Streamline Curvature Wall Model for Pressure from PIV

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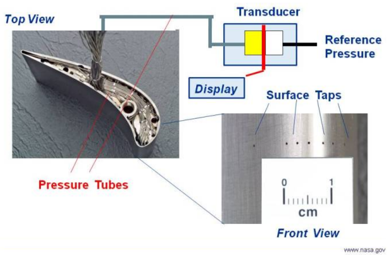
APS DFD, November 2024

Motivation: Why Pressure from PIV?

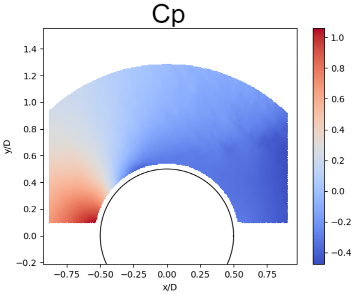
Pressure Taps

- Measurements dependent on leakage, hole diameter, flushness
- Difficult to install
- Length of tubing limits sampling rate



Pressure from PIV

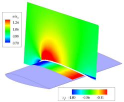
- Completely non-invasive
- High time resolution possible
- High spatial resolution possible

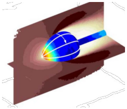


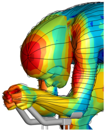
Previous Works on Extracting Surface Pressure from PIV

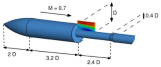
Case	Max Cp Error	Extrapolation Approach	Source
NACA 0012	0.5	parabola fit	Tagliabue et al., 2017
Sphere	0.15	nearest neighbor	Jux et al., 2020
Cyclist	0.2*	nearest neighbor	Jux et al., 2020
Bullet Step	0.02	nearest neighbor	Gent et al., 2018
NACA 0012	0.25	line fit	Ragni et al., 2009

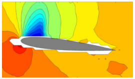
*based on uncertainty analysis (no pressure tap reference)











Common Challenges

- Reflections
- Low Particle Density
- Turbulence

} degrade near wall velocity data

- Wall Curvature
- Boundary Layers

} degrade near wall gradient calculations

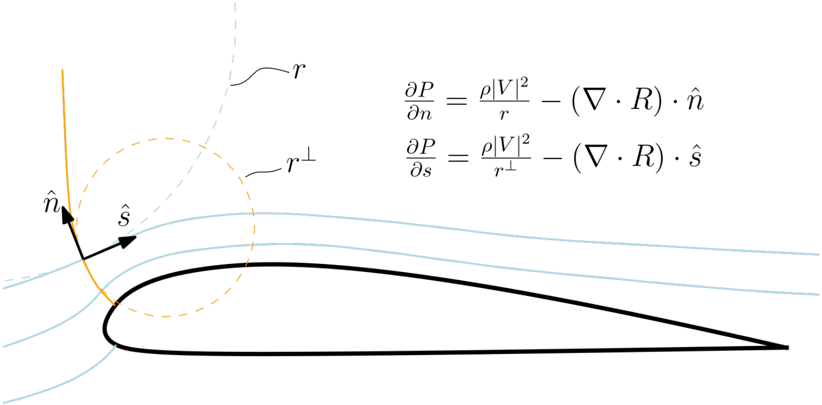
Typical workflow:

$$\begin{matrix} u_{PIV} \\ R_{PIV} \end{matrix} \xrightarrow{\partial_x, \partial_y} \nabla P \xrightarrow{\text{Integration}} P \xrightarrow{\text{Extrapolation}} P_{wall}$$

measured away from wall

Idea: Use geometry to calculate ∇P

Pressure Gradient in Streamline Coordinates



$$\frac{\partial P}{\partial n} = \frac{\rho |V|^2}{r} - (\nabla \cdot R) \cdot \hat{n}$$

$$\frac{\partial P}{\partial s} = \frac{\rho |V|^2}{r^{\perp}} - (\nabla \cdot R) \cdot \hat{s}$$

Summary of the New Method

1. Compute Streamlines
2. Fit Circles
3. Integration
4. Differentiation

LES Airfoil Validation

- Data from Asada and Kawai, 2018
- Grid coarsened from LES
- Added 2% random velocity error

Experimental Setup

Rough Cylinder Expirimental Results

Conclusions and Next Steps

- Robust to noise
- Robust to distance from wall
- Similar or better results in regions with strong pressure gradient

Next Steps:

- Improve treatment of Reynolds stresses
- Improve treatment of critical points (separation, stagnation point)
- Generalization to 3D