Azzaytuna University
Agriculture faculty

مجلة النماء للعلوم و التكنولوجيا

Science & Technology's Development Journal

(STDJ)

مجلة علمية محكمة سنوية تصدر عن
كلية الزراعة جامعة الزيتونة

العدد السادس مارس 2025

STDJ ISSN: 2789-9535

Experimental Study Of Heat Transfer Coefficient For Falling Film Evaporation On Horizontal Tube

Emad Guima TA Ben Hamid[1], Abdulmunem MI Alemari[2]
emadbenhamid@gmail.com

دراسة تجريبية على معامل انتقال الحرارة بعملية تبخير الطبقة الرقائقية الساقطة على أنابيب أفقية

عماد جمعة الطاهر[1]، عبدالمنعم محمد الهادي العماري[2]
[1] المعهد العالي للتقنية الصناعية، إنجيلة، طرابلس، ليبيا
[2] المعهد العالي للعلوم والتقنية، القربولي، ليبيا

الملخـص:

عمليات تبخير الطبقة الرقائقية الساقطة استعملت في العديد من التطبيقات الصناعية المختلفة لوقت طويل بسبب مميزاتها الهامة جداً والتي تتمثل في التصاق السائل بالأنبوب في وقت قصير جداً ومعامل نقل حرارة أعلى وكذلك يمكن إجرائها عند ضغوط أقل ما يمكن، حيث مبدأ عملها يعتمد على التصاق السائل بالأنابيب في وقت قصير جداً مقارنة بالتبخير الذي يكون فيه السائل الساقط على الأنابيب بشكل فيضاني، هذه الدراسة كانت بشكل تجريبي حيث تتطلب تصميم غرفة اختبار وتجهيز أنابيب بيضاوية الشكل وضعت في غرفة الاختبار أفقياً وتم تقييم غرفة الاختبار تحت حالات التشغيل المختلفة. يشمل النظام التجريبي على أربعة أجزاء رئيسية والتي تتمثل في غرفة التبخير ونظام توزيع السائل والتسخين وعملية ادارة السائل بشكل منتظم. في عمليات نقل الحرارة التي يستعمل فيها سقوط الطبقة الرقائقية من السائل على أنابيب افقية فان معامل نقل الحرارة يتأثر بشكل رئيسي بتبخير الطبقة الرقائقية من السائل الساقطة خارج الأنابيب، ولهذا فإن العديد من التجارب قامت بتقييم أداء المبخر تحت حالات التشغيل المختلفة. خلال هذه الدراسة كانت الأنابيب أفقية بيضاوية الشكل بقطري رئيسي 16 ملليمتر وآخر ثانوي 14 ملليمتر وكان نوع المادة المصنوع منها الأنبوب عبارة عن خليط نحاس – نيكل بطول 70 سنتيمتر وضعت بداخلها مسخنات كهربية لتوليد الحرارة على سطح الأنابيب. واختبرت البارومترات المختلفة والمتمثلة في كثافة التدفق واختلاف درجات الحرارة بين درجة حرارة التشبع للماء عند الضغط الجوي ودرجة الحرارة عند سطح الأنبوب، حيث أجريت التجربة عند المتغيرات المختلفة مثل كثافة التدفق (Γ) التي تفاوتت قيمته بين $0.0585 < \Gamma < 0.117$ kg/ms ودرجة حرارة سطحية بين 108.31℃ إلى 118.25 C° وجريان حرارة (q) بين 18.5775 KW/m² إلى 25,2123 KW/m²). خلال مشاهدة النتائج لوحظ زيادة في معامل نقل الحرارة بزيادة كثافة السائل الساقط على الأنبوب الأفقي الشكل ويتناقص أيضاً بزيادة اختلاف درجات الحرارة وجريان الحرارة يزداد بزيادة اختلاف درجات الحرارة مما أدى ذلك إلى تحسين معامل نقل الحرارة.

الكلمات المفتاحية: *معامل انتقال الحرارة، الطبقة الرقائقية، التبخير، كمية الحرارة، كثافة السائل، معدل التدفق.*

Abstract

Falling film evaporation processes have been widely utilized in various industrial facilities for an extended period due to their appealing attributes, including short contact time, higher heat transfer coefficient, minimal pressure drop, and small process fluid holdup in comparison to the flooded tube evaporator. This investigation involved the design of an experimentally rigged horizontal tubular falling film evaporator and the

assessment of its performance under diverse operating conditions. The experimental setup consists of four primary sub-systems supported by auxiliary devices. The key components include the evaporation chamber, feed distribution system, heating , and the water circulating system. In the heat transfer process of falling film using on horizontal tubes the overall heat transfer coefficient is influenced mainly by the falling film evaporation outside tubes, A series of experiments have been performed to evaluate the performance of The evaporator behaves differently under various operating conditions..
A horizontal tubes whit a major diameter 16mm a minor diameter of 14mm and 70cm length copper-Nickel tubes heated by internal electric heaters so that a uniform heat flux was generated on the outside surface of tubes. The evaporator exhibits varying performance under different operating conditions., where examined, the Experiments were conducted at different variable such flow density (Γ) varies between 0.0585 kg/ms < Γ < 0.117 kg/ms, surface temperature from 108.31c̊ to 118.25c̊ and heat flux from 18.5775Kw/m² to 25,2123Kw/m². And the results shows the heat transfer coefficient of falling film evaporation outside horizontal tubes increases with the increase in liquid feeding, the decreases of the temperature differences, the heat flux increases.
Keywords: *falling Film, Evaporator, Heat Transfer, Coefficient, Heat, Flow rate.*

1 - INTRODUCTION

1.1Background

Evaporation is one of the most energy intensive processes , It is a unit operation that is used extensively in processing foods, chemicals, pharmaceuticals, fruit juices, sugar industries, desalination, dairy products, paper and pulp, and both malt and grain beverages. Evaporation process starts with a liquid product and ends up with a more concentrated product from the process. In some special cases, the evaporated, component is the main Product such as in desalination plant (Ulhasan & Ali, 2009). Evaporators are used to concentrate a solution through evaporation. During the evaporators operation two main points are always considered, suitability of the equipment for its best duty and efficient and economical use of the equipment. Therefore, many types of evaporators and many variations in processing techniques have been developed to take into account different product characteristics and operating parameters. The different types of evaporators are, forced circulation evaporators, natural circulation evaporators, rising film tubular evaporators, falling film tubular evaporators, Rising/falling film tubular evaporators, plate evaporators and multiple effect evaporators. Multiple effect evaporators are used to achieve heat economy by recovering heat from vapors, which can be further utilized in other effects operating at lower boiling temperature. (Pacheco & Frioni, 2004)

Since the main objective of all types of evaporators operations is to improve the efficiency and effectiveness of the process through efficient utilization of heat and energy. Therefore reliability of evaporation processes like thermal desalination, processing of sugar juice etc, strongly depends on the calculation of heat transfer coefficient. Heat transfer coefficient is also mainly estimated during the designing of an evaporator (Prost et al., 2006).

Economic and environmental considerations continue to drive strong interest in increasing the efficiency of thermal systems. In many cases, this is achieved by improving the performance of heat exchangers. In widely used shell-and-tube heat exchangers, conventional flooded evaporator designs fill the shell-side area with working fluid. One alternative is designs based on falling-film evaporation, which maintain only a thin liquid film over the tubes. This leads to a reduced working fluid inventory, higher heat transfer coefficients with negligible pressure drops, and closer approach temperatures, yielding more compact designs with potentially lower costs and improved heat transfer performance. Ultimately, this increases cycle efficiencies while reducing the required working fluid charge, which lowers capital costs and environmental impact. This has led to their usage in the refrigeration, petrochemical, and desalination industries (Bustamante et al., 2014).

Falling-film evaporator designs are typically based on films falling over horizontal or vertical round tubes. Recently, horizontal tube designs have demonstrated several advantages over vertical units, including higher heat transfer coefficients, external tube enhancements, and closer approach temperatures (Thome, 2004).

Heat transfer through the process of falling film evaporation has been widely employed in heat exchange devices in chemical, refrigeration, petroleum refining, desalination, dairy, brewing, and coke industries. The horizontal-tube falling-film evaporator usually consists of a bundle of horizontal tubes connected by headers at each end as in a conventional shell-and-tube heat exchanger. In this case, however, the shell-side liquid flow is introduced through spray nozzles at the top of the bundle. Falling, evaporating films are then formed on the outside tube surfaces. Thus, the liquid falls by gravity from tube to tube, redistributing itself on each tube.

The principal advantages of horizontal-tube falling film evaporators are high heat transfer rates at small temperature differences and low liquid requirement as compared with flooded bundle evaporators. Since there is no liquid pool, the effect of hydrostatic head on the heat transfer is eliminated.

The formation of scale on the tube side in a vertical-tube falling film evaporator can reduce the liquid flow in the tube, thereby accelerating the formation of additional scale. By contrast, in a horizontal-tube evaporator, since the film flow is on the outside tube surfaces, the possibility of scale build-up blocking the liquid flow is minimal, and the shell-side deposit is easier to remove. The horizontal-tube falling film evaporators also show advantages over vertical-tube evaporators in dealing with problems such as liquid distribution, leveling, non-condensable gases on the tube side, and liquid entrainment (Yundt & Rhinesmith, 1981).

The horizontal tube multiple effect (HTME) distillation system incorporates horizontal heat transfer tube bundles with steam condensing on the inside of the tubes and brine vaporizing on the outside. The HTME process may produce potable water more economically than other systems due to the efficient heat transfer realized by the thin film evaporation and the elimination of many of the intereffect pumps and the associated equipment .

Horizontal falling-film evaporators have been installed in a wide variety of commercial applications in the chemical process industries. This type of evaporator is used widely in concentrating chemicals that are sensitive to heat, such as ammonium nitrate and urea. Here, minimum heating time is desirable to prevent decomposition. In the closed cycle ocean thermal energy conversion system, a horizontal tube spray film evaporator was proposed to operate at low temperature difference without introducing hydrostatic head problems (Chyu, 1984).

1.2 Principles and types of Falling film evaporation process

Evaporation is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid , This is a thermal separation process, also known as thermal concentration. It involves transforming a liquid product into a more concentrated, yet still liquid and pump able concentrate as the final product. Falling film evaporators operate with either parallel flow or counter flow for the liquid and vapor. The liquid that needs to be concentrated or evaporated is heated to boiling temperature. A uniform thin film is introduced into the heating tubes through a distribution device at the top of the evaporator, descends at boiling temperature, and undergoes partial evaporation. The downward motion, caused by gravity, is further enhanced by the concurrent vapor flow. Falling film evaporation processes operate on different working principles depending on the requirements, yet they all aim to evaporate a certain amount of the working fluid. In air conditioning and refrigeration application the evaporation process is used as a means of heat transfer. On the other hand , in the food industry where many substances are heat sensitive, the process is a means of mass transfer. In this process, a slender layer of the substance undergoing concentration flows down within the heat exchange tubes, while steam forms droplets on the exterior of the tubes, providing the necessary heat to the interior of the tubes. Meanwhile, depending upon the application, the falling film evaporators can be categorized into two main groups; vertical tube falling film and horizontal spray-film evaporator having either parallel flow or counter flow arrangements. The working fluid is preheated near its saturation temperature in a vertical arrangement before being fed through a vertical tube from top to bottom, allowing it to fall due to gravity. Meanwhile, the heat supplying fluid, typically steam, is passed over the outside surface of the tube. In a horizontal tube arrangement, the working fluid flows from one end to the other while the heat supplying fluid flows over the tubes. Depending on the application, the process may also occur in reverse, with the working fluid flowing over the tubes and the heat supplying fluid flowing through the tube (Elias , 2004).

The reliability of the thermal desalination simulators strongly depends on the calculation of the heat transfer coefficients (h) used to model the heat transfer phenomena in the desalting process.

Three types of evaporators: horizontal falling film evaporators (HFF), vertical falling film evaporators (VFF) and vertical rising film evaporators (VRF). The use of the appropriate (h) correlation is essential to provide a reliable set of performance results when a new configuration is being designed.

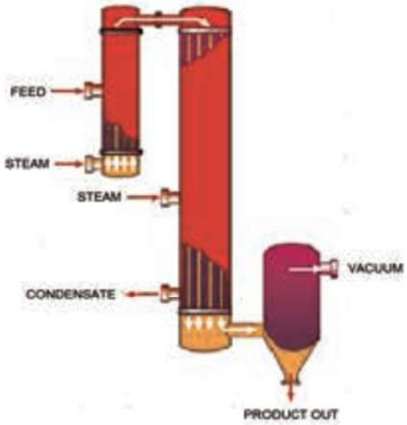
(Uche et al., 2003), compared different heat transfer coefficient correlations for thermal desalination units. They concluded that the performance of the thermal desalination units strongly depends on the calculation of the heat transfer coefficients used to model the heat transfer phenomena in the desalting process. The authors used different correlations for calculating heat transfer coefficient in three types of evaporators, Horizontal Falling Film evaporators (HFF), Vertical Falling Film evaporators (VFF) and Vertical Rising Film evaporator (VRF). Comparison of about six or seven correlations were made for the water and for vapor side of the evaporator/condenser included in the thermal desalination unit. After examining the results from different correlations, the authors selected some correlations which were considered the best alternative to include in the models describing the performance of Multi-Stage Flushing(MSF), Vapor Compression(VC) and Thermal Vapor Compression(TVC) plants.

1.2.1 Vertical Evaporates

In this type of heat exchanger, evaporation takes place inside vertical tubes, and condensation outside them. The seawater is sprayed into the inner tube wall of the vertical tube, and it flows down as a film. Therefore, the brine has to be pumped from the bottom to the top of each effect before being sprayed. Different methods available for finding out heat transfer coefficients for evaporation .

Evaporators installed with a vertical orientation may not be of as great a commercial interest as horizontal evaporators, but certain of the insights gained from the research on vertical evaporators may also apply to horizontal evaporators. the boiling fluid is outside the tubes. Essentially the thickness of the liquid layer will be greater for long vertical tubes which decreases the coefficient of heat transfer at the top of the tube because of the large thickness needed there. Nevertheless, a long tube can generate a turbulent regime that intensifies the coefficient of heat transfer.

The hydrodynamic process of the liquid on the exterior of the tube controls the heat transfer. An Nusselt's early studies examined the creation of a flat film during the condensation process, which expands as the tube length increases. The development of the falling film evaporation technique took nearly fifty years to perfect, as illustrated in Figure 1. The primary challenge was creating a system that could evenly distribute liquid to all the tubes. Unlike the rising film evaporator, where distribution was straightforward due to the full pumping of liquid into the bottom bonnet of the calandria, falling film distribution typically involves a perforated plate above the top tube plate. Some manufacturers also utilize flash vapor generation to enhance liquid spreading. The advantage of the falling film evaporator lies in the fact that the film flows with gravity, resulting in a thinner, faster-moving film, shorter product contact time, and improved heat transfer coefficient (h). (www.apv.com)



Fig(1) Falling film on vertical tube

1.2.2 Horizontal Evaporator

These were the first kind of evaporators that were developed and that came into application. They have the simplest design of all evaporators. It has a shell and a horizontal tube such that the tube has the heating fluid and the shell has the solution that has to be evaporated. It has a very low initial investment and is suitable for fluids which have low viscosity and which do not cause scaling. The use of this kind of evaporator in

the present day is very less and limited to only preparation of boiler feed water. This evaporator is a modification of horizontal tube evaporator. It is a kind of horizontal falling film evaporator and in those evaporator, the liquid is distributed by a spray system. This sprayed liquid falls from one tube to another tube by gravity. In such evaporators, the distribution of fluid is easily accomplished and the precise leveling of fluid is not required (Jaishree, 2010).
Horizontal falling film evaporators have gained widespread acceptance in the desalination industry due to some inherent advantages. Brine is sprayed and distributed as a film over the outside of a horizontal tube bundle as show Fig(2). and the heating steam condenses inside the tubes.

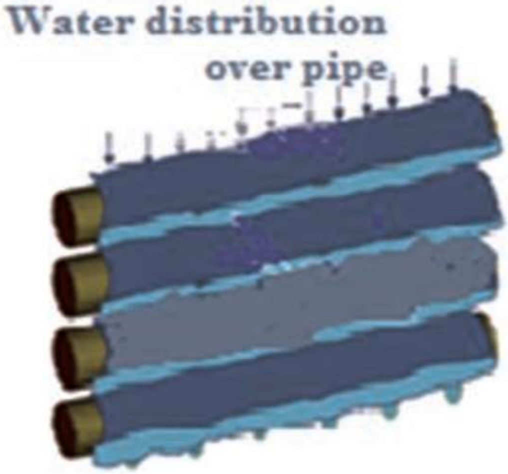


Figure (2). Horizontal tube falling film distribution.
High heat transfer coefficients are achieved (the liquid is in the form of a very thin film), and this design has a number of distinctive practical advantages.
Horizontal evaporators utilizing the principle of falling films have certain advantages over vertical evaporators:
*The coefficient of heat transfer is higher.
*The flow distribution is more uniform that permits a reduction in the recirculation rate needed to avoid dry out, and this feature permits a reduction in the evaporated liquid feed and allows lower pumping cost.
*vertical evaporators must be oriented precisely vertical, while there is greater tolerance of deviation of the orientation from the horizontal in the case of the horizontal evaporator on the other hand, the horizontal evaporator is more vulnerable to dry out because of the interaction of the liquid flow with that of the vapor currents. in the horizontal evaporator where liquid evaporates on the exterior of the tubes, the hydrodynamics of the flow controls the heat-transfer process. It is necessary, then, to design the distribution system to distribute the liquid uniformly over the tube bundle so as to permit wetting of all the tube surfaces.
In general, the distribution system feeds the upper tubes of the bundle in such a way that the liquid drops down from one tube to another. The tubes most likely to suffer dry out are those in the lower portion of the bundle. In the case of large heat exchangers it may be possible to provide some distribution streams in the upper part of the bundle and some originating over the tubes (Gonzalez et al., 1992).

1.3 Objective

In this study, the test facility Mack of a The evaporator consists of three horizontal rows of tubes, with water serving as the working fluid that travels over the tubes, in addition to the use of . electrical heater, through the tubes. to the calculation of heat transfer coefficient between the falling film a tube surface , The main objectives of the research are listed as follows:

• Design and fabrication of an experimental falling film evaporator.

• Measure the tube surface temperature and heat generated from the electrical heater during falling-film evaporation of water over horizontal tubes.

• Calculate the heat transfer coefficient .

2 -The Experimental Set-up

2.1 Facility for Falling Film Technology

The objective of the experimental with the falling film facility was to obtain accurate values of local heat transfer coefficients on an horizontal tube for different surface temperatures. The ranges of experimental conditions tested are shown in Table 2.1.

The ranges of experimental conditions tested are shown in Table 2.1

Table .1: Experimental test conditions3.2

Conditions	Falling Film Evaporation
Test Fluids	water
Tube layout	1x3
Local Heat Flux	18.5775 to 25.2123 KW/m²
Flow Density	0.0585 to 0.1174 Kg/m.s
Conditions	Falling Film Evaporation

2.2 Experimental Setup Description.

Figures 3.1 and 3.2 display the schematic diagram and detailed experimental set-up, respectively. The experimental system comprises four main systems, with the primary system being the evaporation system, primarily made up of . an evaporator tubes and surrounding chamber, a recalculating feed water system, and the associated control system In addition to these systems, the measuring devices. to measure surface temperature, saturation temperature, electrical current ,and thermostat for variation temperature through the Experiment . The details of all components involved in the set-up are given individually in the following section.

2..3 Test section

The requirement for the test facility was designed to provide an even distribution of water at saturation to an electrically heated horizontal tube for specified ranges of flow rate and heating power. , the preheated water was circulated by a pump (driven by a motor, 0.5 hp, 2800 rpm) through a filter, to feed the test chamber. The feed water temperature was preheated 96.25°C,a maximum limit of operation. The flow rate into the test chamber was fine-controlled by a valve, the water was heated in the distribution tank (stainless steel, 80 cm x 20 cm) by an electric heater (BALCIK VDE A1,220V 1000W 4814).the generated vapor was condensed in a water-cooled condenser. The condensate was directed back to the tank. The pressure in the chamber was atmospheric. the test chamber was designed and constructed to perform falling film evaporation. as shown in Fig. 2.1, the test chamber consists of an inner container for liquid distributor, test section consists of three tubes, the main heating elements inside the tubes and auxiliary heater which placed inside the liquid distributer. The other components of the rig are, the pre heater to heat the water to 80č , the condenser, the pump, and feed water tank.

Figure 3. Experimental Setup Details.

2.3.1 The Tube Bundle distributor

Arrangements of the liquid feeder and the two heated tubes that are installed in an airproof chest. The liquid feeder was placed in the highest point of the distributor above the heat tubes copper Nickel the heated tubes has an elliptical shape with of measure Diameters a=16mm and b=14 mm. The space between the tubes is fixed at 10 mm, and the minimum height between the liquid feeder and heated tube is also 10 mm . as show in Fig. (4).

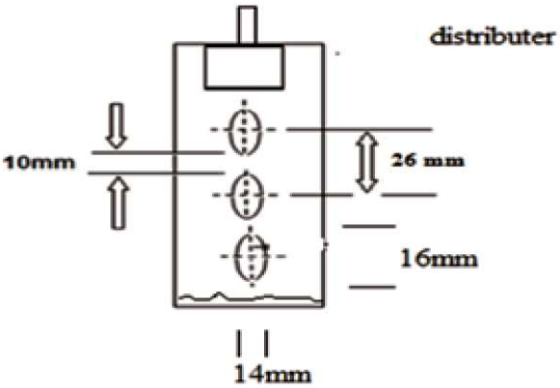


Figure 4. Schematic of the tubes layout

3- Data Collection

The dimensions and layout those used for this study correspond to those similar used in desalination plants. The tube pitch center-to-center was 26mm, allowing three tubes to be installed. With a tube diameters of a=16mm and b=14mm, and intertube spacing's of 10mm.

Using heater inside the tubes to evaporate water on the outside of the tubes. the water undergoes about tubes a saturation temperature remains constant. While the surface temperature change. This produces a variation in variance in temperature among the saturation temperature and average temperature variance in temperature among the tubes. The average wall superheat, ΔT, was calculated by taking The variance between the mean wall temperature and the saturation temperature. the film rate of flow per unit distance per side of tube, Γ(kg/s-m), was calculated by dividing of the total mass flow rate $\dot{m}$ (kg/s), by the cylinder length, L(m), i.e.

$\Gamma=\mathring{m}/l$………3.1

The local heat flux The tube's outer surface could be derived from heated by electric power controlled by a Riostate its Calculated electrically, i.e. .

$Q=IV$…………3.2

The local Total heat transfer coefficient . (h) The heat flux can be used to calculate..

$h=\ddot{q}/\Delta t$……………3.3

3-1 Effect of feed flow rate

The effect of film flow rate on the heat transfer coefficient of the smooth Horizontal tube surface was investigated in more detail. The evaporation heat transfer coefficient vary with the different flow density as shown in Fig. (5),Fig. (6),and Fig.(7) In this experiment feed liquid temperature to the second tube after pre heating on the first tube was 96.25°C, where saturation temperature could not be reached and The temperature at the surface of the tube was varied as fallows 108.31°C,112.25 °C, 116.25°C, and 118.25 °C at every heat flux. three value of heat flux where experimented as fallows 25.2123 KW/m², 21.2314 KW/m², and 18.5775KW/m².From Fig.(5) ,Fig.(6), and Fig.(7) it can be seen that with increasing flow density, the heat transfer coefficient increases. This results is similar to that by (Xu et al., 2004). The reason may be because with the increasing of the flow density, the velocity of the liquid is also increased, which can enhance the fluctuation of falling film. This helps to enhance the convective heat transfer. This helps to enhance the convective heat transfer.

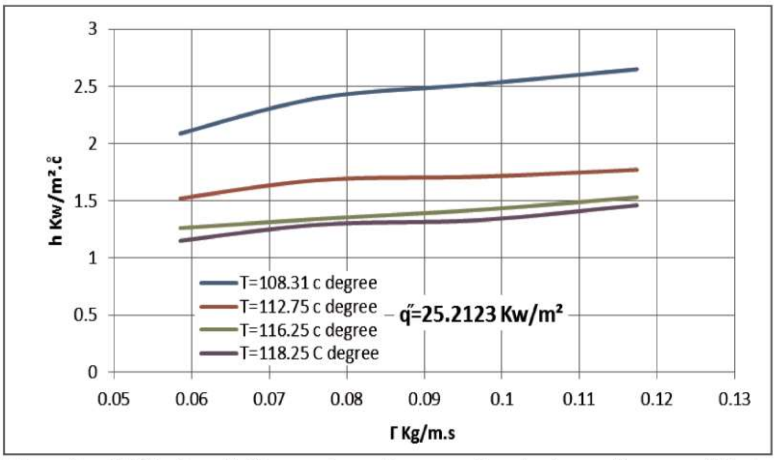


Fig. 5. Effect of flow density on heat transfer coefficient at constant heat flux per area=25.2123 KW/m² and tube surface temperature.

It can be seen in Fig.(6) that with the increasing of the flow density, the heat transfer coefficient increases with all variation surface temperature . This result is similar to that Fig(5) The reason may be because with the increasing of the flow density, the velocity of the liquid is also increased, which can enhance the fluctuation of falling film. This helps to enhance the convective heat transfer, but value of transfer coefficient became lower at heat flux 21.2314 KW/m².

In fig. (7) the flow density the heat transfer coefficient increases with all variation surface temperature, at heat flux 18.5775 KW/m² while values of heat transfer coefficient its higher compare whit values of heat transfer coefficient in Fig (5), and fig(6) , because the values of temperature differences at constant heat flux ($\ddot{q}$=18.5775 KW/m^2) was smaller than values of different temperature at constant heat flux ($\ddot{q}$ =25.2123KW/m^2) , and ($\ddot{q}$ =21.2314KW/m^2).While values heat transfer coefficient its highest at surface temperature (103.75C̊), this is due to decreasing temperature differences (ΔT) at heat flux ($\ddot{q}$ = 18.5775KW/m).

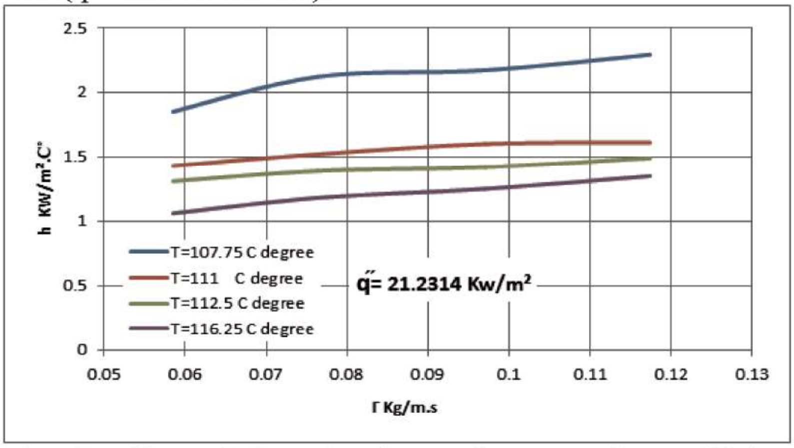


Fig. 6. Effect of flow density on heat transfer coefficient at constant heat flux per area=21.2314 KW/m^2 and tube surface temperature.

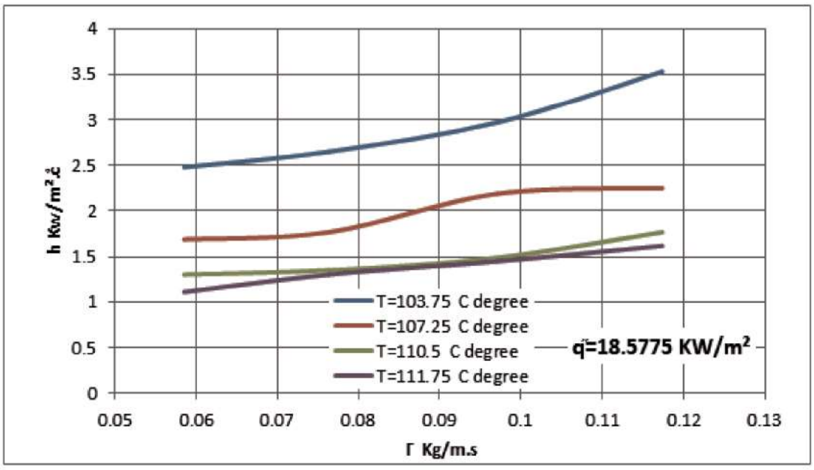


Fig. 7. Effect of flow density on heat transfer coefficient at constant heat flux per area=18.5775KW/m^2 and tube surface temperature.

The experimental results show that the heat transfer coefficient increases with the increase of evaporation temperature in the range of 40 ~ 65 ◦C. Increasing the evaporation temperature is conducive to improve the orc cycle efficiency and the heat transfer efficiency of the evaporator. The improvement of the heat transfer efficiency of the evaporator will reduce the irreversible loss of the evaporator. (Hu & Guo, 2022).

In the convective evaporation regime, several heat transfer coefficient trends have been observed with increasing flow rate. The heat transfer coefficient first increases, reaches a local maximum, then decreases to a local minima and begins increasing again. There is general agreement that the initial increase in heat transfer coefficient is due to reduced levels of dryout on the tube. Then, when the tube is fully wetted, this trend reverses as the laminar thin film becomes thicker, decreasing the heat transfer coefficient. The final increase in heat transfer coefficient as flow rate continues to rise has often been attributed to turbulence (Chyu, 1984).

These conflicting influences of flow rate on heat transfer coefficient have resulted in a number of trends being observed in experimental studies. Several groups have found that the heat transfer coefficient first decreases, and then begins increasing. (Chyu, 1984). Meanwhile, other studies have only observed heat transfer coefficient increasing with flow rate (Fletcher et al., 1975).

3.2 Effect of Different Temperature

Falling film evaporation heat transfer coefficients increase with both heat flux and saturation temperature, as reported by (Chen & Jebson, 1997) showed that. This is generally attributed to the liquid viscosity decreasing with increasing temperature. This decreases the thickness of the film, leading to a lower heat transfer resistance and higher heat transfer coefficients. However, under evaporation conditions , only.

(Li et al., 2010) observed a decrease in heat transfer coefficient with an increase in temperature in tests with horizontal round tubes using water at low Reynolds number. The effect of different temperature on the heat transfer coefficient of the smooth elliptical tube was investigated in more detail. Figure (4.12 to 4.14) presents three heat transfer coefficient (h) vs. deferent temperature (Δt) curves with constant heat fluxes. the heat transfer coefficient decreases as different temperatures increases .

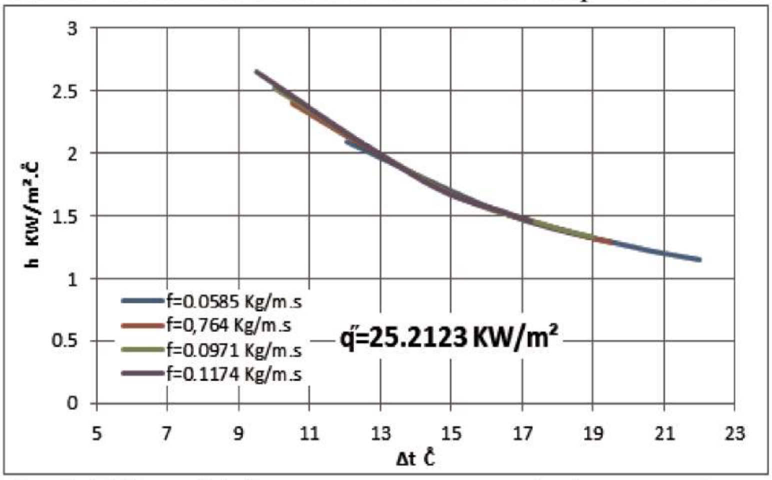


Fig. 8. Effect of deferent temperature on the heat transfer coefficient at heat flux=25.2123 KW/m^2.

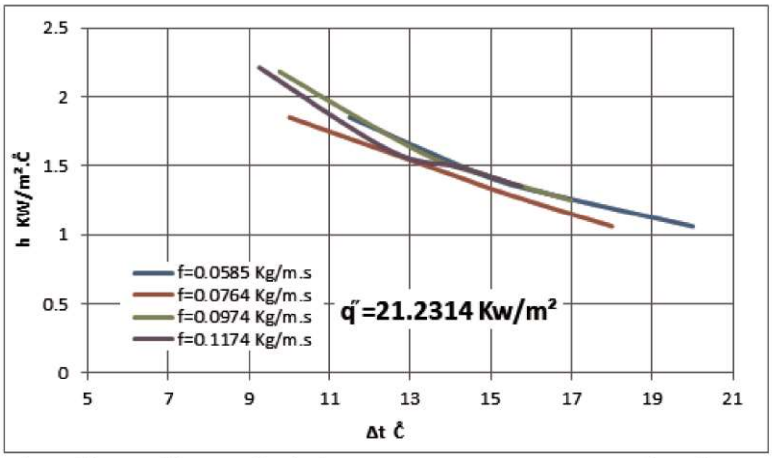


Fig (9). Effect of deferent temperature on the heat transfer coefficient at heat flux=21.2314 KW/m2.

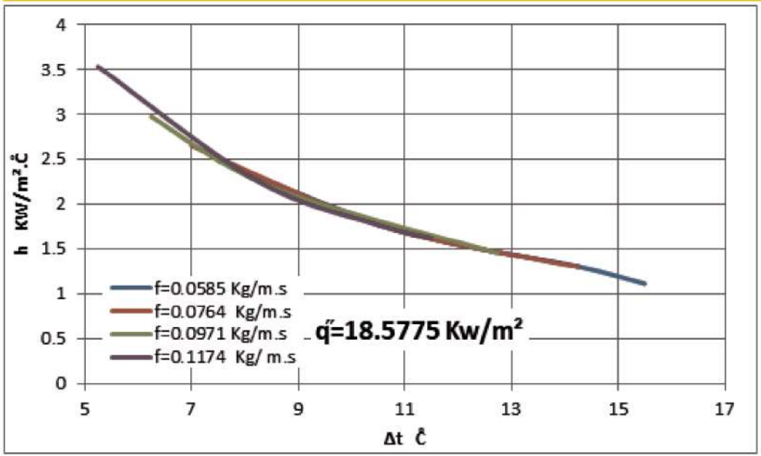


Fig.(10). Effect of deferent temperature on the heat transfer coefficient at heat flux=18.5775KW/m2

4. Conclusion

A falling film evaporation system using the horizontal tube evaporator was designed, fabricated, and tested. A series of experiment have been conducted under different operating conditions. A investigation of falling-film evaporation over horizontal elliptical tubes was conducted, The scope of the present study included three experimental studies: an assessment of liquid distributors for falling-film systems, and measurement of heat transfer coefficients for a range of conditions. Experiments were carried out on heat transfer coefficients of falling film horizontal tube evaporators. the following conclusions can be made:

1) several problems were faced, due to shortage of required technical tools and equipments to conduct the experiment in the best way. But the experiment were carried out with the available and the results were encouraging and similar to several studies , particularly those which used water.

2) When the flow density varies between 0.0585 (kg/m,s) $\leq \Gamma \leq$ 0.1174 (kg/m.s), the increasing of the flow density helps enhance the heat transfer coefficient which in the range of
1.06 kW/m2 C̊) $\leq h \leq$ 3.53 (kW/m2 C̊).

3) The increasing of the temperature different, the heat transfer coefficient increases. With the increasing of the temperature differences, heat transfer coefficient is enhanced. The reason is that with the increasing of the heat flux, temperature differences are increased, the temperature of the tube surface is enhanced.

4) It can be seen very high heat flux (q̈ = 25.2123 KW/m2) at constant surface Temperature (108.31C̊), at all values of flow density this is due to temperature differences (ΔT) was very low.

5) The heat transfer coefficient decreases as different temperatures increases . the low heat flux it became lower heat transfer coefficient approximately at flow density (Γ= 0.0585 Kg /m.s) ,

6) (Γ = 0.0764 Kg /m.s), and (Γ = 0.0971 Kg/m.s),while at flow density (Γ=0.1174 Kg/m.s) remain changeless ,because of there is no mechanism for heat flux to increase heat transfer coefficient.

7) The findings of the present study make a significant contribution to the understanding of falling-film evaporation.

NOMENCLATURE

A area. [m2]
˚C Centigrade
H liquid distributor height. [m]
h Heat Transfer Coefficient.[KW/m²]
Q Heat Input. [W]
. [Kg/s] Mass Flow Rate m
q̈ Heat Flux. [KW/m²]
Tw Wall temperature. [C̊]
Ts Saturation Temperature.[C̊]
I Electrical Current.[A]
V Volt. [Volt]
t Temperature Deference.[C̊]Δ
r Flow Density. [Kg/m.s]
s Second.[sec]
s tube or test section spacing, [m]
W Watt

References:

Bustamante, J. G., Garimella, S., & Hughes, M. (2020). Falling-Film evaporation over horizontal rectangular tubes: Part II—Modeling. *International Journal of Refrigeration*, *120*, 188-199.

Chen, H., & Jebson, R. S. (1997). Factors affecting heat transfer in falling film evaporators. *Food and Bioproducts Processing*, *75*(2), 111-116.

Chyu, M. C. (1984). *Falling film evaporation on horizontal tubes with smooth and structured surfaces*. Iowa State University.

ELIAS, M. (2005). Study of heat and mass transfer in a falling film evaporation process. National University of Singapore.

Fletcher, L. S., Sernas, V., & Parken, W. H. (1975). Evaporation heat transfer coefficients for thin sea water films on horizontal tubes. *Industrial & Engineering Chemistry Process Design and Development*, *14*(4), 411-416.

Gonzalez G, J. M., Jabardo, J. M. S., & Stoecker, W. F. (1992). Falling Film Ammonia Evaporators. *Air Conditioning and Refrigeration Center TR-33*.

Hu, B., & Guo, J. (2022). Experimental study on horizontal tube falling film evaporation in geothermal powered organic Rankine cycle generation. *Energy Reports*, *8*, 546-552.

Jaishree, V. (2010). *Optimization of a multiple Effect Evaporator System* (Doctoral dissertation).

Li, G. Q., Wu, Z., Li, W., Wang, Z. K., Wang, X., Li, H. X., & Yao, S. C. (2012). Experimental investigation of condensation in micro-fin tubes of different geometries. *Experimental thermal and fluid science*, *37*, 19-28.

Pacheco, C. R. D. F., & Frioni, L. S. M. (2004). Experimental results for evaporation of sucrose solution using a climbing/falling film plate evaporator. *Journal of food engineering*, *64*(4), 471-480.

Prost, J. S., Gonzalez, M. T., & Urbicain, M. J. (2006). Determination and correlation of heat transfer coefficients in a falling film evaporator. *Journal of Food Engineering*, *73*(4), 320-326.

Thome, J. R. (2004). Engineering data book III. *Wolverine Tube Inc*, *2010*.

Uche, J., Artal, J., & Serra, L. (2003). Comparison of heat transfer coefficient correlations for thermal desalination units. *Desalination*, *152*(1-3), 195-200.

Ulhasan, S.N., & Ali, S. (2009). Experimental Investigation of Heat Transfer Coefficient in Vertical Tube Rising Film Evaporator. Mehran University Research Journal of Engineering & Technology, volume 30, No. 4,pp. 539-548.

Yang, L., & Shen, S. (2008). Experimental study of falling film evaporation heat transfer outside horizontal tubes. *Desalination*, *220*(1-3), 654-660.

Yundt, B., & Rhinesmith, R. (1981). Horizontal spray-film evaporation.