Laminar Forced Convection Heat Transfer from Two Heated Square Cylinders in a Bingham Plastic Fluid

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Introduction: The momentum and heat transfer characteristics of two heated cylinders of square cross-section immersed in a streaming bingham plastic medium have been studied.

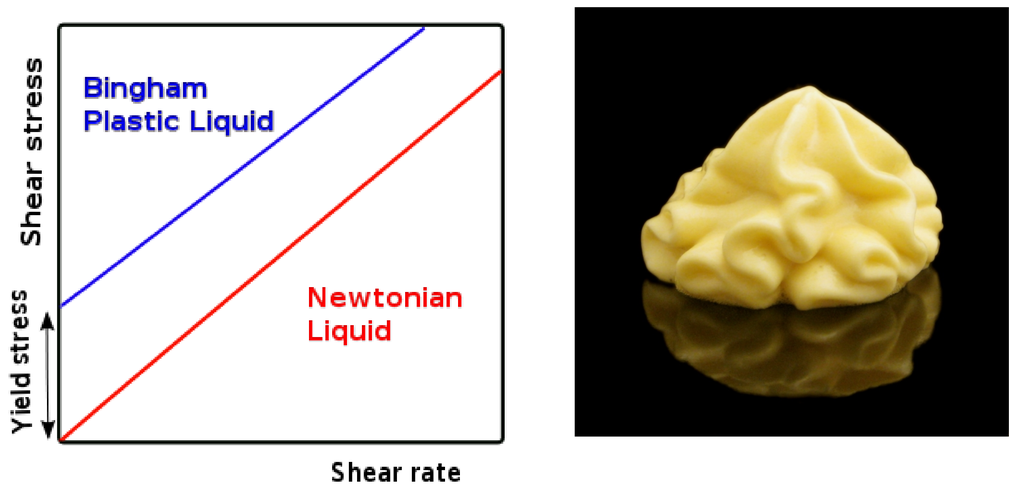
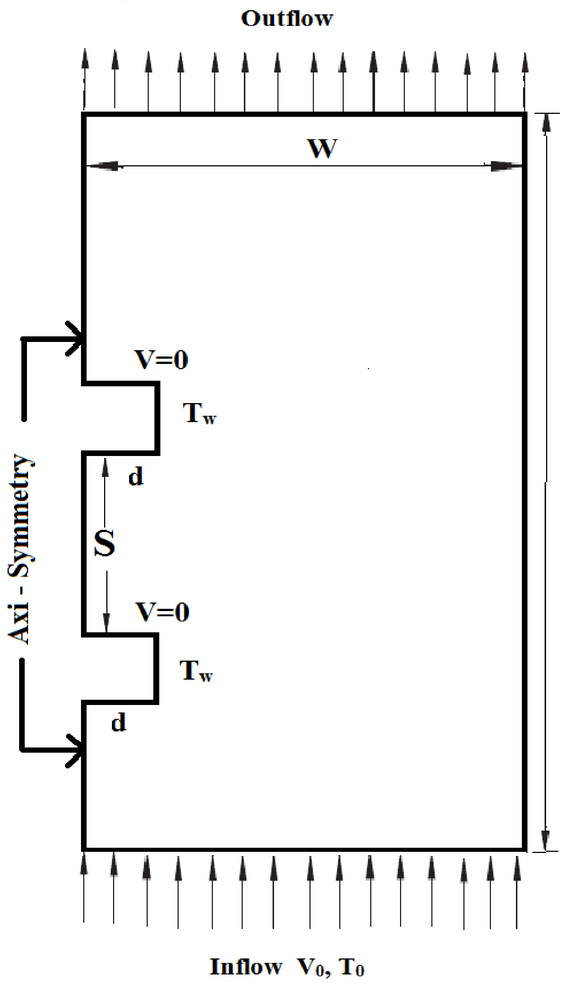


Figure 1. Bingham plastic fluid.

Computational Domain and Governing Equations:



Continuity equation:

$$\nabla \cdot V = 0$$

Momentum equation:

$$V \cdot \nabla V = -\nabla p + \frac{1}{Re} \nabla \cdot \tau$$

Thermal energy equation:

$$V.\nabla\theta = \frac{1}{RePr} \nabla^2 \theta$$

Figure 2. Schematics of flow and of computational domain.

It is worth noting that in Bingham fluid flows, as the viscosity varies throughout the flow, an effective viscosity expressed as might be more representative of the viscous stress within the flow than the constant plastic viscosity μ_B. The range of conditions used are $0.1 \le Re \le 40$, $1 \le Pr \le 100$, $0 \le Bn \le 10$.

$$Bn^* = \frac{Bn}{Bn+1}, \qquad Re^* = \frac{Re}{Bn+1}, \qquad Pr^* = \Pr(Bn+1)$$

Results: The local Nusselt number (Nu_L) shows a positive dependence on Reynolds number (Re), Prandtl number (Pr) and Bingham number (Bn).

Pr=1 Pr=100

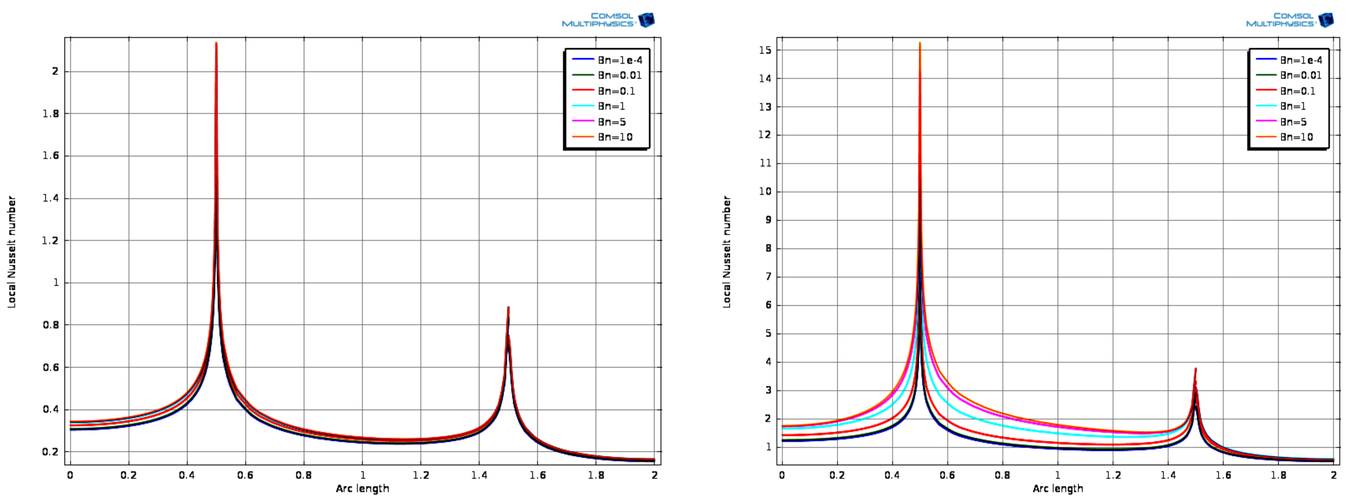


Figure 3. Variation of Local Nusselt number along the surface of the lower cylinder at Re=0.1

Pr=1 Pr=100

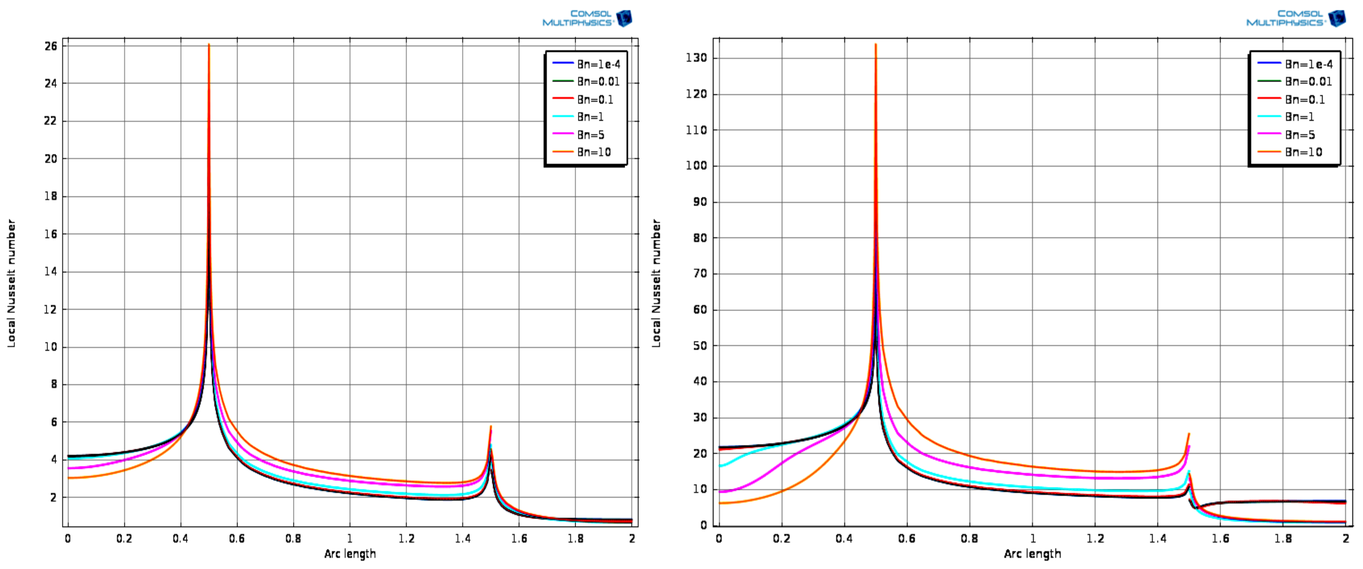


Figure 4. Variation of Local Nusselt number along the surface of the lower cylinder at Re=40

Conclusions: The laminar forced convection heat transfer of a Bingham plastic fluid past two 2-D square cylinders has been studied numerically using the finite element method. The analysis of the present results suggests that the use of an effective viscosity leads to reconciliation of Nusselt number results over wide ranges of Bingham number.

References:

1. N. Nirmalkar, R.P. Chhabra, R.J. Poole, Laminar forced convection heat transfer from a heated square cylinder in a Bingham plastic fluid, Int. J. Heat and Mass Transfer 56. (2013) 625-639