Thermal analysis of a wet and porous moving trapezoidal fin subject to stretching and shrinking

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ABSTRACT

We consider heat transfer with convection and radiation effect on a fully wet and porous longitudinal fin. The trapezoidal fin moving at a constant speed is subject to stretching and shrinking, and their influence on the thermal profile of the fin and the heat transfer rate is investigated. The governing equation of the model mentioned above is nondimensionalized, and the resultant second-order nonlinear differential equation is solved numerically using the Chebyshev collocation method (CCM) and validated using the shooting technique. The impact of the critical dimensionless parameters on the thermal profile of the fin, the fin base heat transfer rate, and the fin tip temperature are analyzed graphically. Fin efficiency is also computed, and the influence of the pertinent parameters on it is inferred. A shrinking fin favors a faster heat transfer at the base of the moving fin, and a stretching fin enhances the thermal profile and fin efficiency. The Peclet number improves the thermal profile and fin efficiency; this variation is maximum for a stretching fin.

1. INTRODUCTION

The heat transfer rate from a surface by convection and radiation processes is proportional to the surface area, the heat transfer coefficient, and the temperature gradient between the surface and the ambient fluid. The latter being fixed, the surface area is to be increased artificially to maximize the heat transfer. These extended surfaces, called fins, aim to enhance the heat transfer from the surface into the ambient fluid. Fins are used in various day-to-day applications ranging from automobiles, heat exchangers in the industries, refrigerators, electric and electronic components, etc., to achieve a faster heat exchange and thus enhance the systems' performance. Owing to its larger practical applications, the extended surface technology continues to attract researchers for the evolving needs.

2. PHYSICAL DESCRIPTION OF THE MODEL

A moving longitudinal fin of the trapezoidal profile of length L and width W, depicted in figure 1, is considered. It is mounted on a primary surface at a temperature T_b and is fully wetted in a fluid at a temperature T_a. Either the fin is considered to be moving with a uniform velocity U along the horizontal axis, or the ambient fluid flows with the said uniform velocity along the stationary fin. The heat entering the fin at the base is lost to the ambiance by convection and radiation from both the longitudinal fin's top and bottom surfaces, which are wet and porous. The heat transfer within the fin is one-dimensional. The fin is in thermal equilibrium with the ambient fluid. The fin is further subjected to stretching and shrinking along its length or the velocity direction.

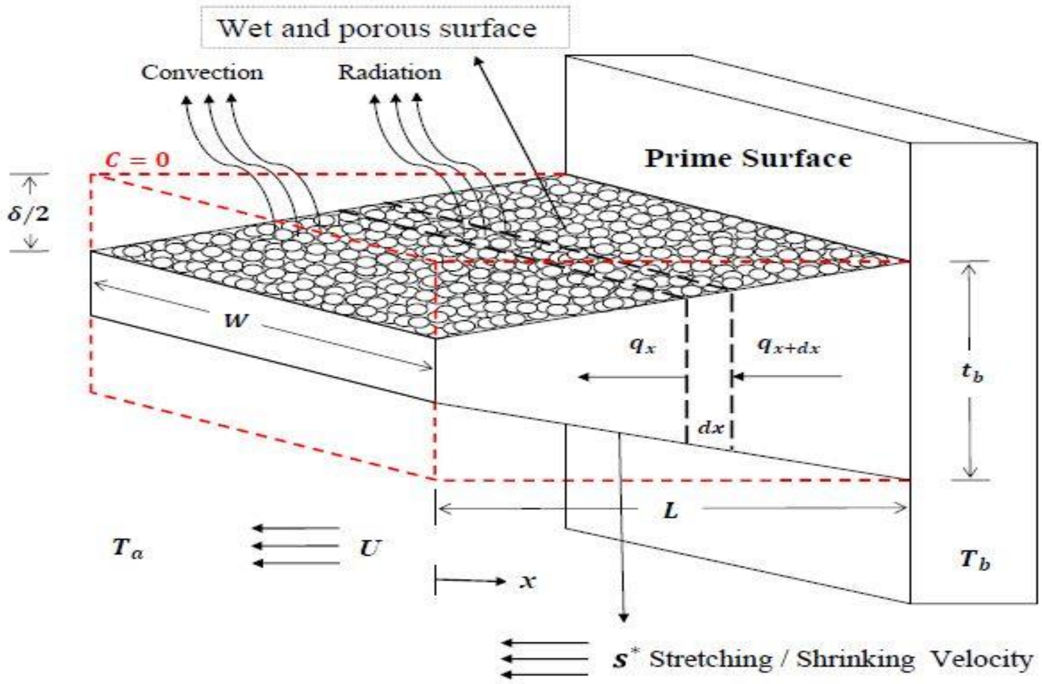

Fig 1 Longitudinal fin of trapezoidal profile

3. SOLUTION METHODOLOGY

The basic energy balance equation describing the physical model is nondimensionalized, and the resultant ordinary differential equation, which is a nonlinear boundary value problem, is solved numerically by CCM and further validated by the shooting technique combining the Runge-Kutta fourth order method and the secant algorithm. For a limiting case, the fin tip temperature is verified by comparing them with the differential transform method result in the literature.

4. IMPORTANT FINDINGS

The thermal profile and the fin efficiency are the least for a shrinking fin and the maximum for a stretching fin. The base heat transfer rate is maximum for a shrinking fin, and hence, it can be utilized for a faster heat transfer from the primary surface when there is a pile-up of heat energy. The thermal profile drops and the base heat transfer rate increases with an increase in the convective, radiative, wet, and porous parameters. This is owing to the enhanced transfer of heat through convection and radiation to the ambiance, resulting in a lower fin temperature, and a more significant wet and porous parameter indicates a larger surface area, which assists the heat transfer to the ambiance, thus resulting in a lower thermal profile. The fin efficiency drops with an increase in these parameters. The Peclet number Pe, indicating the fluid velocity, enhances the thermal profile and the fin efficiency while reducing the base heat transfer rate, and this can be attributed to faster circulation of warmer ambient fluid from the immediate neighborhood of the fin, making way for a much cooler ambient fluid. In contrast, the heat transfer at the base is opposite to the fluid flow, resulting in a reduced heat transfer rate. The variation in the thermal profile, the base heat transfer rate, and the fin efficiency with Pe is the maximum for a stretching fin. Thus, the stretching and shrinking mechanism of the fin can be utilized conveniently for optimum heat transfer management.