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Second law analysis of free convection film condensation on an inclined porous elliptical tube

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ABSTRACT

This paper aims to investigate the entropy generation analysis for the free convection film condensation on an inclined porous elliptical tube. An analytical approach to study the effects of various working parameters, including Rayleigh, Darcy, Brinkman numbers and tilt angles on the entropy generation rate is performed. Although dimensionless heat-transfer coefficient is enhanced with an increase in tilt angles and Rayleigh group parameters, entropy generation number is augmented. Two main irreversible factors-finite-temperature difference heat transfer and condensate film flow friction associated with porous permeability affecting the total entropy generation rate are investigated.

1. Introduction

Condensation of vapor in porous media occurs in various fields of engineering applications, such as waste energy/heat recovery using heat pipes, extraction geothermal energy in reservoirs, nuclear waste disposal and porous insulation. Cheng [1] first investigated the problem of steady film condensation outside a cone embedded in porous media filled with a dry saturated vapor. He employed a two zone model which assumed the condensate and vapor separated by distinct interface. More recently, Chang and Yeh [2] theoretically investigated the problem of steady filmwise condensation flow over the external surface of a horizontal elliptical tube embedded in porous media with suction at the tube surface. Their theoretical results presented that the heat-transfer performance can be enhanced by applying a suction effect at the wall. All above studies focused on the heat-transfer performance; however, entropy generation in thermal engineering systems may destroy system available energy and reduces its efficiency. Hence, the entropy generation rate for the film condensation problem is of great concern and needs to be investigated.

Bejan [3] pioneered to study the entropy generation for the convection processes through fluid saturated porous media and free convection heat transfer due to temperature gradient and viscosity effect in a fluid. Bejan [4] also presented various reasons behind entropy generation in applied thermal engineering where the generation of entropy destroys the available work, called exergy, of a system. Furthermore, entropy generation due to free convection from an isothermal cylinder was presented by Abu-Hijleh et al. [5], who proved that the entropy generation is mostly due to conduction while the contribution of viscous dissipation is negligible. Further, they firstly found that total entropy generation increases with an increase in Rayleigh number, and secondly that total entropy generation will decrease if radius of the cylinder is increased as well. Dung and Yang [6] investigated the entropy generation of free convection film condensation on a circular tube, and found that heat-transfer coefficient and the entropy have a direct relationship such that the generation number can be reduced by decreasing Br/Θ. Makinde and Osalusi [7] investigated entropy generation in a liquid film falling along an inclined porous heated plate. The velocity and temperature profiles were obtained and used to compute the entropy generation number and irreversibility ratio for several values of suction Reynolds number and group parameter (Br/Θ).

Regarding the theoretical approach to film condensation on the porous media wall, Cheng [1] assumed the following models: (a) the condensate and the vapor are separated by a distinct boundary with no two phase zone in between; (b) the condensate has constant properties; and (c) condensate film is thin. Thus such boundary layer approximation is applicable. The first assumption was also employed by Parmentier [8] to study the problem of film boiling in porous media. It is noted that owing to the first

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