Ground Effects

The proximity of a nearby boundary (free or fixed) in a flow can have a major effect on forces experienced by that object. While the effect on the drag can be significant, the effect on the lift can be very consequential and thus we focus on this *ground effect* here.

The ground effect on a lifting body moving close to a solid boundary (Figure 1) is readily understood as

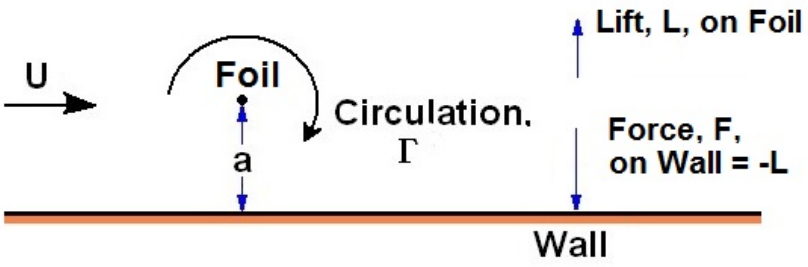

Figure 1: Lifting body in a flow near a wall.

follows. The circulation, Γ, associated with the lift produces a lower fluid velocity and a higher pressure on the underside of the lifting body. The proximity of the wall further decreases the velocity and amplifies the pressure underneath and thus further amplifies this effect and increases the lift force on the body. In the case of planar potential flow (see section (Bgdm)) in which the flow is modeled by a simple planar vortex the lift, L, is given by

$$L \;=\; \rho U \Gamma \left[1 + \frac{\Gamma}{4\pi U a} \right] \tag{Dci1}$$

and therefore increases substantially the smaller the height a and the closer the foil is to the wall. Indeed the front-mounted foils on modern Formula One cars are so close to the ground that they are frequently damaged by contact with the ground; but are so crucial to the cars performance that they have to be replaced as soon as possible.

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One of the more unusual airplanes built to take advantage of the additional lift provided by proximity to the *ground* (or in this case the surface of the sea) is the Russian, Lun class *ekranoplan* shown in Figure 2 abandoned and beached on the shore of the Caspian Sea near Derwent, Dagestan. This huge, $380 ton$ airplane was designed to fly up to 550 km/hr at a height of $1 - 5m$ above the surface of the sea and to accommodate waves up to $2.5m$ in height. (It was abandoned at the end of the Cold War and only recently reclaimed as a park exhibit.) Other similar projects include the *AirFish* built by the company Wigetworks.

Moreover, any beach goer who has watched the flight of pelicans will have noted that they appear to gain advantage by flying close to the water surface almost skimming the tops of the waves. Indeed, it may even be the case that they gain aerodynamic advantage from the waves though I have not seen an analysis that demonstrates this.

Figure 2: Photographs of the Russian Lun class *ekranoplan* beached near Derwent, Dagestan, on the shore of the Caspian Sea.