Pressure-Velocity Correlation

\[ U_e = 10.0 \text{ m/s}; \ L=38.1\text{mm}; \ Re=335,000 \text{ (based on cavity width)}; \ Re_\lambda = 340 \]

Streamwise acceleration \( \Rightarrow \) u increase, p decrease \( \Rightarrow \) \( u' \) (+), \( p' \) (-) \( \Rightarrow \) \( u'p' \) (-);
Streamwise deceleration \( \Rightarrow \) u decrease, p increase \( \Rightarrow \) \( u' \) (-), \( p' \) (+) \( \Rightarrow \) \( u'p' \) (-);

- Hooper and Musgrove (1997) also reported strong negative correlation between fluctuating pressure and streamwise velocity component in a developed pipe flow using a cobra (4-hole) probe.
u-component Turbulence and Pressure Diffusions and the TKE Production

Turbulence diffusion of $u^2$

$$\left(-\frac{\partial u'^2}{\partial x} - \frac{\partial u'^2}{\partial y}\right)(L/U_e^3)$$

Pressure diffusion of $u^2$

$$-\frac{\partial}{\partial x}\left(\frac{2}{\rho}u'p\right)(L/U_e^3)$$

Total TKE production

Note: The magnitude of pressure diffusion is 5 times larger than the turbulence diffusion.

The magnitude of the pressure diffusion is about the same as the total turbulence kinetic energy production.
v-component Turbulence and Pressure Diffusions and the TKE Production

Again, the magnitude of pressure diffusion is 5 times larger than the turbulence diffusion.

The magnitude of the pressure diffusion is at least comparable with the total turbulence kinetic energy production.
Pressure diffusion of $u^2$

$$-\frac{\partial}{\partial x}\left(\frac{2}{\rho} u'\frac{\partial}{\partial x}p\right) \left(\frac{L}{U_e^3}\right)$$

Velocity-pressure-gradient tensor $\Pi_{11}$

$$-\frac{2}{\rho} u'\frac{\partial}{\partial x}p\left(\frac{L}{U_e^3}\right)$$

Pressure-rate-of-strain tensor $R_{11}$

$$\frac{2}{\rho} p'\frac{\partial}{\partial x}u' \left(\frac{L}{U_e^3}\right)$$

Pressure diffusion of $v^2$

$$-\frac{\partial}{\partial y}\left(\frac{2}{\rho} v'p\right) \left(\frac{L}{U_e^3}\right)$$

Velocity-pressure-gradient tensor $\Pi_{22}$

$$-\frac{2}{\rho} v'\frac{\partial}{\partial y}p\left(\frac{L}{U_e^3}\right)$$

Pressure-rate-of-strain tensor $R_{22}$

$$\frac{2}{\rho} p'\frac{\partial}{\partial y}v' \left(\frac{L}{U_e^3}\right)$$

Pressure-rate-of-strain tensor $R_{32}$

$$\frac{2}{\rho} p'\frac{\partial}{\partial y}v' \left(\frac{L}{U_e^3}\right)$$

Pressure-rate-of-strain tensor $R_{31}$

$$\frac{2}{\rho} p'\frac{\partial}{\partial x}v' \left(\frac{L}{U_e^3}\right)$$

Pressure diffusion of $u^2$

$$-\frac{\partial}{\partial x}\left(\frac{2}{\rho} u'p\right) \left(\frac{L}{U_e^3}\right)$$

$U_e = 5.15 \text{ m/s}$
Conclusions

• Pressure velocity and pressure-rate of strain correlations have been measured in a 2D open cavity shear flow.

• In the shear layer, pressure and streamwise velocity are negatively correlated, however, the correlation changes its sign near the corner due to the adverse pressure gradient.

• Near the trailing corner, the magnitude of the pressure diffusion is five times larger than the turbulence diffusion, and is on the same order as the turbulence production term.

• In the cavity shear layer, the pressure-rate-of-strain term $R_{11}$ is mostly negative while $R_{22}$ is positive but with smaller magnitude, implying that the streamwise turbulent energy is redistributed to the lateral direction.
Mean U-component Velocity Distribution

$U_e = 10.0 \text{ m/s}$
Field of View: 50.8mm×50.8mm
Resolution of interrogation window: 0.4mm×0.4mm
Re=335,000 (based on cavity width)

$U_e = 5.0 \text{ m/s}$
Field of View: 25.4mm×25.4mm
Resolution of interrogation window: 0.2mm×0.2mm
Re=167,500 (based on cavity width)

Each Set is Based on 1000 Realizations
Mean V-component Velocity Distribution

\[ \text{Ue} = 10.0 \text{ m/s} \]

\[ \text{Ue} = 5.15 \text{ m/s} \]
Mean Pressure Distribution

Ue = 10.0 m/s

Ue = 5.15 m/s
RMS Values of Pressure Fluctuation

Flow Direction

Leading Edge

Cavity Wall

\( U_e = 10.0 \text{ m/s} \)

\( U_e = 5.15 \text{ m/s} \)

Probability Density Function

\( \text{Cp}' \)

RMS Values of Pressure Fluctuation

\( \text{Cp}_{\text{rms}} \)

Probability Density Function

\( \text{Cp}' \)
Reynolds Stress Distributions

Note: The scales are different. The maximum $u^2$ is almost 3 times larger than $v^2$.

$U_e = 10.0 \text{ m/s}; L=38.1\text{mm}; \text{Re}=335,000$ (based on cavity width); $\text{Re}_\lambda = 340$
Reynolds Normal Stress Distributions

$U_e = 10.0 \text{ m/s}$

$U_e = 5.15 \text{ m/s}$
Reynolds Normal Stress Distributions

$U_e = 10.0 \text{ m/s}$

$U_e = 5.15 \text{ m/s}$
Reynolds Shear Stress Distributions

Ue = 10.0 m/s

Ue = 5.15 m/s

\( \overline{u'v'} \) Unit: m²/s²

\( \overline{u'v'} \) Unit: m²/s²

The diagrams illustrate the shear stress distributions for two different velocities, 10.0 m/s and 5.15 m/s. The shear stress \( \overline{u'v'} \) values are represented on a color scale, indicating the magnitude and direction of the stress.