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Thermal radiation effects on the flow and heat transfer in a liquid film on an unsteady stretching sheet

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SUMMARY

The influence of thermal radiation on the flow and heat transfer within Newtonian liquid film over an unsteady stretching sheet with and without thermocapillarity is examined. The governing non-linear partial differential equations describing the problem are reduced to a system of nonlinear ordinary differential equations using similarity transformation, which is solved numerically for different values of the thermal radiation parameter and the thermocapillarity parameter. The results show that the dimensionless velocity, the film thickness and the local Nusselt number increase as the thermocapillarity parameter increases, while the free surface temperature decreases with increasing the thermocapillarity parameter. Also, both the dimensionless temperature and the free surface temperature increase and the local Nusselt number decreases as the thermal radiation parameter increases. Copyright © 2010 John Wiley & Sons, Ltd.

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KEY WORDS: unsteady stretching sheet; Newtonian fluid; liquid film; similarity solution; thermal radiation; thermocapillarity

1. INTRODUCTION

In recent years the study of flow and heat transfer within a thin liquid film has received considerable attention due to its many theoretical and technical applications in the engineering and technology fields. Examples of these applications include wire and fiber coating, reactor fluidization, polymer processing, food stuff processing, transpiration cooling, etc. Wang [1] first considered the hydrodynamics of a thin liquid film on an unsteady stretching sheet and pointed out that the solutions exist only when the unsteadiness parameter $0 \leqslant S \leqslant 2$. Also, he found that the solution approached the analytical solution obtained by Crane [2] when $S \longrightarrow 0$ with infinitely thick layer of fluid, i.e. $\beta \longrightarrow \infty$ and the limiting solution corresponding $S \longrightarrow 2$ represents a liquid film with infinitesimal thickness, i.e. $\beta \longrightarrow 0$. Usha and Sridharan [3] studied a similar problem of axisymmetric flow of a liquid film. The momentum and heat transfer in a laminar liquid film on an unsteady stretching sheet studied numerically by Andersson *et al.* [4] and analytically by Wang [5] uses series solution by means of the HAM. Dandapat *et al.* [6] extended the hydrodynamic problem considered by Andersson *et al.* [4] to a general case where the effect of thermocapillarity is considered. Later Dandapat *et al.* [7] have studied the effects of variable fluid properties on a liquid film on an unsteady stretching surface in the presence of thermocapillarity. Hayat *et al.* [8] studied the thin film flow problem for a third grade fluid on an inclined plane. The flow and heat transfer problem of a second-grade fluid film over an unsteady stretching sheet is investigated by Hayat *et al.* [9].

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