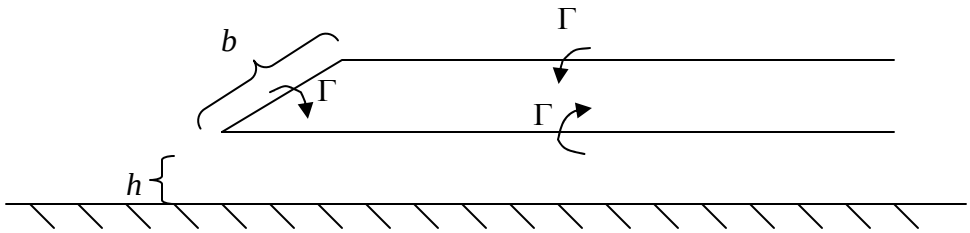
Ground Effect Using Single Vortex Model

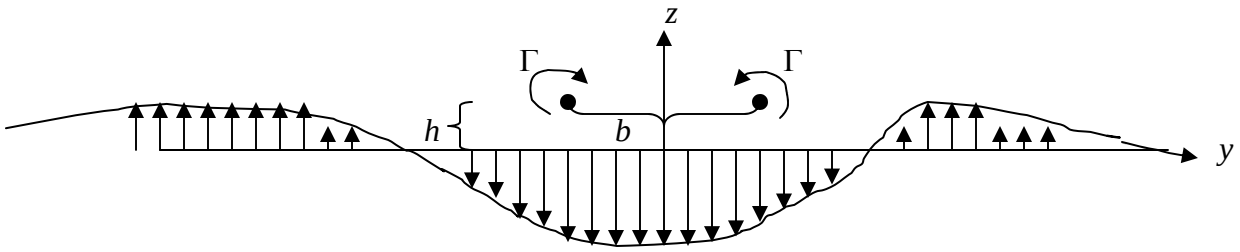


What is the boundary condition at ground ($z = 0$) and does a single horseshoe vortex satisfy it??

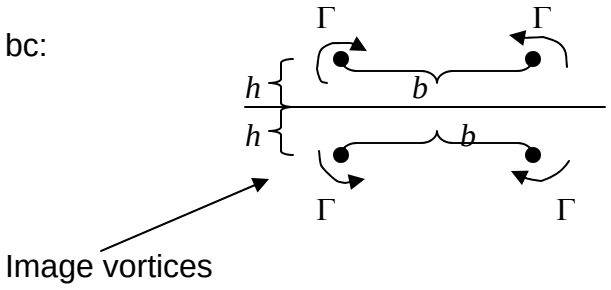
B.C.: "solid wall" $\Rightarrow \vec{u} \cdot \vec{n} = 0$

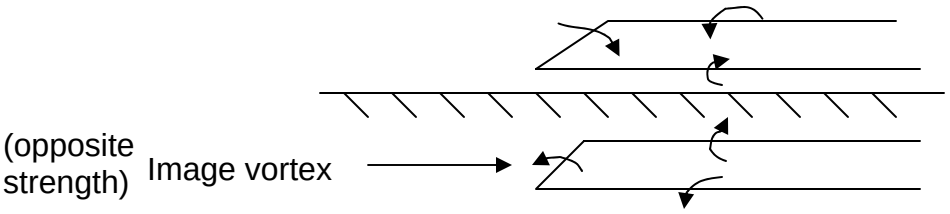
$\Rightarrow w = 0$ at $z = 0$!

Consider from far downstream:



So, to satisfy bc:





Result: downwash is decreased due to upwash "caused" by ground plane (which is modified by image vortex).

For our simple model:

$$w_i = -\frac{\Gamma}{\pi b} + \frac{\Gamma}{\pi b}\left[\frac{1}{1+16(\frac{h}{b})^2}\right]$$

original "isolated" wing effect

ground effect

$\frac{()_i}{()_{i\infty}}$ are true for fixed L (i.e. Γ)

$$w_i = \underbrace{-\frac{\Gamma}{\pi b}}_{w_{i_\infty}} \frac{16(\frac{h}{b})^2}{1+16(\frac{h}{b})^2} = w_{i_\infty}\frac{16(\frac{h}{b})^2}{1+16(\frac{h}{b})^2}$$

$$D_i \cong -L\frac{w_i}{V_\infty} = \underbrace{\frac{L\Gamma}{\pi b V_\infty}}_{D_{i_\infty}} \frac{16(\frac{h}{b})^2}{1+16(\frac{h}{b})^2}$$

$$D_i = D_{i_\infty}\frac{16(\frac{h}{b})^2}{1+16(\frac{h}{b})^2}$$

$$C_{D_i} = C_{D_{i_\infty}}\frac{16(\frac{h}{b})^2}{1+16(\frac{h}{b})^2}$$