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PORTFOLIO

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Fluid structures generated from a low Reynolds number miniature radial fan

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Fluid structures generated by rotating blades have both fundamental and practical importance in many applications. Vortices generated through the abrupt discontinuity of a fan blade at the blade tip can inhibit fan performance characteristics [Yen and Lin 2006]. In miniature heat transfer applications, however, heat sink designs that conserve such fluid structures can be advantageous for increasing heat dissipation levels [Egan et al. 2009, Stafford et al. 2010]. Miniature radial fan designs have been shown to experience a scale effect due to viscous dominance at low Reynolds numbers [Walsh et al. 2009, Walsh et al. 2010]. As this

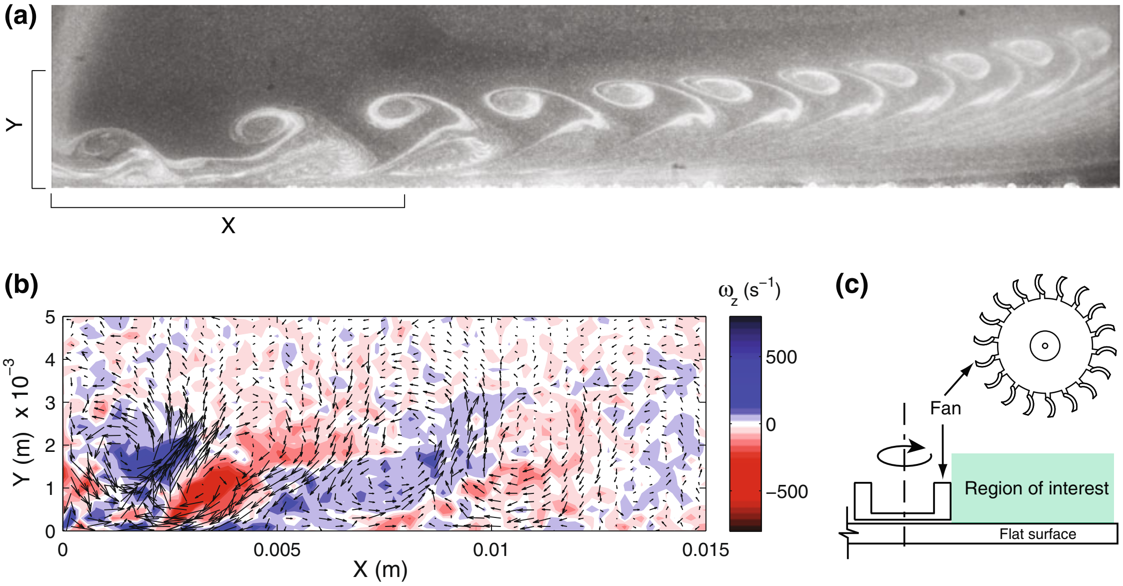

Fig. 1 Fluid structures (**a**) and vorticity (**b**) generated by a miniature radial fan operating at $Re = 115$. The experimental configuration is detailed in (**c**)

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effect results in much lower flow rates than anticipated through conventional scaling laws, the creation of vortex structures can be beneficial to promote fluid mixing and hence enhance heat transfer to a sufficient level at these scales. In this experiment, a 15 mm diameter fan (forward curved) with 4 mm blade height was rotated above a flat surface for a Reynolds number of 115, based on the blade tip velocity and chord length as characteristic length scale (Fig. 1). This experiment was conducted in a free environment without a volute, allowing air to exit radially in all directions. Flow visualization and particle image velocimetry (PIV) were used to investigate the fluid structures at the exit of the miniature radial fan. Seeding was introduced into the flow field, resulting in a Schmidt number of 2.78, using a Rosco fog generator. Images were acquired using an 11MP CCD camera, synchronized with a Nd:YAG laser to illuminate a two-dimensional field which was in-line with the fan axis of rotation. The maximum inter-frame pixel displacement was 0.25 of the 32×32 pixel interrogation regions. Out-of-plane motion inevitably limited the laser pulse separation time due to the 3D flow generated by radial fans. Uncertainty in the velocity field measurement of 1.9% was estimated [Forliti et al. 2000]. The flow visualization image in Fig. 1a shows vortex pairs, generated by the rotating miniature fan blades, traveling in the radial direction. A time-average of 1,000 velocity vector maps has been subtracted from an instantaneous vector field for Fig. 1a to produce a vorticity profile of the near exit region, shown in Fig. 1b. This region is defined in Fig. 1a by X and Y. Figure 1b highlights the counter rotational nature of these vortices upon exiting the fan blades. The clockwise vortices in Fig. 1a are stretched by the mean radial flow and consequently diffuse into the boundary layer over the flat surface. The vorticity profile indicates that both the clockwise and counterclockwise vortices diffuse rapidly over the 15 mm interval shown in Fig. 1b. Indeed, examination of the velocity field for $X > 15$ mm confirms that these large scale vortical structures are no longer discernible by $X = 25$ mm. The counterclockwise vortices shown in Fig. 1a are less affected by the mean radial flow, unlike the clockwise vortices. Therefore, the counterclockwise vorticity diffuses prior to the diffusion of the tracer patterns in Fig. 1a, which continue to move in the direction of the mean flow. This can be attributed to both the Reynolds number and the Schmidt number of the tracer in air.

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