Planar Pressure PIV Error Optimization with Applications to Structural Loading on a Circular Cylinder

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Direct numerical simulations of flow over a circular cylinder are performed for ReD = 100, 300 and 1575, respectively spanning laminar, transitional, and turbulent wake regimes. Random errors typical for Particle Image Velocimetry (PIV) measurements are applied to synthetic PIV data extracted from numerical results and a parametric study encompassing ranges of temporal and spatial resolutions is performed for each ReD using four common pressure estimation techniques. Comparison to DNS solver pressures allows the identification of optimal temporal and spatial resolutions which minimize the propagation of random and truncation errors to the integrated pressure. A model derived from error propagation theory describing these optimums is developed and captures the effects of reducing spatial and temporal scales with increasing ReD, and shows good agreement with methods based on the Poisson equation as well as the Navier Stokes equations. The effect of three-dimensional wake structures is also quantified relative to the random and truncation errors for planar integration techniques, and is shown to exhibit substantial growth local to the wake vortices as flow transitions to turbulence. The results of the present study are further used to evaluate control volume and surface pressure integration force estimation techniques, providing recommendations for the use of pressure and force estimation techniques from experimental PIV measurements in vortex dominated laminar and turbulent wake flows.