Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

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Concept of forced and free convection

- Course: Heat and Mass Transfer (DI05019071)
- Unit 2: Convection
- Lecture 17: Forced and Free Convection

Lecture Agenda

- 1. Recap of Convection Basics
- 2. What is Forced Convection?
- 3. Mechanisms and Examples of Forced Convection
- 4. What is Free (Natural) Convection?
- 5. Mechanisms of Free Convection (Buoyancy)
- 6. Forced vs. Free Convection Comparison
- 7. Mixed Convection

Recap of Convection

- Convection involves heat transfer by macroscopic fluid motion.
- Governed by Newton's Law of Cooling: q = hA(T_s - T_\infty)
- The driving force for heat transfer is the temperature difference.
- But what drives the fluid motion? This question leads us to our two types.

Forced Convection

- Definition: Fluid motion is artificially induced by an external agent.
- External agents include fans, blowers, pumps, or wind.
- The fluid is forced to flow over a surface or through a tube, regardless of the temperature differences present.

Mechanisms of Forced Convection

- High fluid velocities are achievable.
- Results in thinner boundary layers (we will discuss these later).
- Consequently, forced convection yields much higher heat transfer coefficients (h) compared to free convection.
- Flow can be easily controlled to achieve desired cooling/heating rates.

Examples of Forced Convection

- 1. Air conditioning and heating systems (fans blowing air).
- 2. Automobile radiators (water pump circulating coolant).
- 3. Cooling of electronic components (CPU cooling fans).
- 4. Flow of fluids through heat exchangers in chemical plants.

Free (Natural) Convection

- Definition: Fluid motion is induced by natural means, without any external agent.
- The motion is driven entirely by density differences within the fluid.
- These density differences are created by temperature gradients in the fluid itself.

The Mechanism: Buoyancy Forces

- 1. A hot surface heats the adjacent fluid.
- 2. The fluid expands, its density decreases.
- 3. The lighter, warmer fluid experiences an upward buoyancy force and rises.
- 4. Cooler, denser fluid moves in from the sides to replace it.
- This continuous circulation is natural convection.

Examples of Free Convection

- 1. Cooling of a hot cup of coffee in a still room.
- 2. Heat dissipation from standard home radiators (despite the name, they operate mostly via free convection and radiation).
- 3. Cooling of power transmission lines on a calm day.
- 4. Oceanic and atmospheric circulation patterns.

Forced vs. Free Convection

- — Feature — Forced Convection — Free Convection —
- ——————
- — Cause of Flow — External agent (fan/pump) — Buoyancy forces (density diff) —
- — Fluid Velocity — Generally high — Generally low —
- — Heat Transfer Coeff (h) — High — Low —
- — Control — Easily controllable — Difficult to control —

Mixed Convection

- In reality, free convection is always present as long as there is a temperature difference and gravity.
- Mixed convection occurs when both forced and free convection effects are significant.
- Example: A slow fan blowing air over a very hot surface.
- Buoyancy forces can either assist or oppose the forced flow.

Summary

- Forced convection uses external power (fans, pumps) to move fluid.
- Free convection relies on buoyancy forces generated by temperature-induced density changes.
- Forced convection generally achieves much higher heat transfer rates than free convection.
- Mixed convection happens when both mechanisms are of comparable strength.

Next Lecture Preview

- Topic: Overall heat transfer coefficient - conduction and convection
- Key questions:
- - How do we calculate heat transfer when a wall has convection on both sides?
- - What is the overall heat transfer coefficient 'U'?