Phase-averaged Investigation on Fire Ant Wingbeat Induced Flows with digital PIV

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A particle image velocimetry (PIV) system was developed and applied to investigate the air flows induced by the motion of fire ant alate wings. The experimental setup is shown in Fig. 1. A special fluid is injected into the heater of the fog generator ③ by a syringe pump ② with a flow rate of 0.1 ml per minute to create fog particles of a few micro-meters in diameter. The fog is clean and not harmful for humans and the tested insects. Fresh air is mixed with the fog particles and driven by heat convection into the test chamber of 100×100×150 mm^3 ⑥ through a Ø75 mm aluminum pipe with a low flow speed that can be ignored in comparison to the fire ant wing beat induced flow velocity. The tested flying fire ant alate ⑨ is tethered on a fine metal wire (Ø0.3mm) and held at the test position in the fog chamber ⑥ by a 3-D traverse system ⑤. A pulsed beam from a Nd:YAG laser ④ is converted to a thin (≈0.5 mm) light sheet in the test region through a set of light sheet optics ⑦ that includes a cylindrical divergent lens, a mirror and a cylindrical condenser lens. The laser is controlled by a delay & pulse generator ① so that double laser pulses of 100 μs time interval are sent out at repeating rate of up to 30 Hz to illuminate the fog particles in the light sheet. A PCO 2000 camera ⑧ is synchronized to the laser pulses with the delay & pulse generator ① to acquire particle image recording pairs. The acquired particle image recording pairs are evaluated with a correlation-based central difference image correction method (CDIC) to determine instantaneous velocity vector maps.

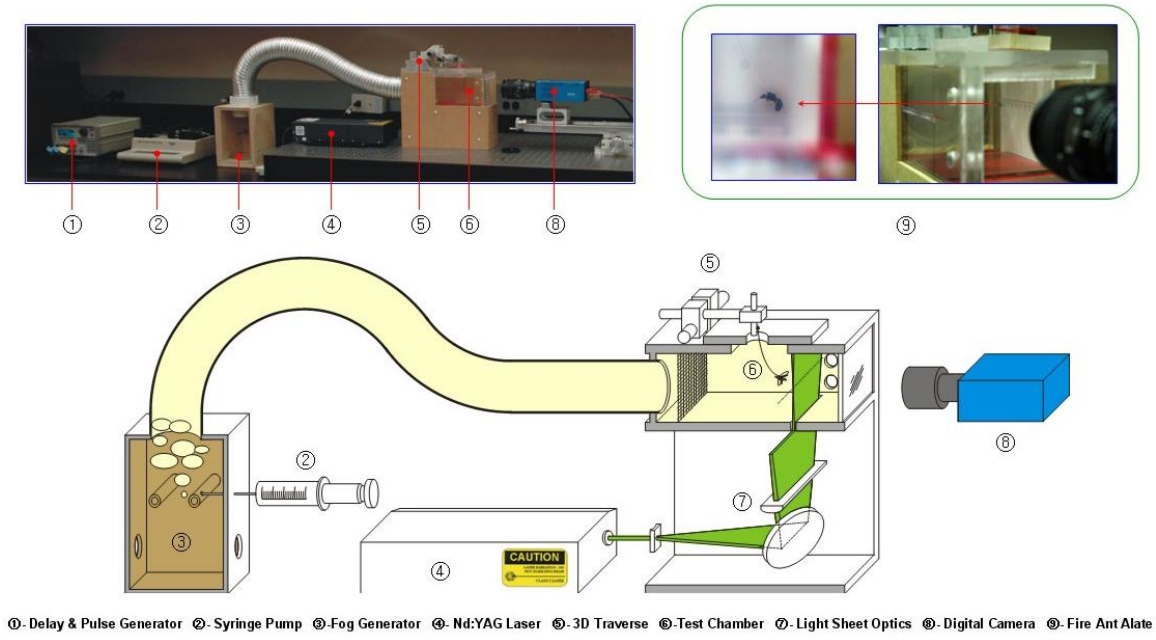

Figure 1: Experimental setup for measuring air flows induced by the fire ant wingbeat

Statistical analysis is applied to groups of instantaneous velocity vector maps to quantify the mean velocity distributions and velocity fluctuations, i.e. the normal and shear Reynolds stresses of the turbulent flows. To investigate the velocity, vorticity and turbulent value variations in a wingbeat period, a phase averaged analysis was conducted as follows: (1) Acquire more than 10,000 PIV recording pairs that include the fire ant images in the background; (2) Process images with high-pass filters and evaluate image pairs to determine flow velocity vector maps; (3) Process images with low-pass filters to enhance wing images for determining phase of each vector map; (5) Divide the vector maps into around 20 groups according to the phases; (4) Conduct statistical analysis for each phase group, i.e. of around 500 velocity vector maps. Tests results will be presented and discussed in the MEA annual meeting, October 25-26, 2007.