How Wings Actually Work: Navier-Stokes and Viscosity not Coanda or Others

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Since the equal transit time theory for lift has been "proven false" [1], it has been replaced by Coanda almost ubiquitously in science education, which is used as a non-mathematical substitute for circulation. CASA even regulates that Coanda is taught to pilots to explain lift. However, the Coanda effect is not present around a conventional aerofoil or wing. Coanda requires a jet of air (or other fluid) with significantly greater momentum than the fluid around it [2]. This produces a turbulent mixing layer between the jet and static air, entraining the static fluid in the shear layer. If the jet is located near a surface, it will restrict airflow, which via entrainment is being removed. The net result is a rarefied and hence low-pressure region near the surface, giving a pressure gradient force (PGF) on the jet, towards the surface. Fluid forces will tend to result in the jet flowing along the surface, even around shallow curves. However, as with all fluid flows, the direction of the fluid motion is dictated by the net result of many forces. For example, if the curvature is too great, inertial forces will tend dominate resulting in separation. Coanda is typically demonstrated by blowing on a piece of paper to make it lift. However, that is not how wings work, there is no jet of air in front of a wing. That said, you can add a jet of air to a wing and generate more lift, such as the blow flaps of the Blackburn Buccaneer or the Lockheed F-104 Starfighter [3].

Circulation is the other theory used to explain lift, primarily by engineers, with the "magic" left to Kutta, the condition needed to resolve D'Alembert's paradox [1]. However, circulation and the Kutta condition are results not explanations, and they result from the viscosity of the fluid [4]. Invoking Coanda achieves the same outcome, it is a name used to "explain" the effects of viscosity. In which case, viscosity should be correctly attributed, to Navier and Stokes, assuming a name is needed. Similar misconceptions are true for Babinski and his "correct explanation for lift" [5]. Here, the relationship between the PGF and the curvature of streamlines is correct; however, without viscosity you get curved streamlines with no lift, D'Alembert's paradox, where the streamlines above and below an aerofoil are symmetric, resulting in equal transit [1]. The asymmetry of real flow is the result of viscous effects. Finally, the same is true for a pure Newtonian moment description of lift (circulation, Coanda, and even Babinski are all seeking to explain the origins of the "downwash"). That is, if the wing goes up, according to Newton, the air must go down. However, without viscosity, the amount of upwash equals the amount of downwash, hence there is not net change in momentum, and no lift!

[1] G. Wild, *arXiv preprint arXiv:2110.00690* (2021).
[2] N. A. Ahmed, *Coanda Effect: Flow Phenomenon and Applications*. (CRC Press, 2019).
[3] N. Beck, R. Radespiel, C. Lenfers, J. Friedrichs and A. Rezaeian, *J Aircraft* **52** (5), 1422-1436 (2015).
[4] T. Liu, S. Wang and G. He, *AIAA J* **55** (11), 3990-3994 (2017).
[5] H. Babinsky, *Physics Education* **51** (3), 030108 (2016).