Fin designs of TEFC motor: heat dissipation enhancement

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Abstract

Literature on the study of fins for heat transfer enhancement mainly focused on the low speed airflow for small electronic devices. For heat removal from large devices such as TEFC motors, studies were limited. In this work, several fin designs based on the dimensions of the TECO TEFC motor were attempted and studied numerically in use of the commercial software ANSYS. The simulation system consists of flat-plate fins periodically mounted on the frame and a wind shield; Fig.1 shows one period of the system. Cold air of 298K at speed U_{in}=20m/s is directed into the flow channels between fins to cool the hot area maintained at 333K of the frame, which has an area of $L \times P$. The remaining part of the frame is insulated. The RNG k-ε model was used, in conjunction with the standard wall function, to capture the turbulent effect. A 3D hybrid mesh composed of structured as well as unstructured grids was employed for spatial discretization. No-slip boundary conditions were imposed at all solid walls.

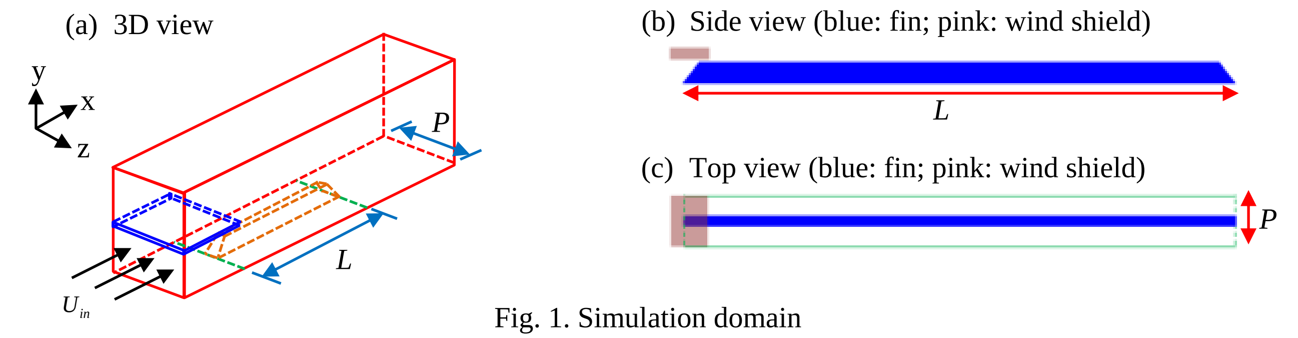

Fig. 1. Simulation domain

Five types of fin designs were attempted and shown in Fig. 2. Fins of types I – IV are modified based on ideas which can be easily found from literature. In the design of type V, we make no change in the fin but elongate the wind shield. From Table 1, it is found that only designs of type III and type V are capable of enhancing heat dissipation. This is because the flow leakage is suppressed particularly in the design of type V and consequently the heat transfer is enhanced. All the other commonly used mechanisms for heat transfer enhancement fail for the high speed airflow applications.

<u>Types I & II: Perforated and staggered fins</u>

Designs of types I & II aim at turbulence intensification, which is favorable for convection heat transfer. Yet, simulation results reveal that the performance is not improved. In the design of type I, recirculation regions are formed within the pores/slots and cold air can not effectively flow through them, not to mention that the total contact area of fins with fluid decreases due to the perforation. For the design of type II, surprisingly big recirculation regions are created behind the upstream fins. They dramatically block lateral heat transfer from the fins to the cooling air. To eliminate these recirculation regions, the fin period must be enlarged which however results in less fins that can be mounted on limited space.

<u>Type III: Fins with increasing fin height</u>

With the tilted fin crest, the design of Type III successfully reduces the hot spot temperature. Herein, the fin height at the beginning is as the same as that in the original design (Type I and II); it increases linearly with downstream distance. At the expense of fin mass, this design provides larger fluid-solid contact area and yields a larger total heat dissipation rate. As far as the heat dissipation rate per unit fin volume is considered, this design is not superior to the original design nonetheless.

Type IV: Wavy fins

Targets of Type IV design are turbulence intensification as well as a larger solid-fluid contact area. However, simulation results show that none of them is achieved but instead the flow leakage phenomenon is deteriorated, leading to a substantial decrease of heat dissipation.

Type V: The elongated wind shield

The design of Type V makes no change in the fins but simply elongate the wind shield for the sake of suppressing the flow leakage. Since the flow rate is well maintained, Type V is easily justified for heat dissipation enhancement. An optimum length is found as also shown in Fig.2 which gives a maximum total heat dissipation rate. Yet, due to the added shield mass, such enhancement may be related to a higher cost for manufacturing.

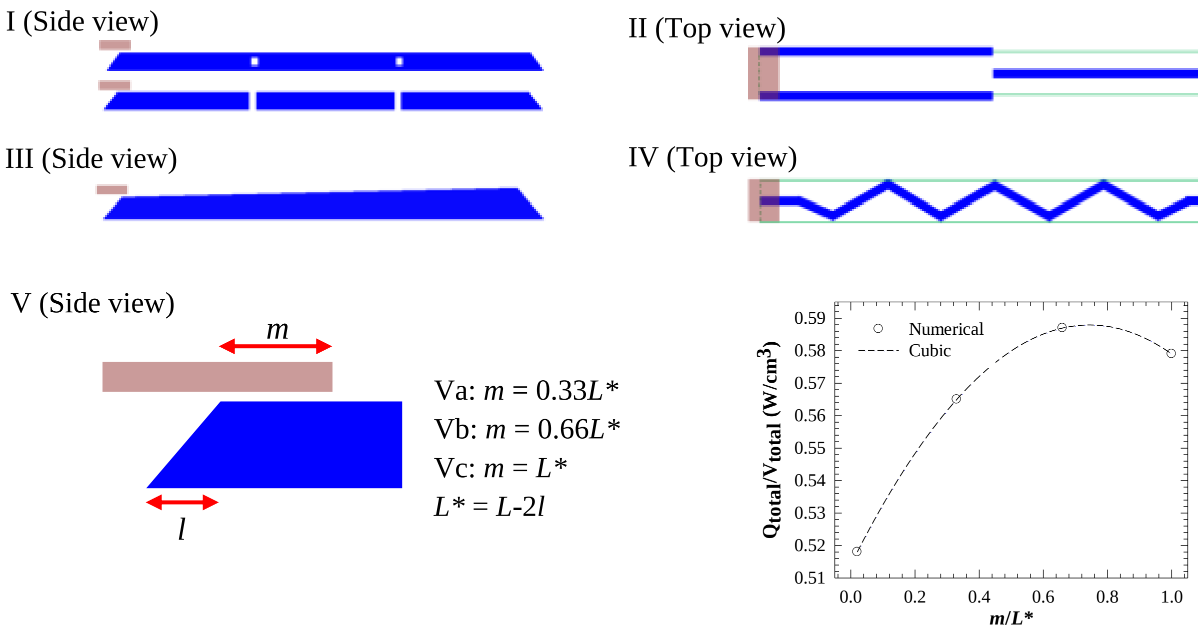

Fig. 2. Fin designs of Types I – V

Type	original	I (pores)	I (slots)	II	III	IV	Va	Vb	Vc
Q_{total} (W)	395.2	394.8	389	332.7	421.6	346.4	449.1	487.4	500.5
Q_{total}/V_{total} (W/cm^3)	0.518	0.520	0.520	0.424	0.449	0.449	0.565	0.587	0.579

Table 1 Simulation results of various fin designs

Keywords：Fin design; Heat dissipation enhancement; Flow leakage