drag is known to rise steeply around here, but it is not computed in this paper——what is examined here is that beyond this, what carries the weight changes.

3. Floating

Computation 3.1: **with a wetted area of $12\ \mathrm{m}^2$, friction drag and its exponent were derived.**

speed	friction drag	exponent
1 m/s	**20.8574** N	**1.815296**
2 m/s	**73.6928** N	**1.826408**
3 m/s	**154.7267** N	**1.832310**

Observation 3.2

floating, friction drag grows almost as the square of the speed.The wetted area is fixed, so drag is the square of the speed times the friction coefficient. The friction coefficient falls a little at higher speed, so the exponent is a little below 2——double the speed, and friction alone nearly quadruples the drag.

4. Planing

Computation 4.1: **for the wetted area to fit within a bottom of $9.6\ \mathrm{m}^2$ (0.8 of length times beam), lift alone must carry the weight at some speed. That speed was 4.4646 m/s, or 8.6784 knots (Froude number 0.5820).**

Computation 4.2: **the wetted area, drag and exponent while planing were derived.**

speed	wetted area	drag	exponent
10 m/s	1.9135 m^2	991.4226 N	0.054595
15 m/s	0.8504 m^2	1014.6101 N	0.059531
20 m/s	0.4784 m^2	1032.7001 N	0.063380

The part of the drag from the trim angle was 685.7478 N at every speed. Drag divided by weight was 0.101097 at 10 m/s and 0.105306 at 20 m/s.

> **Observation 4.3**
>
> this is the core: when lift carries the weight and the boat planes, drag hardly grows with speed.Lift goes with the square of the speed, so the faster the boat, the smaller the area needed to carry the weight, and the wetted area shrinks with the inverse square of the speed. Friction is the square of the speed times the area, so the two cancel, and friction drag becomes nearly weight times friction coefficient divided by lift coefficient. The trim drag is weight times $\tan\tau$ and does not depend on speed——the exponent fell from a little over 1.8 when floating to about 0.06.

5. The Separator

> **Observation 5.1**
>
> the separator is whether the weight is carried by buoyancy or by lift.Buoyancy does not depend on speed, so neither does the wetted area, and friction acts as the square of the speed. Lift goes with the square of the speed, so the wetted area shrinks by that much, and friction's response to speed disappears——the same boat in the same water changes its exponent of drag when what carries it changes.

> **Observation 5.2**
>
> beside Paper 390 and Paper 256.Paper 390 showed that a sailing craft can outrun the wind and stated that planing was not its subject. Paper 256 showed that a model scaled by the Froude number cannot match friction, so ships split their resistance into wave-making and friction——here the friction side was counted as changing its exponent in speed from a little over 1.8 to about 0.06 when the support changes.

Observation 5.3

what is not said.Wave-making drag and the hump in drag before planing are not computed. The trim angle and lift coefficient were held constant, though in real planing they move with speed. The performance of real boats is not discussed——what is shown is how a difference in support changes the exponent of friction.

6. Roll Call and Closing

1. **Froude number 0.398942 for wave length equal to boat length** (Computation 2.1): $1/\sqrt{2\pi}$.
2. **5.9485 knots for 6 m** (Computation 2.1): **the speed at which waves surround the boat.**
3. **floating exponent 1.815296 to 1.832310** (Computation 3.1): **nearly squared.**
4. **lift alone carries at 8.6784 knots** (Computation 4.1): **with the bottom set.**
5. **wetted area 1.9135 to 0.4784 m^2** (Computation 4.2): **inverse square of speed.**
6. **planing exponent 0.054595 to 0.063380** (Computation 4.2): **hardly grows.**
7. **trim part 685.7478 N** (Computation 4.2): **independent of speed.**
8. **drag over weight 0.101097 to 0.105306** (Computation 4.2): **nearly constant.**
9. **shrinking area cancels squared speed** (Observation 4.3): **the core.**
10. **buoyancy or lift** (Observation 5.1): **the separator; Paper 390 and Paper 256.**

Closing: **A floating boat carries its weight by buoyancy, and a planing boat by lift.Floating, the wetted area does not change, and friction drag grew almost as the square of the speed (exponent 1.815296 to 1.832310).Carried by lift, the wetted area shrank with the inverse square of the speed, and the exponent of drag fell to 0.054595 to 0.063380 ——lift, acting as the square of the speed, cancels friction, acting as the square of the speed.The separator is whether the weight is carried by buoyancy or by lift.Placed among the earlier papers——in the seat for planing left open by Paper 390, the friction side of Paper 256 changes its exponent.To be honest——wave-making drag and its hump are not computed, and this is an example with the trim angle and lift coefficient held constant.**

References

1. International Towing Tank Conference (1957). *Proceedings of the 8th International Towing Tank Conference*.
2. Savitsky, D. (1964). Hydrodynamic design of planing hulls. *Marine Technology*.
3. Yamagishi, Y. (2026). *The Only Scale at Which Dynamic Similarity Is Exact Is One* [Paper 256]. Zenodo. 10.5281/zenodo.22168919

4. Yamagishi, Y. (2026). *Going Faster Makes the Wind Stronger, Which Is Why a Sailing Craft Can Outrun the Wind* [Paper 390]. Zenodo. 10.5281/zenodo.22699203

— From thinking to syncing. —

Yuuki YAMAGISHI (山岸 勇輝)

© 2026 Yamagishi Complexity Torus Lab, Japan · Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0)