Design and Analysis Filmwise and Dropwise Condensation

Mr.V.PRABAHARAN ME., Assistant Professor Mechanical engineering Shree venkateshwara Hi-tech engineering college Gobi,638455,erode, Tamilnadu,india,

HARIHARAN G Mechanical engineering Shree venkateshwara Hi-tech engineering college Gobi,638455,erode, Tamilnadu,india,

JEEVANANTHAM K, Mechanical engineering Shree venkateshwara Hi-techengineering college Gobi,638455,erode, Tamilnadu,india,

MANIKANDAN S Mechanical engineering Shree venkateshwara Hi-tech engineering college Gobi,638455,erode, Tamilnadu,india,

SUBASH C Mechanical engineering Shree venkateshwara Hi-tech engineering college Gobi,638455,erode, Tamilnadu,india

Abstract— Water condensation was studied on salinized (superhydrophobic) and fluorinated (super oleophobic) micro-rough aluminium surfaces of the same topography. Condensation on superhydrophobic surfaces occurred via film-wise mechanism, whereas on super oleophobic surfaces it was drop-wise. The difference in the pathways of condensation was attributed to the various energy barriers separating the Cassie and Wenzel wetting states on the investigated surfaces. The higher barriers inherent for super oleophobic surfaces promoted the drop-wise condensation. Triple-stage kinetics of growth of droplets condensed on super oleophobic surfaces is reported and discussed. Keywords: super oleophobic. The chapter covers four main areas of condensation heat transfer. The process at the vapor-liquid interface during condensation is first discussed. In many cases it is adequate to assume equilibrium at the interface but in dropwise condensation and condensation of metals the interface temperature discontinuity plays and important role. The traditional problems of laminar film condensation on plates and tubes are covered in some detail including natural and forced convection problems, the effect of vapor superheat and of the presence of non-condensing gases in the vapor. The specific problems of condensation on finned surfaces and in microchannels are treated in some detail. An extensive section covers dropwise condensation and incudes both experimental investigations and theory

I.INTRODUCTION

Film wise condensation is a process in which a vapor condenses directly into a liquid film on a solid surface. This type of condensation typically occurs when the vapor contacts a surface that is colder than its dew point temperature. In film wise condensation, the condensate forms a continuous film on the surface, which can be advantageous in certain applications because it promotes efficient heat transfer. The liquid film allows for a high rate of heat transfer due to the direct contact between the condensate and the solid surface. Film wise condensation is commonly observed in industrial heat exchangers, where it is desirable to maximize heat transfer efficiency. By promoting the formation of a thin liquid film, film wise condensation helps to maintain a high rate of heat transfer and can be more efficient compared to other modes of condensation, such as dropwise condensation. However, film wise condensation may not always be feasible or desirable in all applications. Factors such as surface roughness, surface chemistry, and the presence of contaminants can influence the condensation process and may Favor other modes of condensation. In film wise condensation, the cooled surface is smooth and friction-less which results in quick falling movement of drops formed at the surface. Due to swift movement of drops under gravity, they coalesce to form a film or a continuous stream of dropsComposite materials

DROPWISE CONDENSATION

Dropwise condensation starts from the nucleation of droplets formed at favourable nucleation sites. Then direct condensation promotes the growth of these tiny droplets until they approach each other and coalescence happens. Direct condensation and coalescence events simultaneously dictate droplet growth. As a typical vapor-liquid phase-change process, condensation occurs when water vapor is cooled and turns into liquid on solid surfaces. Depending on the physicochemical properties of solid surfaces, condensation is characterized by two modes. On a hydrophilic surface, condensation is characterized by the formation of a continuous liquid film over the cold surface, known as film wise condensation. In comparison, dropwise condensation collects condensate in the form of droplets over non-wetting surfaces. Because of the highly mobile of discrete droplets, dropwise condensation promises 5–7 times higher heat transfer coefficient when compared to film wise condensation . As such, since the first report by Schmidt et al. dropwise condensation attracts an exponentially growing interest [3,4,6,8]. Dropwise condensation starts from the nucleation of droplets formed at favourable nucleation sites. Then direct condensation promotes the growth of these tiny droplets until they approach each other and coalescence happens. Direct condensation and coalescence events simultaneously dictate droplet growth. Once droplets reach a critical size, they will leave the substrate due to external forces. The blank substrate exposed by coalescence and sliding permits new droplets to become available. Consequently, dropwise condensation involves complex droplet mobility having spatial and temporal multiscale features.

II. LITERATURE REVIEW

Experimental Investigation of Dropwise Condensation Heat Transfer: This study by Kim et al. (2019) presents experimental findings on dropwise condensation heat transfer over a range of surface characteristics and operating conditions. The research explores the impact of surface properties, such as wettability and roughness, on dropwise condensation heat transfer coefficients.

Theoretical Analysis of Film wise Condensation Heat Transfer: Liu et al. (2020) conducted a theoretical investigation into film wise condensation heat transfer mechanisms. The study employs mathematical modelling to analyse the heat transfer characteristics of thin liquid films formed during film wise condensation on various surfaces.

Comparison of Dropwise and Film wise Condensation: This comparative study by Patel et al. (2018) evaluates the heat transfer performance of dropwise and film wise condensation under similar operating conditions. The research highlights the advantages of dropwise condensation over film wise condensation in terms of higher heat transfer coefficients and lower pressure drops.

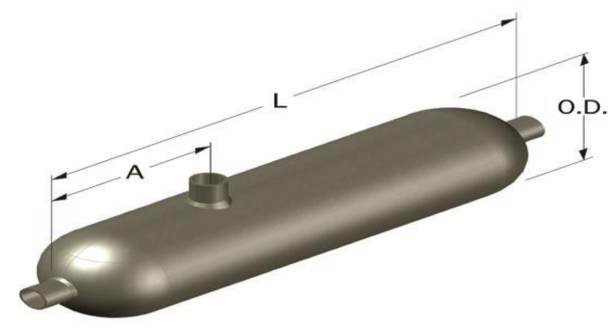
III. DESCRIPTION COMPONENTS

STEAM CHAMBER

1. Industrial Steam Chamber: In industrial processes, a steam chamber might be a sealed enclosure where steam is used for various purposes such as sterilization, cooking, or chemical processing. It's often a controlled environment where steam is utilized to achieve specific results in manufacturing or treatment processes.

2. Sauna or Steam Room: In a spa or wellness context, a steam chamber could refer to a sauna or a steam room where individuals go to relax and enjoy the benefits of steam. These chambers are typically heated to produce steam, which helps in relaxation, detoxification, and skin cleansing.

3. Geological Steam Chamber: In geology, a steam chamber could refer to a cavity within the Earth's crust where water is heated to produce steam. These chambers can be associated with volcanic activity or geothermal energy production.



PRESSURE GAUGE

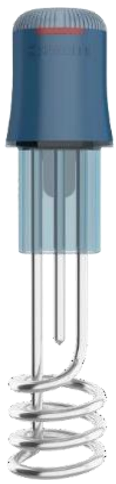
1. **Industrial Processes:** Pressure gauges are commonly used in manufacturing plants, refineries, and other industrial facilities to monitor the pressure of fluids in pipelines, tanks, and vessels. They help ensure that systems are operating within safe and optimal pressure ranges.
2. **HVAC Systems**: Pressure gauges are essential components in heating, ventilation, and air conditioning (HVAC) systems. They are used to measure the pressure of refrigerants and air within the system, helping to maintain proper airflow and temperature control.
3. **Automotive and Transportation**: Pressure gauges are used in vehicles to monitor tire pressure, engine oil pressure, and other critical parameters. They provide drivers with important information about the condition of their vehicles and help prevent accidents and mechanical failures.

HEATER

A water heater is a household appliance used to heat water for various purposes, such as bathing, cooking, cleaning, and space heating. There are several types of water heaters, including:

- **Storage Tank Water Heater:** This is the most common type, where water is heated and stored in an insulated tank until needed. These tanks typically range in size from 20 to 80 gallons.

- **Tankless (On-Demand) Water Heater:** These units heat water directly as it flows through the device, without the need for a storage tank. They are more energy-efficient than storage tank heaters because they only heat water when it's needed.
- **Heat Pump Water Heater:** This type of water heater uses electricity to move heat from one place to another instead of generating heat directly. They are more energy-efficient but can be more expensive upfront.
- **Solar Water Heater:** These systems use solar collectors to absorb energy from the sun to heat water, which is then stored in a tank. They are environmentally friendly and can significantly reduce energy costs over time.



TEMPERTURE SENSORS

Temperature sensors are devices used to measure temperature, a fundamental parameter in various applications across industries. They are vital in ensuring optimal operation and safety in many systems. Here are some key points about temperature sensors:

1. **Types:** There are several types of temperature sensors, each with its own principles of operation and suitable applications. Common types include:

- Thermocouples: These sensors generate a voltage proportional to the temperature difference between two junctions. They are rugged, inexpensive, and suitable for a wide temperature range.
- Resistance Temperature Detectors (RTDs): RTDs are based on the principle that the electrical resistance of certain materials changes predictably with temperature. Platinum RTDs are widely used due to their high accuracy and stability.
- Thermistors: Thermistors are semiconductor devices with a resistance that varies significantly with temperature. They offer high sensitivity and are often used in applications requiring precise temperature measurement.

STAINLESS STEEL BOILER

A stainless-steel boiler refers to a boiler system or vessel constructed as the primarily of stainless steel, a type of corrosion - resistant alloy known for it's the durability, strength, and resistance to rust and corrosion. Here are some key points about stainless steel boilers:

1. **Material**: Stainless steel boilers are typically made from grades of stainless steel that offer high resistance to corrosion and oxidation, such as 304

stainless steel (also known as 18-8 stainless steel) or 316 stainless steels (also known as marine-grade stainless steel). These materials are preferred for their ability to withstand harsh environments, high temperatures, and corrosive substances commonly found in boiler systems.

2. **Applications**: Stainless steel boilers find applications in various industries where cleanliness, hygiene, and corrosion resistance are critical factors. They are commonly used in food processing, pharmaceutical manufacturing, chemical processing, breweries, distilleries, and in residential and commercial heating systems.

WORKING PRINCIPLE

Film wise Condensation: In film wise condensation, the condensate forms a thin film on the surface, and heat transfer occurs through this film. The condensate film thickness is relatively uniform, leading to predictable heat transfer rates. This mode of condensation is commonly observed when the surface is clean and smooth. Film wise condensation is well-understood and often described by empirical correlations such as the Nusselt equation.

Dropwise Condensation: Dropwise condensation occurs when individual droplets form and grow on the surface. These droplets enhance heat transfer by effectively removing the condensate from the surface, exposing it to fresh vapor. Dropwise condensation typically results in higher heat transfer coefficients compared to film wise condensation. However, achieving and maintaining dropwise condensation can be challenging as it often requires surface modifications or additives to promote droplet formation and shedding. The research highlights the advantages of dropwise condensation over film wise condensation in terms of higher heat transfer coefficients and lower pressure drops.

FILM WISE AND DROP WISE CONDENSETION READINGS

The balance of evidence suggests that dropwise condensation is a more effective method of heat transfer than film wise condensation, and the presence of air instream vapour significantly reduces the heat transfer.

The final observation is confirmed in the Handbook of Phase Change. which quotes that at atmospheric pressure, the Heat Flux in dropwise condensation can be more than film wise. This can be explained in terms of how the condensation forms on the condenser.

The vapour drops in dropwise condensation are discrete and are continually formed and released which means that the surface of the condenser is also continually exposed. In comparison, the film created in film wise condensation always covers the surface of the condenser . As a relatively poor conductor of heat, this film creates a thermal resistance which is the reason why the value for Heat Flux is lower for film wise in comparison to dropwise condensat

APPEXDIX

SAMPLE SPECIMEN

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