Numerical Investigation of Thermo-Hydraulic Characteristics for a Visco-Plastic Fluid within a Partially Porous Wavy Channel under LTNE Condition

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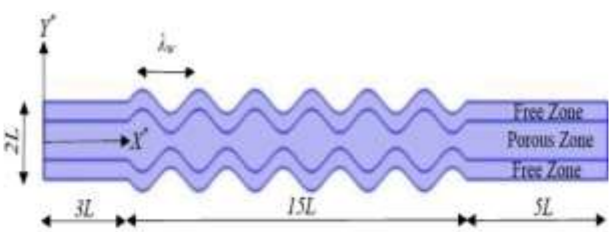
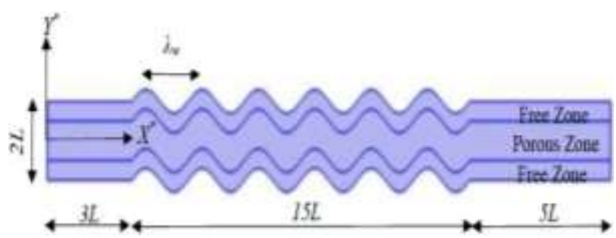
1. INTRODUCTION & OBJECTIVE

Heat transfer augmentation from any type of maco or micro level heat generating objects gains a subject of interest in recent past for its wide range of engineering applications. The active mode of heat transfer enhancement is a primitive technology which required sufficient amount of driving or pumping power which inturns decreses the overall performance of the device. Whereas, the passive mode of heat transfer augmentation overcomes the decrement of overall performance by decreasing the required driving power. Among the various available methods of passive heat transfer augmentation, the use of corrugated channels and presence of partially saturated porous media have been proven one of the emerging techniques. In this regards, the primal numerical study was carried out by Wang and Chen [1]. They have showed that the presence of wall corrugation changes the hydrodynamic boundary layer and disrupt the formation of entrance length by developing the recirculation zone between two corrugated parts. Bhowmick et al. [2]. Aabidy et al. [3] showed that the thermo-hydraulic characteristic within a partially porous corrugated channel is altered by the porous layer thichness and porosity of the porous medium. The effect of magneto-hydrodynamic flow within a partially saturated porous cavity was investigated by Selimefendigil et al. [4]. The alteration of Hartman number along with Darcy number influences the flow characteristics and entropy generation. The effect of various Non-Newtonian flow within any heat exchanger devices attracts the modern researcher regarding its vast applications in petroleum industries. In this regard a comparative study was carried out by Dey et al. [5] within a raccoon and serpentine channel. They concluded that amplitude, wavelength of the wall corrugation along with viscoplastic flow characteristics number influenced the flow as well as thermal characteriscs.



(a)



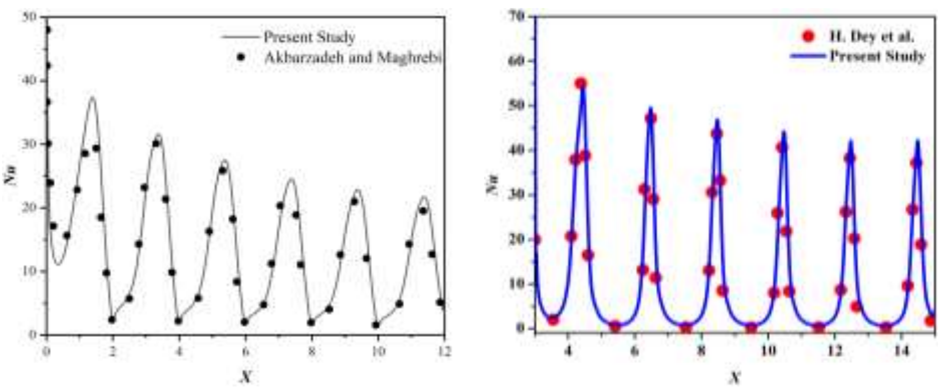
(b)

Figure 1: Schematic domain of (a) Raccoon and (b) Serpentine channels.

Although a significant number of numerical and experimental research work has been carried out on the domain of hydro-thermal characteristics within different types corrugated channels and porous media but the combied influenced of wall corrugation and addition of porous substrate for a Non-Newtonian fluid have not been studied so far. In the present numerica study, an effort has been made to investigate the thermo-hydraulic characteristics within a raccoon and serpentine channel, partially saturated with porous medium under local thermal non-equilibrium condition for a laminar viscoplastic fluid. The schematic of the adopted problem has been shown in Figure 1.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The results has been discussed in form of streamline distribution and variation of average Nusselt number for Bingham number (*Bn*) = 0.01, 0.1, 1, 10 and 100; flow behavior index (*n*) = 0.5, 0.8 and 1; Darcy number (*Da*) = 10^{-1}, 10^{-2} and 10^{-3}; LTNE parameter (γ) = 0.1, 10 and 100; wall amplitude (α) = 0.1, 0.2, 0.3 and 0.4; corrugated wall wavelength (λ_w) = 3, 6 and 9 for Reynolds number (*Re*) = 400 and Prandlt number (*Pr*) = 7.



(a) (b)

Figure 2: Validation study: (a) Comparision of local Nusselt number with the results of Akbarzadeh and Magherbi for *Da* = 10^{-3}. (b) Comparision of local Nusselt number with the results of Dey et al. for *Re* = 300, *Bn* = 100, *n* = 0.8, α = 0.3 and λ_w = 6

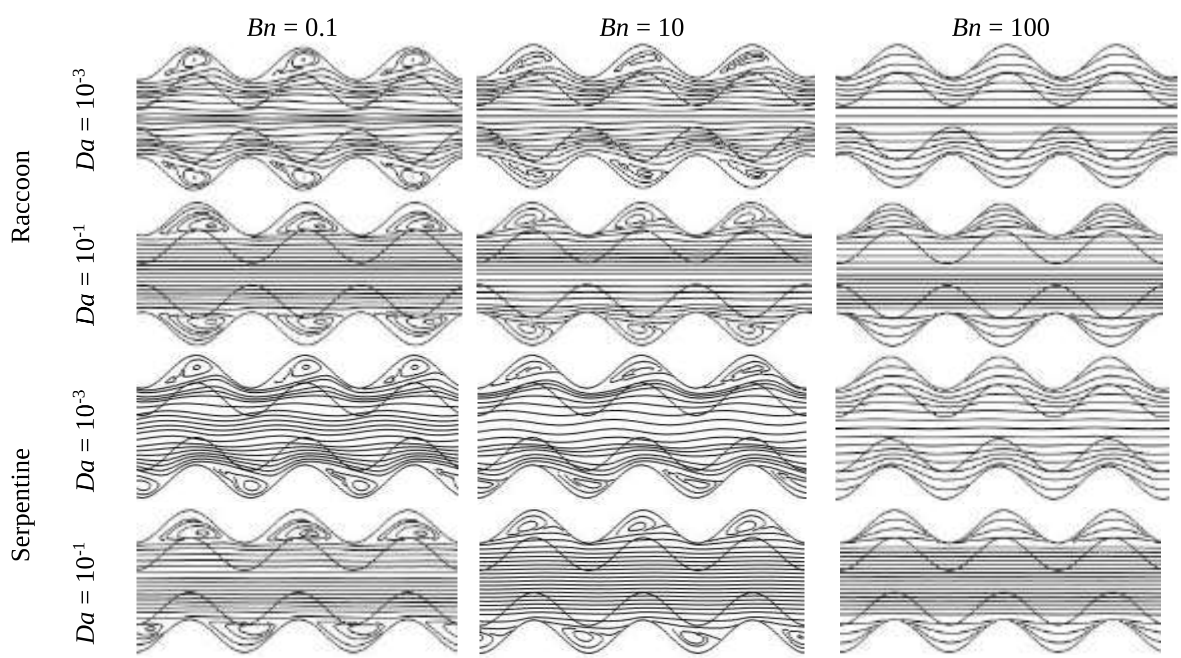
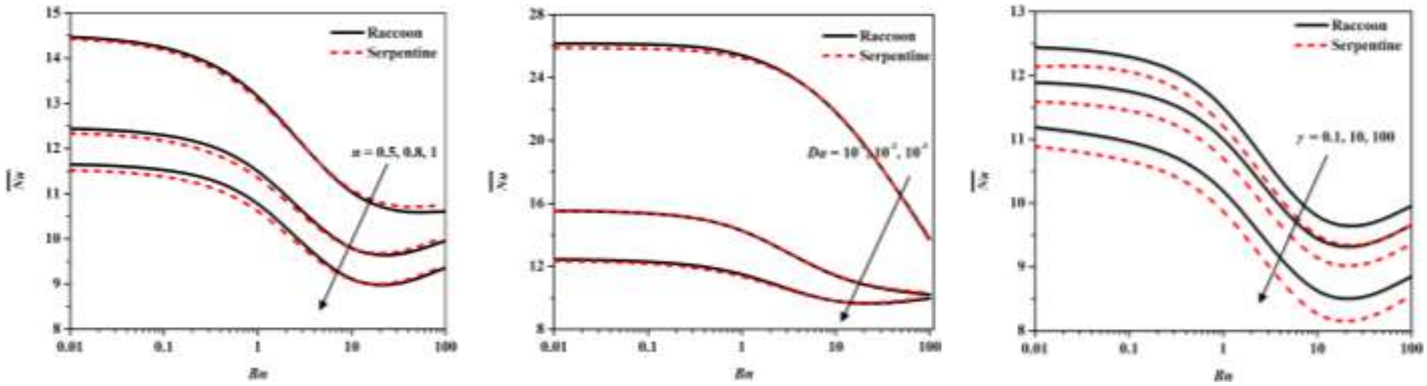


Figure 3: Streamlines for serpentine and racoon channels for various Bringham number for α = 0.3, λ_w = 6 and γ = 0.1

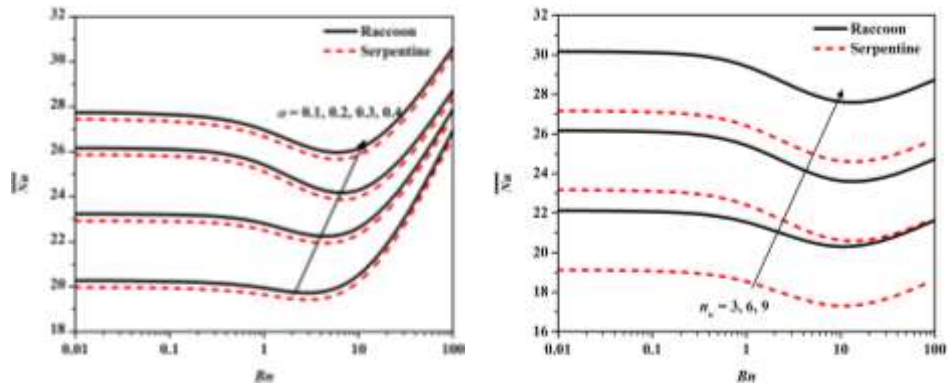
- The presence of wall corrugation regulates the recirculation zone at lower *Bn* number.
- Lower *Da* number increses the effective heat transfer area, irrespective of *Bn*.
- Moreover, the LTNE parameter plays a key role in heat transfer augmentation.

- A higher value of α and λ_w , regulates the flow circulation in positive way which inturn affects the heat transfer rate.



(a) (b) (c)

Figure 4: Variation of average Nusselt number $(\overline{Nu})$ with *Bn* within a raccoon and serpentine channel for (a) different values of *n* (b) different values of *Da* and (c) different values of γ for α = 0.3 and λ_w = 6



(a) (b)

Figure 5: Variation of average Nusselt number $(\overline{Nu})$ with *Bn* within a raccoon and serpentine channel for (a) fifferent wall amplitude and (b) different wavelength for *Da* = 10^{-3}, *n* = 0.8 and γ = 0.1.

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