# UNIVERSITI TEKNOLOGI MARA

# MARANGONI CONVECTION IN A HORIZONTAL LIQUID LAYER WITH INSOLUBLE SURFACTANT

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# ABSTRACT

Thermocapillary (Marangoni) convection either steady or oscillatory is known to cause imperfection in the quality of products. The dynamics of the convective motion in a thin fluid layer and the gradients of the surface tension can be significantly altered by the presence of insoluble surfactant, internal heat generation and the application of a feedback thermal controller. In this study, linearly dependent surface tension gradient on temperature and surfactant concentration with the effects of thermal feedback control and internal heat generation are considered to examine the instability of the steady Marangoni convection. The objectives of this study are to analyze theoretically the effect of heat generation and feedback control on Marangoni convection in a horizontal liquid layer with insoluble surfactant. The layer is bounded from below by a rigid heat-conducting plate and above by a free surface. The linear stability theory of the system is performed to undertake a detail investigation. The critical Marangoni numbers for condition of uniform heat flux revealed lower values in contrast to uniform temperature condition. The system with uniform temperature condition is more stable than the condition of uniform heat flux. Small controller gains are able to stabilize the system but large controller gain becomes a destabilizing factor. Internal heat source destabilizes the system and insoluble surfactant of low concentration has a stabilizing effect. The ability to control by either delaying or advancing the onset of instability can lead to better material processes and achieve optimum outcomes.

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# CHAPTER ONE
# INTRODUCTION

## 1.1 BACKGROUND OF STUDY

Convective motion in a liquid layer is mainly driven by surface tension gradients and buoyancy effects. The buoyancy effects are due to density differences because of gravity while the surface tension gradients are generated by temperature or chemical concentration at an interface. The convective motion that occurs because of the surface tension gradients due to temperature differences is known as thermocapillary convection.

Buoyancy-driven convection is influenced by gravitational forces. When a layer of fluid is heated, assume that a disturbance due to temperature nonuniformities creates local hot spot at the surface. The fluid closer to the hot spot expands and experiences upwards buoyancy effects due to density variation in the presence of gravitational field. Buoyancy forces overcome the viscous forces and drive the fluid motion in which the hotter fluid rises. By conservation of mass, the underneath neighbouring fluid also rises to fill the void. The rising hot fluid cools down at the free surface, becomes denser and falls. In a very thin layer of fluid or in microgravity, thermocapillary is dominant.

Thermocapillary and buoyancy effects are the two main physical mechanisms that give rise to convection. To describe the convection due to surface tension gradients, consider a layer of liquid bounded below by solid heated wall and cooled from above as shown in Figure 1.1. The upper surface is free and in contact with a gas phase. Assume that there is a hot spot at the interface between liquid and gas phase created by disturbances due to temperature nonuniformities. The surface tension decreases with temperature and the temperature differences along the interface induce shear stresses. A net surface traction at the surface causes liquid flows from hot region (low surface tension) to cold region (high surface tension). The hot rising liquid from the lower layer moves to the upper layer and flows away from the hot region to the cold region. The void is then filled by the liquid from below due to the continuity. Convection caused by surface tension gradients due to temperature differences is known as thermocapillary convection or Bénard-Marangoni (BM) convection.