Volumetric three-component velocimetry measurements of the turbulent flow around a Rushton turbine

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Abstract Volumetric three-component velocimetry measurements have been taken of the flow field near a Rushton turbine in a stirred tank reactor. This particular flow field is highly unsteady and three-dimensional, and is characterized by a strong radial jet, large tank-scale ring vortices, and small-scale blade tip vortices. The experimental technique uses a single camera head with three apertures to obtain approximately 15,000 three-dimensional vectors in a cubic volume. These velocity data offer the most comprehensive view to date of this flow field, especially since they are acquired at three Reynolds numbers (15,000, 107,000, and 137,000). Mean velocity fields and turbulent kinetic energy quantities are calculated. The volumetric nature of the data enables tip vortex identification, vortex trajectory analysis, and calculation of vortex strength. Three identification methods for the vortices are compared based on: the calculation of circumferential vorticity; the calculation of local pressure minima via an eigenvalue approach; and the calculation of swirling strength again via an eigenvalue approach. The use of two-dimensional data and three-dimensional data is compared for vortex identification; a ‘swirl strength’ criterion is less sensitive to completeness of the velocity gradient tensor and overall provides clearer identification of the tip vortices. The principal components of the strain rate tensor are also calculated for one Reynolds number case as these measures of stretching and compression have recently been associated with tip vortex characterization. Vortex trajectories and strength compare favorably with those in the literature. No clear dependence of trajectory on Reynolds number is deduced. The visualization of tip vortices up to 140° past blade passage in the highest Reynolds number case is notable and has not previously been shown.

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