Reconstructing the vortex skeleton of the desert locust using phase averaged POD approximations from time resolved thin volume tomographic PIV

D. Michaelis¹*, R. Bomphrey², P. Henningsson³, D. Hollis⁴

1: LaVision GmbH, Göttingen, Germany
4: LaVision UK Ltd, Grove, U.K.

* correspondent author: dmichaelis@lavision.de

Keywords: Insect flight, tomographic PIV, proper orthogonal decomposition (POD)

Introduction

Previously, stacking of planar 2D 3C PIV measurements have been used to create a pseudo 3D image of insect and bird wakes. Assuming an ideal homogeneous transport of the flow features with the free stream velocity, vorticity vectors and flight efficiency had been estimated from the pseudo 3D vector fields, replacing spatial derivatives by time derivatives and accepting some level of uncertainty due to the violation of this assumption in real flow conditions. In this study tomographic PIV measurements allow the direct calculation of spatial derivatives leading to a more accurate evaluation of vortex structures. Tethered locusts appear to fly in a passive or active flight mode, where only the active flight mode resembles natural free flight conditions. Features extracted from velocity data allow an a posteriori classification of the flight mode. Limited laser power led to a relatively poor signal to noise ratio, requiring post processing to show the vortex structures more clearly. Proper orthogonal decomposition and phase averaging is used for noise reduction revealing structures in the reconstructed vortex skeleton that have been missed hitherto.

Experimental setup

Tomographic PIV measurements have been conducted in a low speed wind tunnel with a 0.5 x 0.5 x 1 m³ closed test section. Locusts are tethered just in front of the vertically and span-wise oriented measurement volume. A dual cavity Litron LDY 301 (10 mJ) laser and four cameras Photron SA-3 were used for particle image recording. Images were recorded in frame straddling mode: the cameras were recording at 2 kHz frame rate (0.5 ms frame separation). The time delay between two laser pulses was set to 100, in this way vector fields could be calculated with 1 ms time separation or at 1 kHz.

Proper Orthogonal Decomposition

Noise was very prominent in current velocity field results (fig. 2, left). Proper orthogonal decomposition (POD) and phase averaging were therefore applied as post processing filters. Periodic flow often can be represented by a low dimensional POD approximation. In the current experiments up to 75 % of the total energy was captured using only twenty from about 1300 spatial modes. Examining the higher modes from current results revealed a more and more noise like structure without any significant flow structure observable. Omitting all but the 20 strongest spatial modes is therefore a powerful noise reduction filter (fig. 2, right).

Fig. 2 Left: Raw velocity data, right: phase averaged POD approximation.

From this data a pseudo 3D volume is reconstructed by stacking the thin measurement volumes (fig. 3). Different from previous approaches using stereo PIV data, here, vertically aligned parts of the vortex tubes can be identified. These important structures are related to instants of strongest thrust generation.

Fig. 3 Reconstructed, pseudo 3D wake (isosurfaces of Q)