Benjamin Berné Flow Control AME 70634 Homework 3

4.1.1 $F_+ = \frac{fL}{U_\infty}$, $F_+ = 1 \rightarrow U_\infty = fL$

Substitute U_∞ Simplify

$\frac{\omega \phi}{U_\infty} = 0.075 \rightarrow \frac{2\pi f \phi}{fL} \rightarrow \frac{2\pi\phi}{L} = 0.075 \rightarrow \boxed{\frac{\phi}{L} = \frac{0.075}{2\pi} = 0.0119}$

4.1.2 $\boxed{\frac{\delta}{\phi} = 10 \quad \therefore \quad \frac{\delta}{\phi}\frac{\phi}{L} = \frac{\delta}{L} = 0.119}$

4.5.1 Optimum Spacing $= 0.8\delta$

$\frac{\delta}{\theta} = 4$, $\frac{\omega\theta}{U_\infty} = 0.12$

$\lambda_x = \frac{2\pi}{\omega}$

$\omega = \frac{U_\infty}{\theta} 0.12 \rightarrow \boxed{\lambda_x = \frac{2\pi}{\left(\frac{U_\infty}{\theta}\right)0.12} = 52.36\left(\frac{\theta}{U_\infty}\right)}$

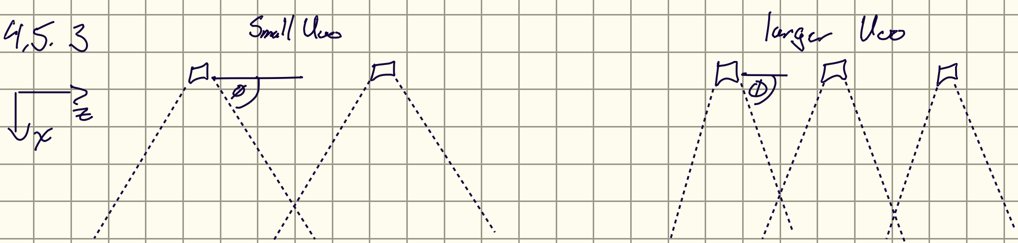
4.5.2 $\theta/\delta \simeq 0.1$ Assuming $\lambda_z = 0.8\delta$

$$\phi = \tan^{-1}\left(\frac{\lambda_z}{\lambda_x}\right) = \tan^{-1}\left(\frac{0.8\delta}{52.36\,\frac{\theta}{U_\infty}}\right) = \tan^{-1}\left(\frac{0.8\cdot 10\cancel{\theta}}{52.36\left(\frac{\cancel{\theta}}{U_\infty}\right)}\right) = \tan^{-1}\left(\frac{8\,U_\infty}{52.36}\right)$$

U_∞	ϕ (deg)
5	37.4
10	56.8
15	66.4
20	71.9

$\lambda_z = \frac{436}{\mu}$

4.5.3



At larger U_∞ the wave angle is larger and the waves are more 3D.
Therefore the vortices travel a smaller spanwise distance and therefore more are needed to effectively mix the Boundary-Layer.

4.6.1

$L \geq T_c V_\infty$

$T_c = 1.5 ms \rightarrow 0.0015 s$

$V_\infty = 68 m/s$

$V_j = 3$ (conservatively)

$\boxed{L \geq 0.0015 * 68 \Rightarrow L \geq 0.102 m}$ minimum required length

4.6.2 $V_j/V_\infty > 0.8$ $\quad T_c = \alpha V_j \Rightarrow \frac{T_c}{V_j} = \alpha$

$$\frac{T_c}{V_j} = \frac{0.0015}{3} = \frac{T_{c\,new}}{0.8 \cdot 68} \rightarrow T_{c\,new} = 0.0272 s$$

$$\boxed{L \geq T_{c\,new} \cdot 68 = 1.85 m}$$

4.6.3 This justifies the relatively small holes needed for wall jets because they are $D \lll L$ at these scales and therefore much less restrictive than the plasma Actuators.

4.2.1

Suction: $\frac{\partial}{\partial\theta}\downarrow$ Favorable pressure gradient, the Boundary layer to gain momentum and increase the Velocity gradient.
Blowing: $\frac{\partial}{\partial\theta}\uparrow$ Adverse pressure gradient, causing the Boundary layer to Billow and the Velocity gradient near the wall to approach zero.

4.2.2

The profile $\frac{\partial}{\partial\theta}$ changes the Magnitude of Amplification and the most Amplified frequency of the shear layer instability. Based on Fig 4.13. The Magnitude of Amplification increases as the shear layer seperates. The frequency however, increases until the shear layer Seperates and the most Amplified frequency decreases slightly.
The effects are on the shear layer are the Same for wall normal Suction and tangential Blowing.

4.2.3 Wall Suction:

1.) Reduction of Boundary layer thickness.

2.) Increased momentum Near Wall and increasing the Velocity gradient near the Wall.

3.) Delay of Adverse Pressure gradients and therefore delays Seperation.

Tangential Blowing:

1.) Enhancement of Sheer Stress at the wall, which works to prevent seperation.

2.) Thickening of Boundary layer through addition of momentum into flow.

3.) Suppression of Vortical structures.