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Heat transfer characteristics in wake region of a single finned obstacle

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ABSTRACT

The development of the electronic components is limited due to the maximum allowable chip operating temperature. Therefore, the heat transfer from a heated plate placed behind unfinned and finned obstacle in a rectangular duct is investigated numerically using ANSYS Fluent 14.0. In the current study, unfinned and finned obstacle are used, in order to test the effect of fin size and number of fins on heat transfer from the heated plate. In addition, two different heated plate positions (horizontal and vertical) are studied. During the study the effect of separation between the obstacle and the plate are studied at Reynolds number ranges from 3000 to 9000 and dimensionless separation number, P, ranging from 1.92 to 9.78. The average Nusselt number is used as a key parameter to evaluate the heat transfer characteristics. The numerical solutions obtained reveal how an increased number of fins in obstacle leads to reduction in heat transfer from a heated plate in the wake flow region.

1. Introduction

The reliability of electronic components is significantly depending on maintaining the temperatures of the components within operational limits. Accordingly, the appropriate cooling processes have to be performed for these components that may be placed on a board in a group of several components with different quantities of generating heat. Most of these components are different shapes, generally rectangular and in different size that cause wake flow [1]. As a result, the cooling process becomes complicated due to irregular flow field formed due to non-organized positions of electronic components. This indicates why the cooling of electronic components is crucial and critical. Enhancement convective heat transfer can be achieved using active and passive methods. Active methods, which provide better enhancement, require additional external forces and/or equipment which can increase the complexity, capital and operating costs of the system. While passive heat transfer enhancement can be achieved by changing flow geometry, surface modification and adapting thermophysical properties of the working fluid [2].

The complexity of flow characteristics around complicated geometries leads to difficulties for a purely analytical approach. However, experimental and numerical methods are available and give promising results. Understanding the fluid flow and heat transfer characteristics around these complicated geometries has been a subject of interest due to the important practical applications such as cooling of electronic components. As a result, extensive investigation and understanding of turbulence, vortices formation, boundary layers, as well as the impact of turbulent flow structures on heat transfer and pressure drop have been performed. According to the previous experimental and numerical investigation, the flow characteristics around obstacles act as turbulence promoters and improve the downstream heat transfer coefficient, while pressure drop increased [3]. A brief literature survey presentation is performed in this paper.

Kuo et al. [4] investigated experimentally the wake flow pattern and the modified pattern using small control cylinders at low Reynolds number. They showed that how these two small cylinders modify the wake flow domain with respect to Reynolds numbers. The significant delay of the vortex formation was attributed to the fluctuating lift. Whereas in 2008, a hot wire anemometry was used by Shadaram et al. [5] to study experimentally the turbulence characteristics of the near wake flow behind a rectangular cylinder for cylinder having various aspect ratios (width to height ratios). The results indicated a decreased turbulence intensity in the wake flow as the aspect ratio increases.

The effect of obstacle shape at varies orientation angles of the plate were extensively investigated experimentally by Sarac et al. [1]. In this study three types of the obstacles were investigated rectangular, triangular and circular cross sectioned in order to study the effect of obstacle shape on the characteristics of heat transfer from the test plate at plate orientation angles of 0°, +45°, 90° and −45° for Reynolds number ranged from 2700 to 13000 and flow blockage ratio of 9.33%, 18.66% and 28%. Based on the results of Sarac et al. results, variations in the Nusselt number through the flow direction are obtained due to the plate orientation angles and the unstable wake generation behind the obstacles. But, in general it was reported that the obstacle shape and size

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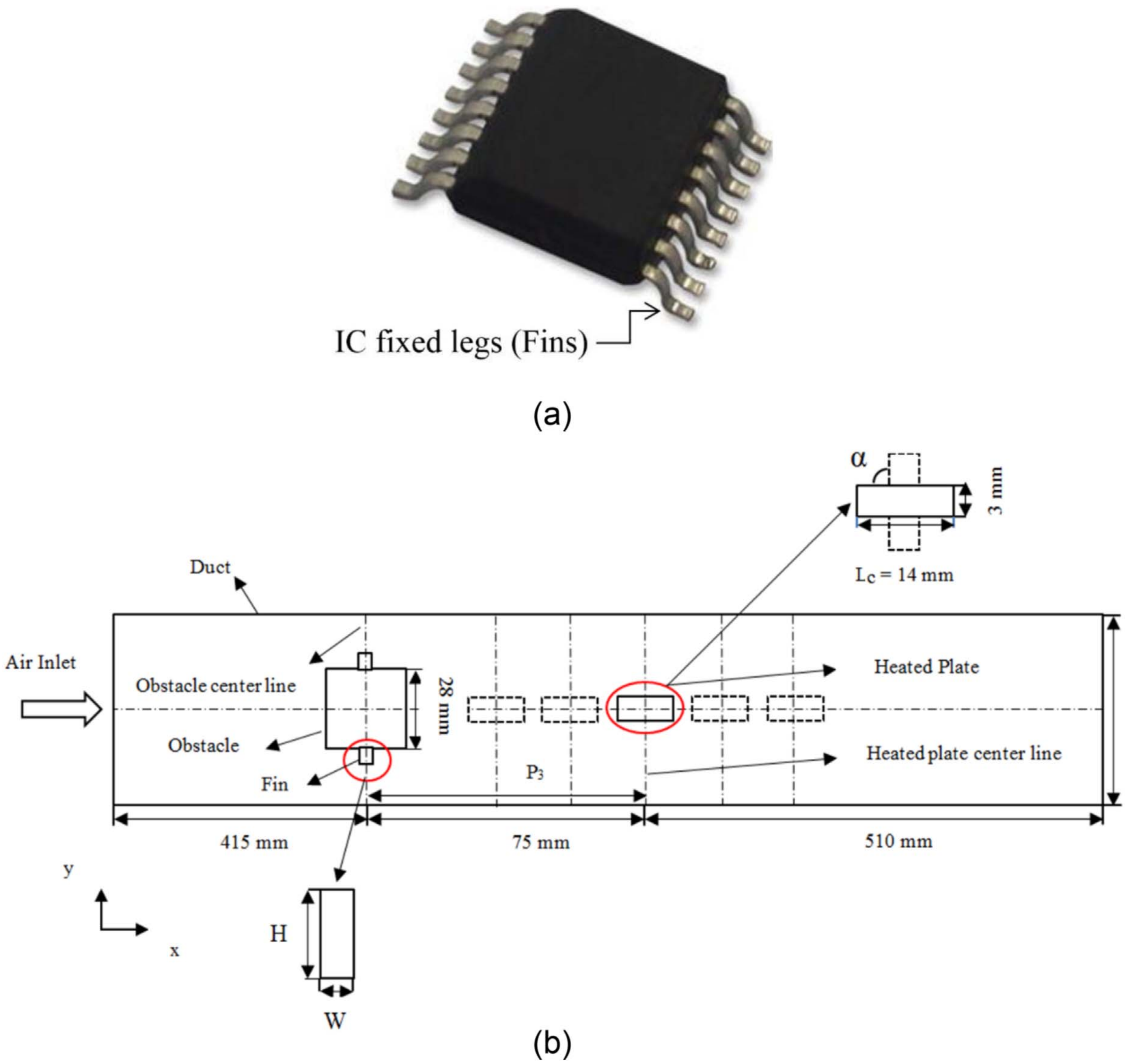

Fig. 1. (a) Electronic component and (b) schematic of the flow domain geometry and dimensions.

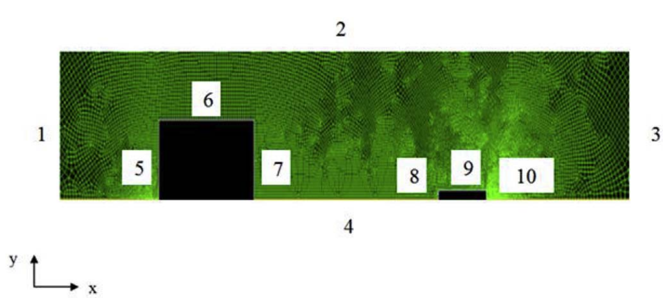

Fig. 2. Discretized flow domain.

Table 1
Number of cells and boundary condition for each edge in the used model.

Surface	Number of Cells			Boundary condition
	Mesh 1	Mesh 2	Mesh 3	
1	50	75	100	Velocity inlet
2	200	400	600	Wall, adiabatic
3	50	75	100	Pressure outlet
4	304	458	600	Symmetry line
5, 7	14	28	42	No slip, constant wall temperature
6	28	42	56	No slip, constant wall temperature
8, 10	3	6	9	No slip, constant wall temperature
9	14	28	42	No slip, constant wall temperature

and plate orientation angle significantly affect the heat transfer from the plate in the wake flow region.

According to the experimental results obtained by Sarac et al. [1], a significant variation takes place due to the complexity of flow field. As a result numerical studies is considered as a powerful tool to explore the behavior of flow and its effect on the heat transfer characteristics.

Oztop et al. [6] investigated numerically 2D steady forced convection in laminar flow ($400 \leq Re \leq 1300$) to explore the effect of a triangular cross sectional bar on the heat transfer augmentation and flow characteristics over three blocks attached on channel bottom wall. The control element was located at different vertical positions "y" from the blocks and the results obtained were compared for no control element case. It was found that insertion of control element enhanced the heat transfer for all Reynolds number and the best heat transfer was obtained for the position with $y = 3.5$.

Togun et al. [7] studied numerically the heat transfer and turbulent flow over double forward facing steps. Different step heights, Reynolds number ranged from 30,000 to 100,000 and temperature ranged from 313 to 343 k are the key parameters in this study. It was found that the