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Vortex Generation to Model the Airflow Downstream of a Piezoelectric Fan Array

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Abstract : Numerical methods are used to generate vortices in a domain. Through considered design, two counter-rotating vortices may interact and effectively drive one another downstream. This phenomenon is comparable to the vortex interaction that occurs in a region immediately downstream from two counter-oscillating piezoelectric (PE) fan blades. PE fans are small blades clamped at one end and driven to oscillate at their first natural frequency by an extremely low powered actuator. In operation, the high oscillation amplitude and frequency generate sufficient blade tip speed through the surrounding air to create downstream air flow. PE fans are considered an ideal solution for low power hot spot cooling in a range of small electronic devices, but a single blade does not typically induce enough air flow to be considered a direct alternative to conventional air movers, such as axial fans. The development of face-to-face PE fan arrays containing multiple blades oscillating in counter-phase to one another is essential for expanding the range of potential PE fan applications regarding the cooling of power electronics. Even in an unoptimised state, these arrays are capable of moving air volumes comparable to axial fans with less than 50% of the power demand. Replicating the airflow generated by face-to-face PE fan arrays without including the actual blades in the model reduces the process's computational demands and enhances the rate of innovation and development in the field. Vortices are generated at a defined inlet using a time-dependent velocity profile function, which pulsates the inlet air velocity magnitude. This induces vortex generation in the considered domain, and these vortices are shown to separate and propagate downstream in a regular manner. The generation and propagation of a single vortex are compared to an equivalent vortex generated from a PE fan blade in a previous experimental investigation. Vortex separation is found to be accurately replicated in the present numerical model. Additionally, the downstream trajectory of the vortices' centres vary by just 10.5%, and size and strength of the vortices differ by a maximum of 10.6%. Through non-dimensionalisation, the numerical method is shown to be valid for PE fan blades with differing parameters to the specific case investigated. The thorough validation methods presented verify that the numerical model may be used to replicate vortex formation from an oscillating PE fans blade. An investigation is carried out to evaluate the effects of varying the distance between two PE fan blade, pitch. At small pitch, the vorticity in the domain is maximised, along with turbulence in the near vicinity of the inlet zones. It is proposed that face-to-face PE fan arrays, oscillating in counter-phase, should have a minimal pitch to optimally cool nearby heat sources. On the other hand, downstream airflow is maximised at a larger pitch, where the vortices can fully form and effectively drive one another downstream. As such, this should be implemented when bulk airflow generation is the desired result.

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