# Heat and Mass Transfer (DI05019071)

## Complete Lecture Deck

Milav Dabgar

Lecturer, GP Palanpur

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# Concept of Heat Pipe

- Course: Heat and Mass Transfer (DI05019071)
- Unit 4: Heat exchanger
- Lecture 37: Concept of Heat Pipe

# Lecture Agenda

- 1. Introduction to Heat Pipes
- 2. Working Principle
- 3. Components of a Heat Pipe
- 4. Working Fluid Selection
- 5. Capillary Action and Wick Structures
- 6. Advantages and Limitations
- 7. Applications

# What is a Heat Pipe?

- A heat pipe is a highly efficient heat-transfer device that combines the principles of both thermal conductivity and phase transition.
- It can transfer heat between two solid interfaces efficiently.
- It has an effective thermal conductivity much higher than solid conductors like copper or aluminum.
- Operates passively without any moving parts or external power supply.

# Working Principle

- Heat is applied to the evaporator section, causing the working fluid to vaporize.
- The vapor pressure drives the vapor through the adiabatic section to the condenser.
- At the condenser, heat is removed, and the vapor condenses back into a liquid.
- The liquid returns to the evaporator via capillary action in the wick structure.

# Components of a Heat Pipe

- 1. Container: Provides structural integrity and isolates the working fluid from the outside environment.
- 2. Working Fluid: Absorbs and releases latent heat. Chosen based on operating temperature.
- 3. Wick Structure: Provides the capillary pumping pressure to return the liquid to the evaporator.

# Working Fluid Selection

- Selection depends heavily on the operating temperature range.
- Cryogenic: Helium, Nitrogen (0-200 K)
- Room Temperature: Water, Ammonia, Methanol (200-500 K)
- Liquid Metals: Sodium, Potassium, Lithium (500-1500 K)
- Properties desired: High latent heat, high surface tension, high thermal conductivity, and good thermal stability.

# Wick Structures and Capillary Action

- The wick is responsible for pumping the condensed liquid back to the evaporator against gravity or friction.
- Types of Wicks:
- - Sintered Metal Powder: Excellent capillary force, can work against gravity.
- - Grooved Tube: Low capillary force but low flow resistance; best for horizontal use.
- - Screen Mesh: Balance between capillary force and permeability.

# Heat Pipe Limitations

- Capillary Limit: Wick cannot pump liquid back fast enough (dry out).
- Sonic Limit: Vapor velocity reaches the speed of sound, choking the flow.
- Entrainment Limit: High vapor velocity strips liquid droplets from the wick.
- Boiling Limit: Film boiling occurs in the evaporator, blocking liquid flow.

# Advantages of Heat Pipes

- Very high effective thermal conductivity.
- Passive operation (no moving parts, zero maintenance).
- Isothermal operation over long distances.
- Lightweight and compact compared to solid metal conductors.
- Flexible geometries (can be bent or flattened).

# Applications: Electronics Cooling

- Laptops and PCs: Moving heat from CPU/GPU to the cooling fan at the edge.
- Smartphones: Ultra-thin vapor chambers (flattened heat pipes) for processor cooling.
- Power Electronics: Cooling high-power transistors and LEDs.

# Applications: Aerospace & Industrial

- Aerospace: Thermal control of satellites, moving heat from sun-facing side to shaded radiators.
- HVAC: Energy recovery ventilators (air-to-air heat exchangers).
- Industrial: Waste heat recovery systems, nuclear reactors.

# Summary

- Heat pipes transfer heat efficiently using evaporation and condensation.
- They consist of a sealed container, working fluid, and wick structure.
- They operate passively with very high effective thermal conductivity.
- Widely used in electronics, aerospace, and energy recovery.

# Next Lecture Preview

- Topic: Compact Heat Exchangers
- Key questions to ponder:
- - What makes a heat exchanger 'compact'?
- - Where are compact heat exchangers used, and why are they necessary?