# Generation of wing-tip vortices by flapping rigid plate, optimization of PIV measurements and identification of vortices using various algorithms

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## 1. INTRODUCTION & OBJECTIVE

To fulfill the requirements of extremely challenging military and civil applications of Micro Air Vehicles (MAV's), the flying vehicles should be small, should possess hover capability, perching capability, and high maneuverability. These qualities can be achieved by flapping wing flight; the best example could be the natural flyers and the fixed wing MAV limitations are well known. The flow physics of flapping wing flight is extremely complex and not yet well understood. Therefore there is ample scope for further study of unsteady nonlinear aerodynamics of flapping flight and would be useful for the development of mechanical fliers. In flapping flight, wing-tip vortex plays an important role in generation of necessary forces [1, 2]. The present work is focused on generation of wing-tip vortices by flapping the rigid rectangular plate (wing) at 1.5Hz in simple (main) flapping motion. The generated wing-tip vortices have been captured and analyzed using particle image velocimetry (PIV) measurements.

In PIV measurements, it is known that interrogation window size should be large enough to ensure enough matching particles for robustness and accuracy. And smaller interrogation windows could be utilized, leading to an increase of spatial resolution (number of vectors) [3, 4]. In the present work, interrogation window size has been varied from 64 X 64 to 16 X 16 pixel size and keeping the shape as square, window overlapping as 50%, displacement range limitation as 25% (N/4), also called one-quarter rule. Different types of cross-correlation techniques have been used to optimize the PIV methodology. Experimental uncertainty calculations have been performed. Algorithms like $\lambda_2$ criteria, Helicity, Q criteria etc. have been used for vortex identification [5, 6]. The flow around the flapping wing consists of large regions of vortical coherent structures, shear flow near the moving surface.

## 2. RESULTS

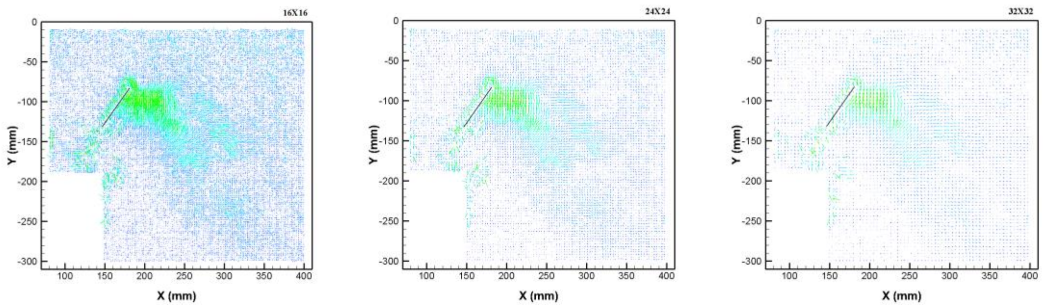


**Figure 1.** Velocity vector field by varying the interrogation window size (velocity magnitude in m/s).

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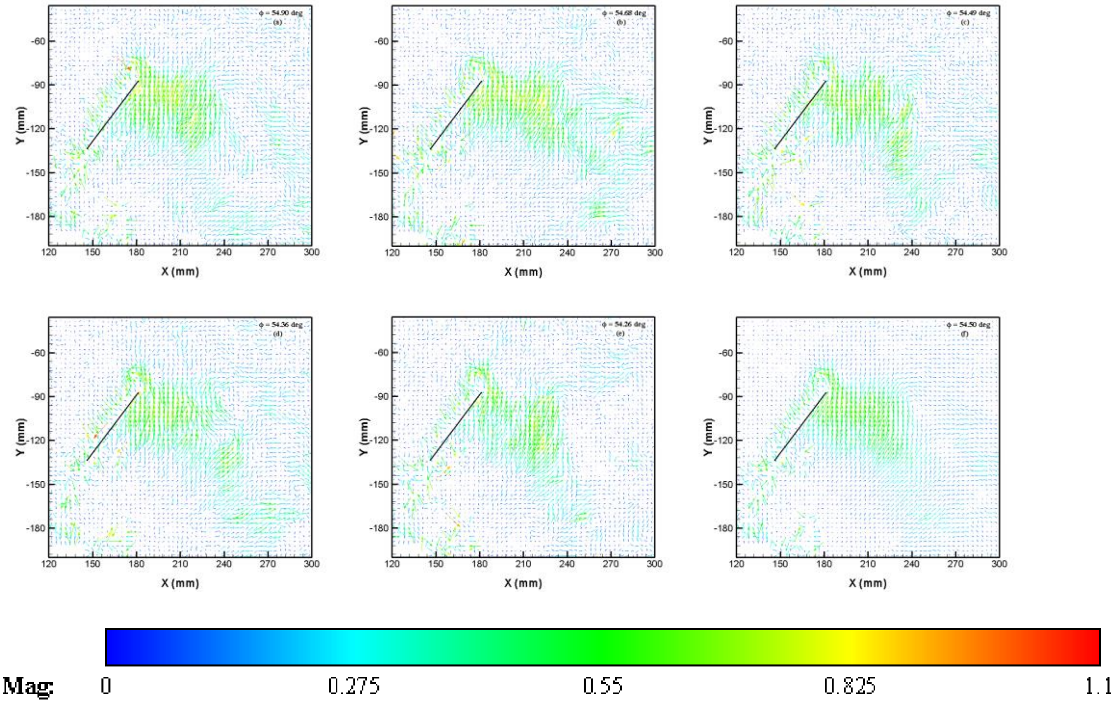
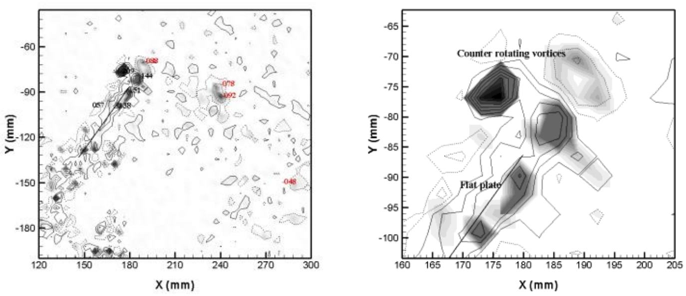
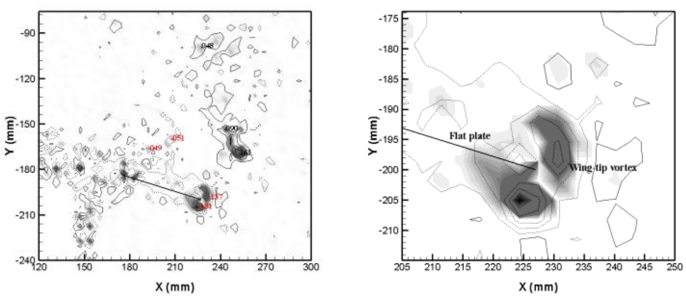



**Figure 2.** (a) to (e) is the instantaneous velocity vector field and (f) is the phase averaged velocity vector field (velocity magnitude in m/s).




(a)




(b)

**Figure 3.** Vorticity and $\lambda_2$ criteria: (a) at the beginning of downstroke and (b) at the beginning of upstroke of the flapping cycle.

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