EXPERIMENTAL AND NUMERICAL STUDY OF MARANGONI – NATURAL CONVECTION IN SHALLOW LIQUID LAYERS

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Introduction

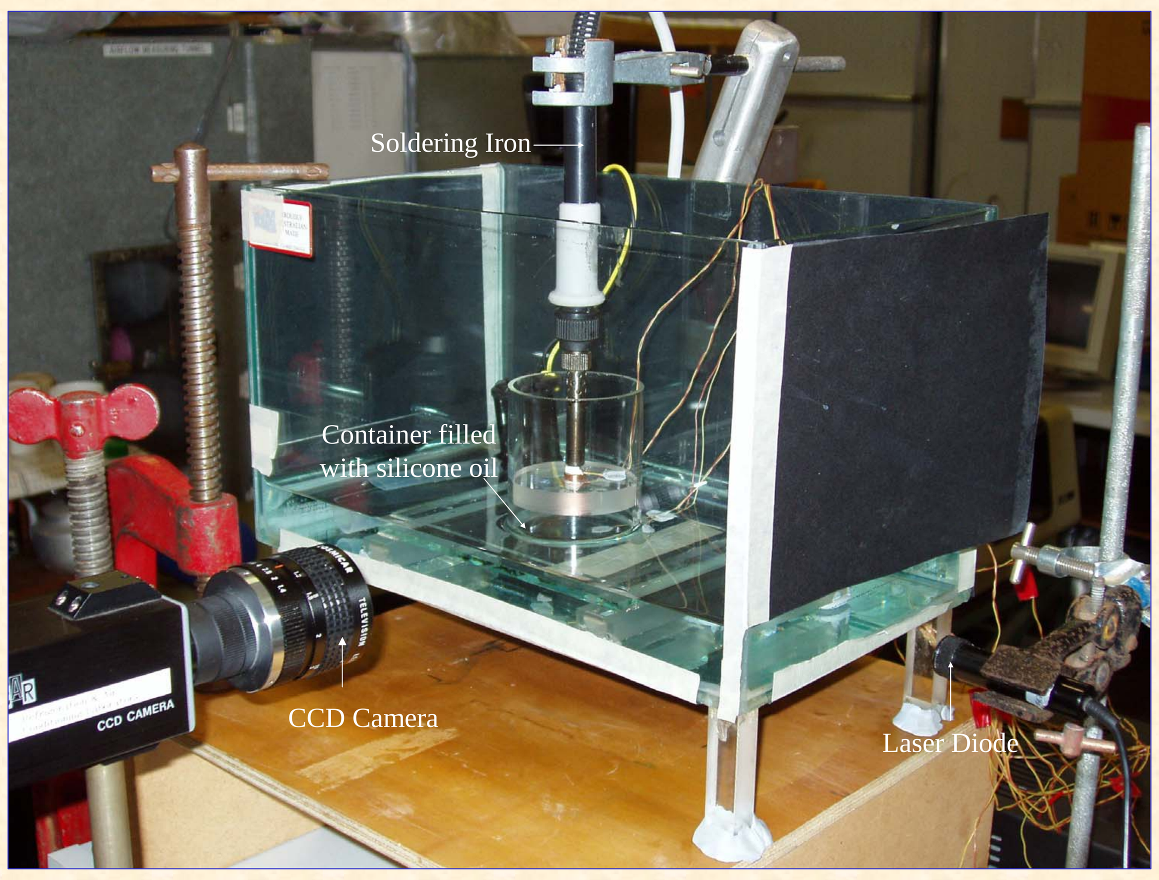
An experimental and numerical study of thermal Marangoni – natural convection in shallow liquid layers was carried out. The shallow layers enable surface tension forces to dominate over buoyancy under normal gravity conditions.

Particle Image Velocimetry (PIV) was used to obtain steady state flow patterns and velocity vectors to compare with numerical predictions using FLUENT V6.

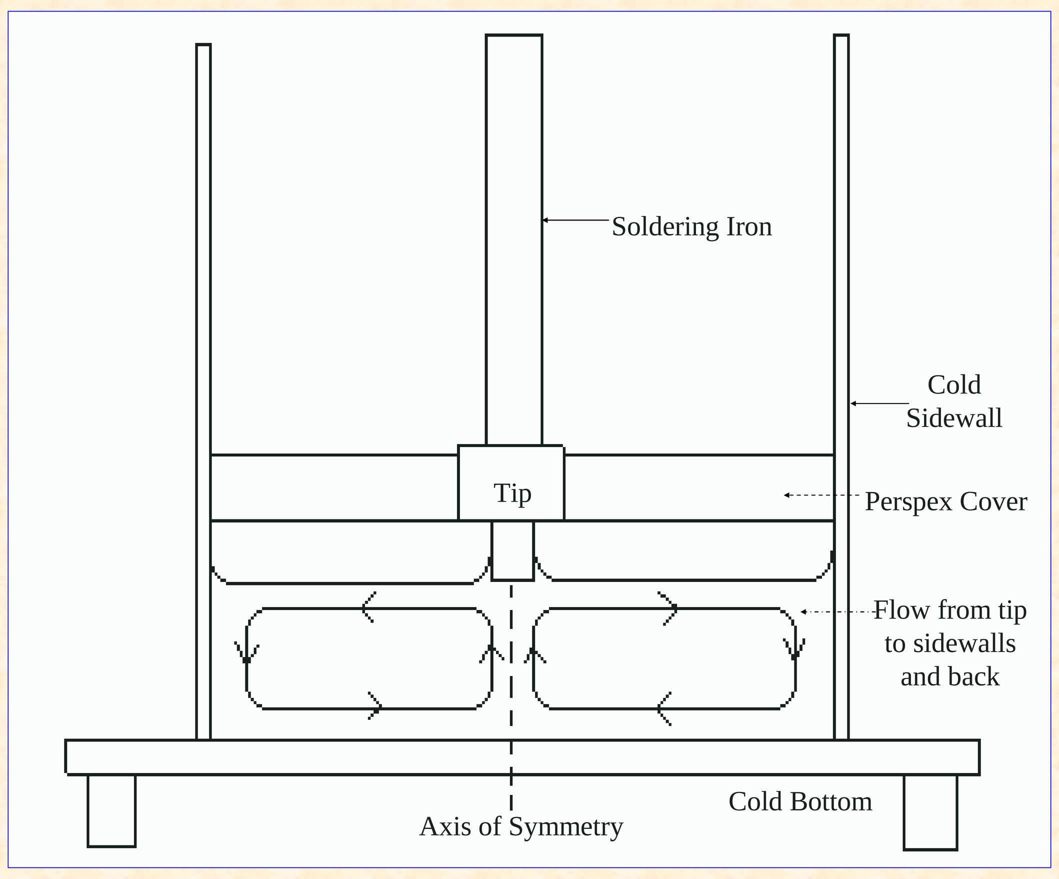
Assumptions

- Newtonian, incompressible fluid with constant physical properties
- Axisymmetric flow with the Boussinesq approximation
- Free surface is undeformable and surface tension is a linear function of temperature

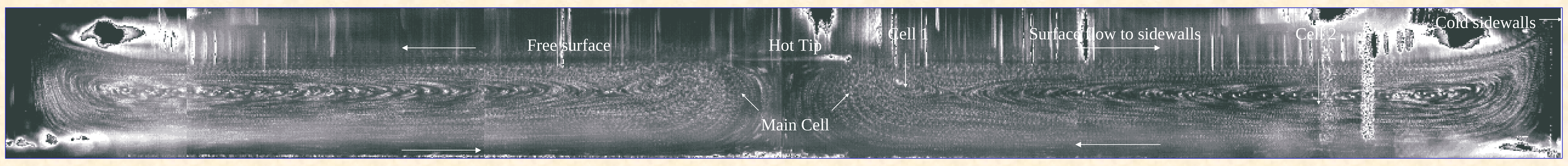
Experimental Setup



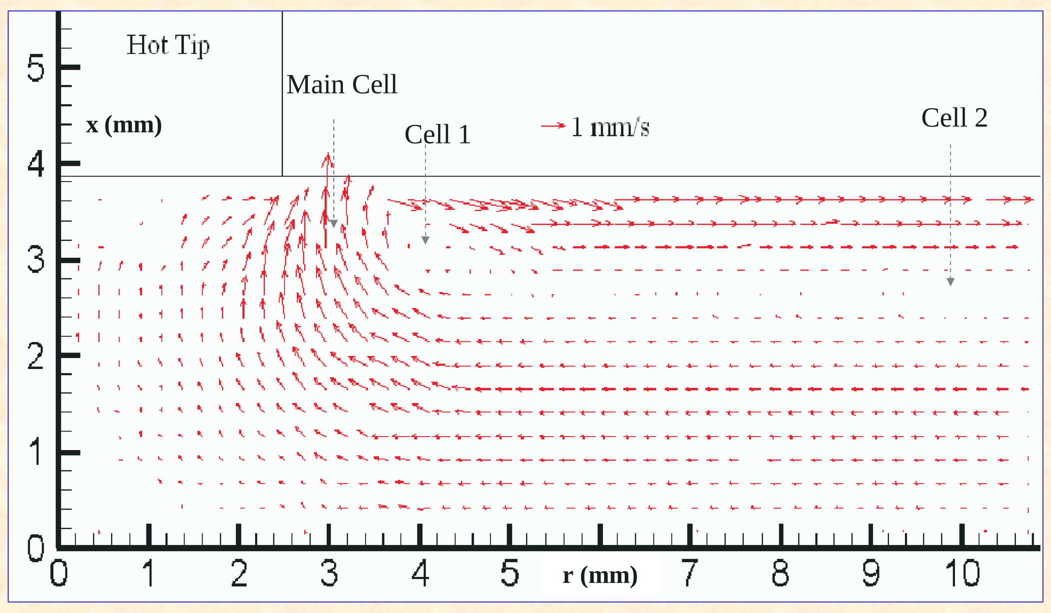
Basic Flow Schematic



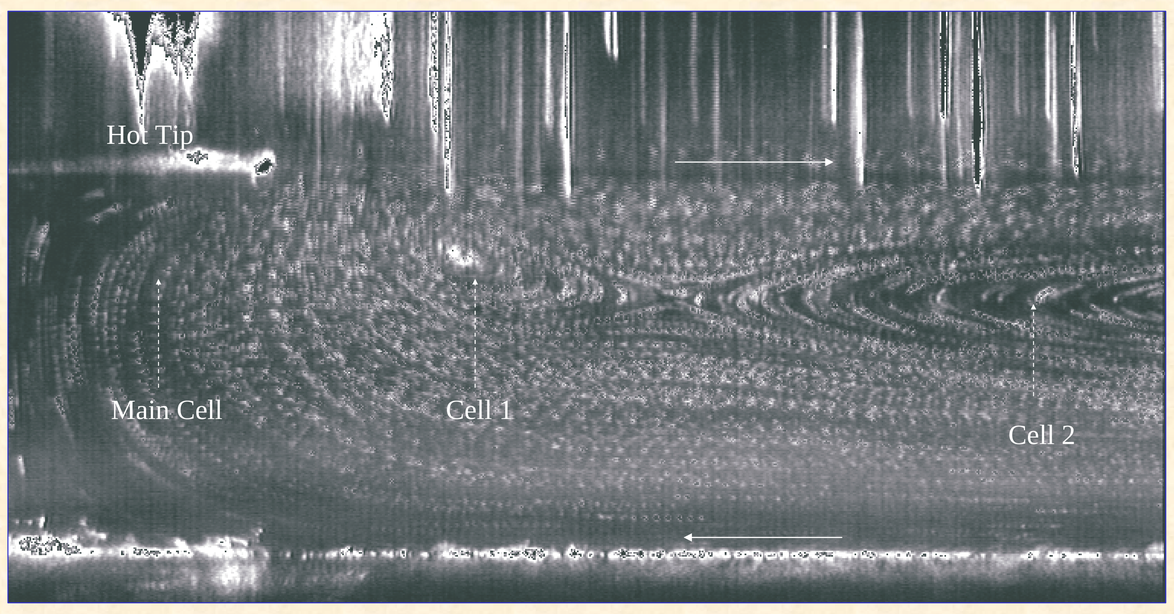
Flow Patterns



(a)



(b)



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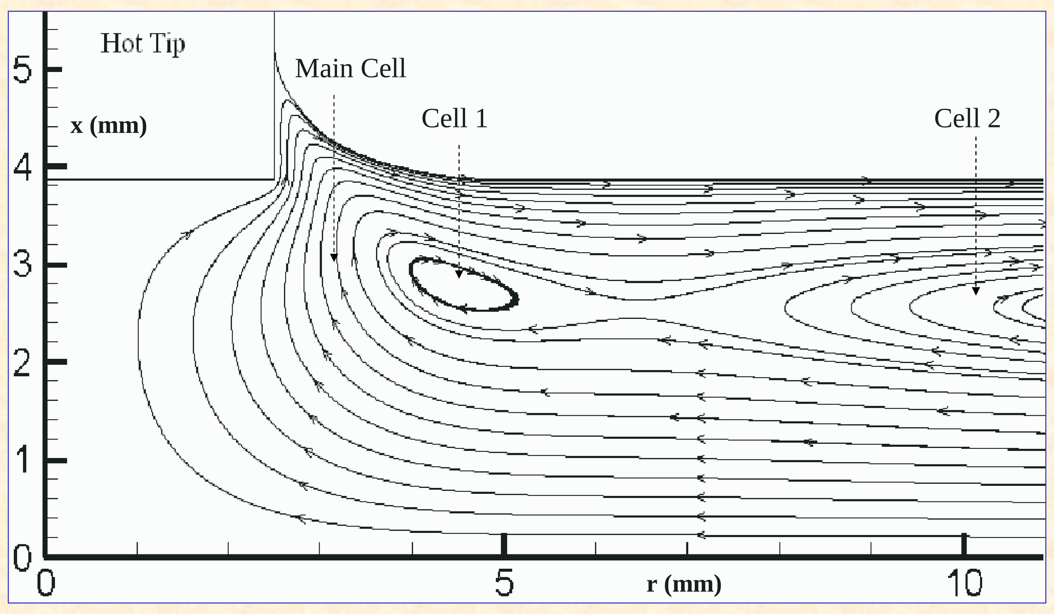
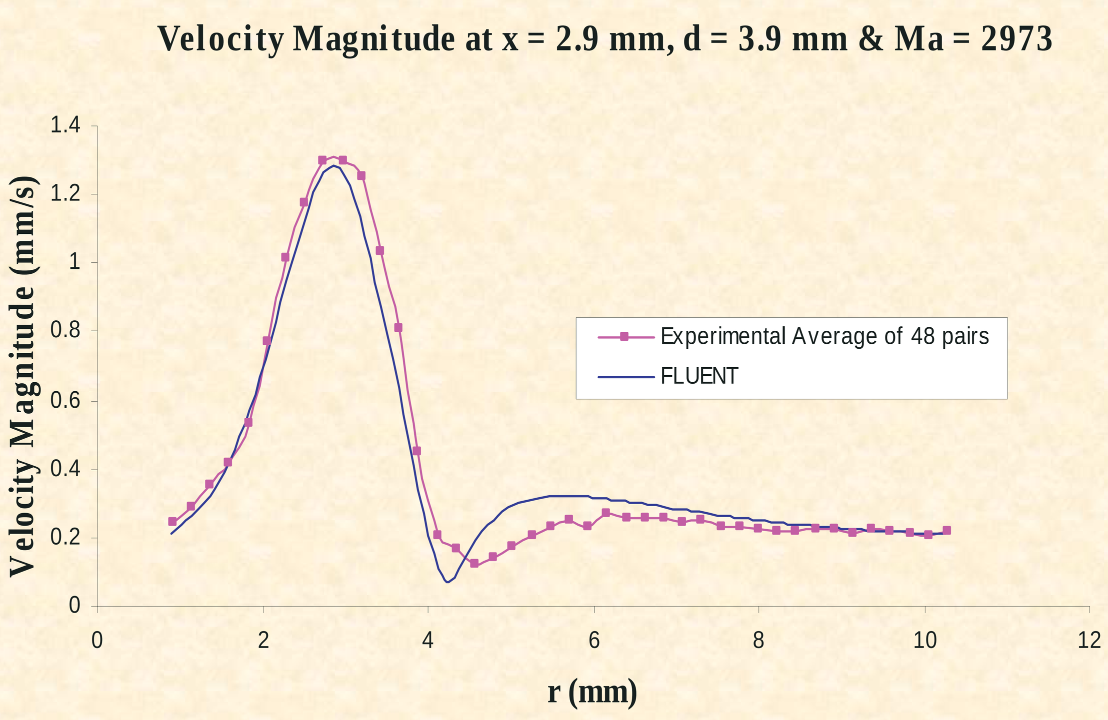
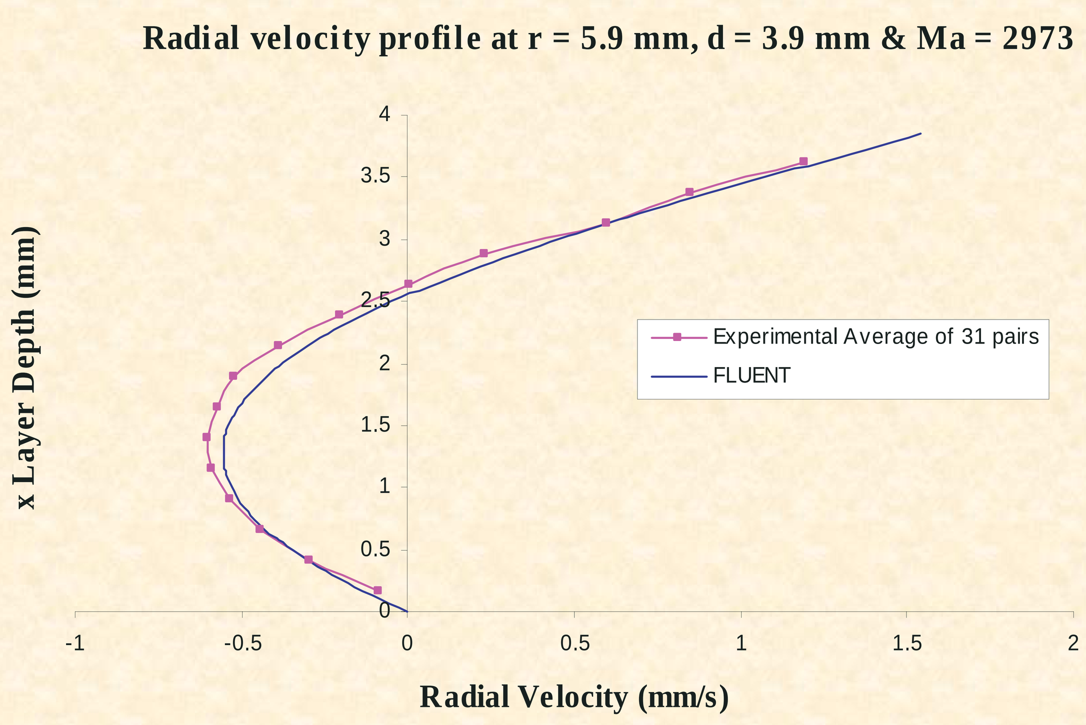


(d)

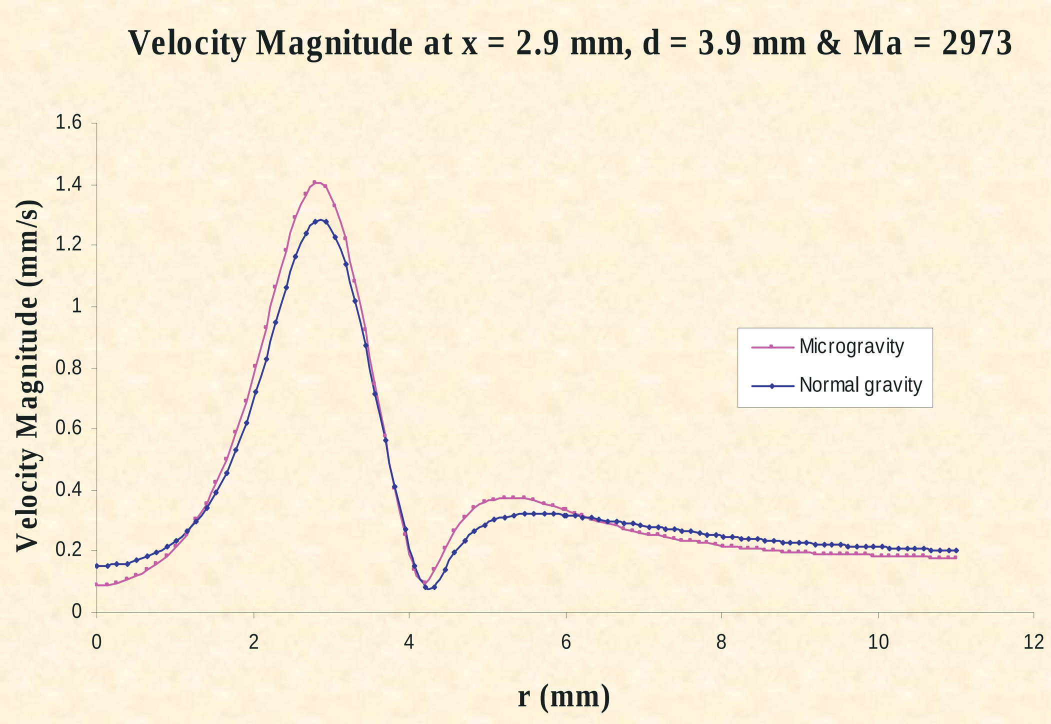
Results for layer depth d = 3.9 mm and *Ma* = 2973: (a) Flow patterns, (b) PIV vector field (pair of images), (c) Close-up of streamlines and (d) FLUENT results



(e)



(f)



(g)

Results for layer depth d = 3.9 mm and *Ma* = 2973: (e) Experimental and FLUENT velocity magnitudes at *x* = 2.9 mm , (f) Experimental and FLUENT radial velocity profiles across layer depth at *r* = 5.9 mm, and (g) FLUENT velocity magnitudes at x = 2.9 mm under normal and microgravity

Conclusions

- Good agreement is obtained between experimental and numerical results
- The modelling of the liquid meniscus at the heating tip is crucial for good quantitative validation of the numerical model
- The layer depths used for the experiment were proven to be shallow enough for Marangoni convection to dominate over buoyancy under normal gravity