Experimental Study of Pollen Trajectories and Deposition on Pine Cones

N. Jacobson(*) and R. van Hout(**)
Faculty of Mechanical Engineering, Technion -IIT, Technion city, 32000, Israel
(*) - jacobson.netalee@gmail.com
(**) - rene@technion.ac.il

Biomimetics explores natural evolutionary designs, both to improve our understanding of nature as well as develop better engineering solutions. For example, conifers (*Pinus*) make use of wind pollination (*anemophily*) in their reproductive ecology and it has been suggested that pine cones modulate the ambient flow field to their advantage [1, 2, 3, 4]. Pine cone structural morphology would create vortical structures that result in increased entrainment probability for the pollen (male) cone and increased pollen capture efficiency for the ovulate (female) cone. However, no studies exist on pine pollen dispersal in the near vicinity of male cones and the only two existing studies on ovulate cone capture mechanisms have produced contradictory results, one favoring simple inertial impaction [5] while the other showed favorable flow patterns for pollen capture [1, 2, 3, 4].

Here, we experimentally study possible fine-tuning between the pine pollen and the cone’s morphology (Fig. 1). Measurements were conducted in a wind tunnel (Fig. 2a) using in-line, digital holographic cinematography in order to track 3D pollen trajectories around an ovulate cone. The holographic system (Fig. 2b) consisted of a high-speed laser (10 µJ @ 10 kHz, 527 nm, CrystaLaser), a neutral density (ND) filter, a spatial filter (10 µm pinhole and focusing lens), a collimating lens \( f = 200 \text{ mm} \) and a lensless high-speed camera (Photron Ultima APX, 1024x1024 pixels @ 2kHz). An ovulate cone (size range: 0.4-1 cm and height range: 0.8-1.5 cm) was mounted using a thin wire at 84 cm from the end of the inlet contraction and several types of pollen (size range: 45-100 µm) were dispersed using a vibrating sieve device (“salt and pepper” shaker) mounted on top of the wind tunnel ~70 cm upstream of the cone. The collimated laser beam passed the test section vertically as shown in Fig. 2b. Any objects present, cause diffraction (object beam) and a hologram is created by the interference of the object beam and the undiffracted reference beam at the camera’s sensor plane. The acquired holograms are digitally reconstructed at different planes using the convolution approach in order to retrieve information on the object’s position and shape (depending on spatial resolution). Experiments were performed at mean air velocities of 0.5 to 2.5 m/s and holograms were acquired at sampling rates of 1 kHz to 4 kHz. These high sampling rates allowed the 3D tracking of the pollen near to the female cones. The field of view was 17.4x17.4 mm at 1 kHz and half the image size at 4 kHz, both at a spatial resolution of 17 µm/pixel.

Results indicate both inertial deposition of pollen on the windward cone surface occurs as well as leeward deposition by the wake flow generated by the cone. The latter effect corresponds to the
expected response of the pine pollen that are characterized by Stokes numbers of order one. Here the Stokes number is defined as the ratio between the pollen response time, \( \tau_p \), and the flow time scale, \( \tau_f \): \( \text{St} = \frac{\tau_p}{\tau_f} \). Data processing of the holograms is ongoing. Furthermore, Particle Image Velocimetry (PIV) experiments are underway to characterize the flow field around the ovulate cones.

Fig. 1. Pine pollen and cone morphology (a) SEM image of pine pollen (Owens 1998) (b) Windward side of female cone after wind tunnel experiment, the bright dots on the cone surface are deposited pine pollen.

Fig. 2. Schematic of experimental layout. (a) Windtunnel setup (side view), (b) Holography setup (Cross section). Not to scale

References: