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Heat Transfer Coefficient for Dropwise Condensation on Teflon

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Abstrak

Setelah pioner Schimidt dkk. (1930) memunculkan hasil penelitiannya mengenai kondensasi tetes, mulailah tema tersebut dikembangkan oleh para peneliti lainnya. Kondensasi tetes menghasilkan nilai koefisien perpindahan panas lebih baik dibandingkan kondensasi film. Tujuan dari studi ini adalah mempelajari karakteritik dari proses kondensasi yang terjadi pada permukaan kondenser yang dilapisi oleh lapisan tipis Teflon. Kondenser yang dilapisi oleh lapisan emas, teflon dan campuran tembaga dengan bron diukur kemampuan perpindahan panasnya. Uap air mengalir melalui pipa-pipa kondenser yang didinginkan oleh air menghasilkan kondensasi film dan atau tetes. Kondenser yang dilapisi oleh teflon menghasilkan koefisien perpindahan kalor yang lebih tinggi dibanding yang lainnya dan membuktikan kondensasi tetes lebih baik.

Abstract

Since it was first reported in 1930 by Schimidt et al., dropwise condensation has been of interest to many investigators. It has higher heat transfer coefficients than those achieved with filmwise condensation. The purpose of study is to understand characteristics of condensation processes on a teflon coated surface. A comparison among gold-coated condenser, Teflon-coated condenser, and natural finished surface condenser is made to compare their performance. The steam from boiled pure water at saturation temperature is condensed by the water-cooled condenser surface. The Teflon coated condenser has a better performance than a filmwise condenser due to its capability to promote dropwise condensation.

Key Words: condenser, dropwise, filmwise, Teflon, heat transfer coefficient.

1. Introduction

The efficiency of a condenser is an important thing. It can influence the cost of operation and maintenance. Because of this economical consideration, it is worth to find a better type of condenser. Through a series of laboratory experiments, we discuss about Heat Flux and Heat Transfer Coefficient in the film and dropwise condensation, which is narrowed, only in the vertical condenser with a certain thermodynamic and physical condition.

Dropwise condensation was achieved by coating the condensing surface with an organic promotor. Unfortunately, these promotors (waxes, oils, greases, soaps) wash off rapidly, and the condensation becomes filmwise. Polymer coatings such as Teflon (polytetrafluoroethylene) can produce dropwise condensation, but if the thickness is great enough to give durability, the heat transfer benefits are cancelled by the thermal resistance of the low-thermal conductivity coating.

In recent years, teflon coatings have been developed. Thousands of micro-grooves were observed on the surface of the teflon wall. Gases, majority of which is air, present in the micro-pores would increase the contact angle of liquid as shown in Figs. 1a and 1b, as a consequent of it, the liquid tends to lose its adherence to the solid surface. The heat transfer coefficient value from teflon coated condenser as the result of the data calculation with the heat transfer coefficient of filmwise condensation to be compared.

Fig. 1a Shape of dropwise on a teflon

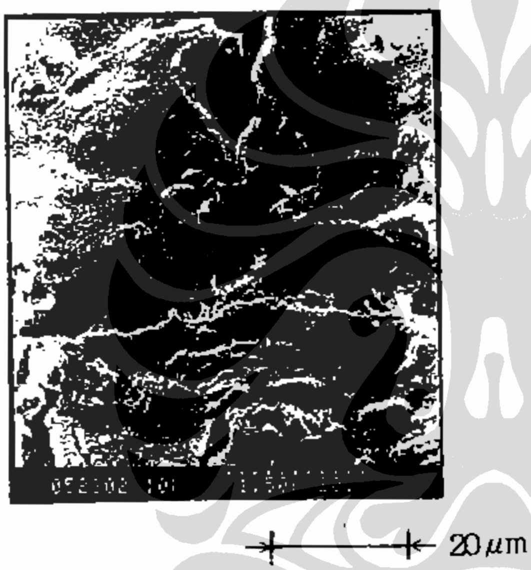

Fig. 1b Micrograph of the teflon wall observed by SEM

The condensers are made of copper with a mix of bronze to create an even temperature on the condenser surface and one of them is coated by thin gold to create a dropwise condensation and we applied a Teflon coat on the other condenser.
The fluid being used as the condensate is distillated pure water and as the cooler is water. During the observation, the steam is in a constant saturation condition; meanwhile the cooling water temperature depends on the atmosphere's condition.

2. Theoretical Background

2.1 Physical Mechanism

Condensation naturally happens because a contact between vapor with a colder surface. When latent energy from the vapor is being released, heat transferred to the surface and condensate is formed.

A vapor condensing on a solid surface can either form widely separated liquid drops, a mode termed dropwise condensation, or a uniform liquid film, a mode termed filmwise condensation. In this respect there are similarities between condensation and boiling at solid surface. In both nucleate boiling and dropwise condensation, nucleation occurs at preferred nucleation sites, the number of which increases with increasing temperature difference – as does the heat flux; the drops on which condensation begins originate in recesses in the surface where liquid remains after a drop leaves, much as nucleate boiling. In both film boiling and filmwise condensation, a layer of fluid acts as an insulator between the solid surface and the pool of fluid of unchanged phase.

The drops grow by direct condensation and by coalescence. The rate of direct condensation on the larger droplets is less than for the smaller droplets because of the resistance to the heat conduction through the drop. The larger drop therefore grow mainly by coalescence. Coalescence between smaller is negligible. The smaller drops grow mainly by condensation and are responsible for the major fraction of the heat transferred. During dropwise condensation of steam at 1 bar pressure about 60% of surface is covered by drops greater than 50 μm, 10% of the surface is bare and the remaining 30% is occupied drops of radius is less than 50 μm. This latter fraction of the the surface transfers 90% of the heat.

2.2 Contact Angel

Prediction of occurrence of dropwise condensation requires a determination of the ability of the fluid to wet the solid surface. Dropwise condensation is likely when the liquid cannot wet the surface, whereas film condensation is likely when the liquid can wet the surface. Heat flux in dropwise condensation is bigger than in filmwise condensation.

The heat transfer coefficient is bigger for gold-coated condenser and Teflon-coated condenser than filmwise condenser. It means that the condenser performance in dropwise condensation is better than filmwise condensation. This shows that condenser with coated surface cause a non-wetable surface is better than natural finished surface condenser on condition that the condensation process is occurred in a certain range of steam to surface temperature difference. If the temperature difference were too big, the condenser performance will be worse.

3. Experimental Set-up

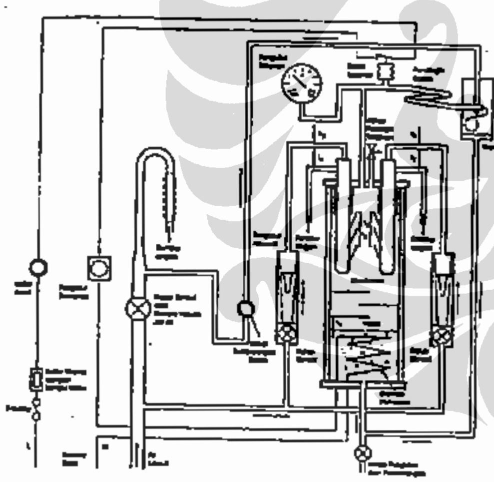

Fig. 2 Experimental set up for filmwise and dropwise condensation

Fig. 2 shows the experimental set up. Two water cooled mounted in upper cylinder cover. Specially designed and fabricated from copper and brass, incorporating a heat exchanger to minimize variation of surface temperatur. Dropwise condenser-gold plated. Filmwise condenser natural finish. Each condenser shell is fitted with three thermocouples connected to measure the mean metal temperatur and two thermocouples to measure the inlet and outlet water temperature respectively. A teflon coat applied on the filmwise condenser to see the influence to condenser performance. The teflon coat on the outer surface of the condenser is approximately 10 μm thick.

The heat flux and the heat transfer coefficient value depend on the inlet and outlet temperature of cooling water, which indicate the amount of heat transfer.

4. Results and Discussion

4.1 Data Analysis

From Fig. 3, we can see that heat flux on both gold-coated and teflon-coated condenser, is bigger than the filmwise condensation. The amount of heat flux is about 25% bigger for gold-coated condenser and 45% bigger for teflon coated condenser than filmwise condenser. This figure also shows that the steam to surface temperature difference effects the heat flux increase in dropwise condensation.

From Fig. 4, we see the difference between the film and dropwise condensation curve. The amount of heat transfer coefficient is averagely 20% bigger for gold-coated condenser and 35% bigger for teflon coated condenser than filmwise condenser. The heat transfer coefficient for each condenser decreases with increasing temperature difference. From the experiment, we find that dropwise condensation heat flux is bigger for gold-coated condenser and Teflon-coated condenser than heat flux in filmwise condensation. This also show that Teflon coat on a condenser surface can promote a dropwise condensation.

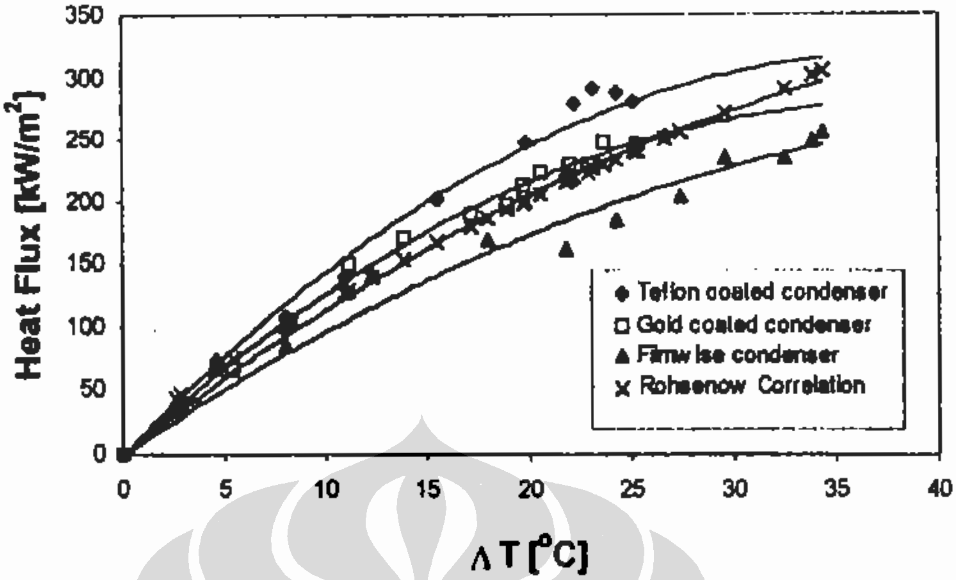

Fig. 3 Comparison between the heat flux and temperature different

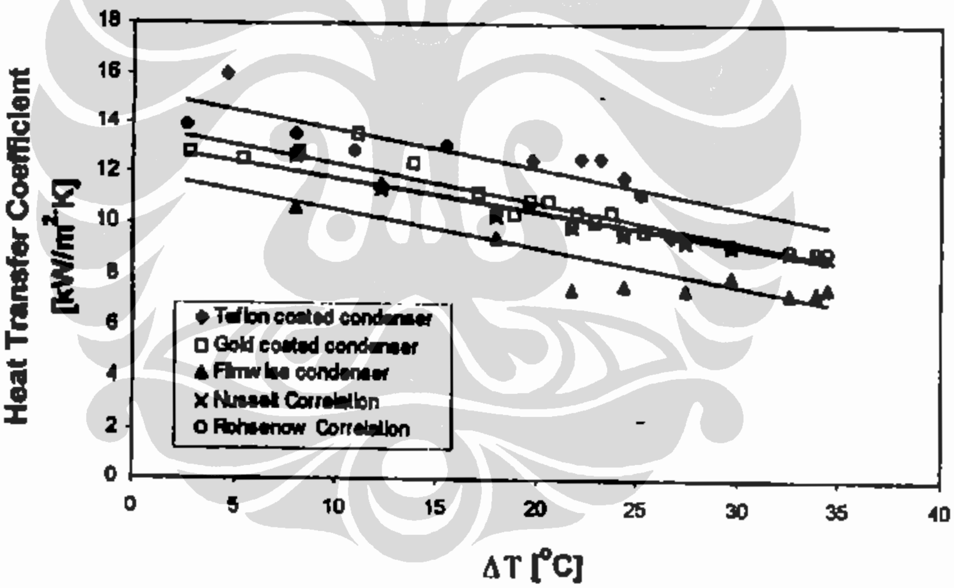

Fig. 4 Comparison between the heat transfer coefficoent and temperature different

5. Conclusion

Carefully arranged experiments and analysis help the writer to better understand effects of the dropwise. Heat flux in dropwise condensation is bigger than in filmwise condensation. From the experiment, we find that dropwise condensation heat flux is is bigger for gold-coated condenser and Teflon-coated condenser than heat flux in filmwise condensation. This also show that Teflon coat on a condenser surface can promote a dropwise condensation.

The heat transfer coefficient is bigger for gold-coated condenser and Teflon-coated condenser than filmwise condenser. It means that the condenser performance in dropwise condensation is better than filmwise condensation.

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