INTISARI

Peningkatan konsumsi energi global mendorong kebutuhan akan sistem termal yang lebih efisien, khususnya pada sistem refrigerasi dan pendingin udara yang memiliki konsumsi energi listrik cukup besar. Salah satu komponen penting pada sistem tersebut adalah kondensor, yang berfungsi melepaskan kalor melalui proses kondensasi. Performa kondensasi dipengaruhi oleh karakteristik permukaan dan kondisi pendinginan, sehingga modifikasi permukaan pipa menjadi salah satu pendekatan yang banyak dikembangkan untuk meningkatkan perpindahan kalor. Penelitian ini bertujuan untuk menganalisis karakteristik perpindahan kalor kondensasi eksternal pada pipa horizontal, mengevaluasi pengaruh variasi kondisi permukaan pipa dan temperatur *chiller* terhadap laju perpindahan kalor *(q)*, heat *flux* (q"), koefisien perpindahan kalor kondensasi *(h)*, serta degree of subcooling (ΔT_{sub}) sekaligus menentukan konfigurasi yang memberikan performa kondensasi terbaik.

Penelitian dilakukan secara eksperimental menggunakan fasilitas perpindahan kalor kondensasi pada pipa horizontal dengan fluida kerja berupa uap air dan fluida pendingin berupa *aquades*. Variasi permukaan yang digunakan terdiri atas pipa halus, pipa kasar, dan pipa dengan *hydrophobic coating*, sedangkan temperatur *chiller* divariasikan pada 20°C, 15°C, dan 10°C. Selama pengujian dilakukan pengukuran temperatur, tekanan, dan laju aliran fluida, kemudian data diolah untuk memperoleh nilai *q*, *heat flux*, koefisien perpindahan kalor kondensasi, dan *degree of subcooling*. Selanjutnya dilakukan analisis terhadap pengaruh masing-masing variabel serta mekanisme kondensasi yang terjadi pada setiap variasi permukaan berdasarkan hasil eksperimen dan pengamatan visual.

Hasil penelitian menunjukkan bahwa variasi kondisi permukaan pipa dan temperatur *chiller* memberikan pengaruh yang signifikan terhadap karakteristik perpindahan kalor kondensasi. Dibandingkan pipa halus, penggunaan pipa dengan *coating*meningkatkan laju perpindahan kalor (*q*), *heat flux* (*q''*), dan koefisien perpindahan kalor kondensasi (*h*) masing-masing hingga 94,12%, 98,00%, dan 113%. Penurunan temperatur *chiller* dari 20°C menjadi 10°C meningkatkan laju perpindahan kalor hingga 83,85%, *heat flux* hingga 83,85%, dan koefisien perpindahan kalor kondensasi hingga 65,9% pada seluruh variasi permukaan.Analisis mekanisme kondensasi menunjukkan bahwa permukaan hidrofobik mempermudah pelepasan kondensat sehingga mengurangi hambatan termal dan meningkatkan efektivitas perpindahan kalor. Berdasarkan seluruh parameter yang dianalisis, konfigurasi terbaik diperoleh pada pipa dengan *coating*pada temperatur *chiller* 10°C, dengan nilai laju perpindahan kalor sebesar 2,01 kW, *heat flux* sebesar 584,43 kW/m², dan koefisien perpindahan kalor kondensasi sebesar 7,63 kW/m²·°C.

Kata kunci: kondensasi eksternal, perpindahan kalor, pipa horizontal, *hydrophobic coating*, *heat flux*, koefisien perpindahan kalor kondensasi, *degree of subcooling*, temperatur *chiller*.

ABSTRACT

The increasing global demand for energy has driven the need for more efficient thermal systems, particularly in refrigeration and air-conditioning applications, which account for a significant portion of electricity consumption. One of the key components in these systems is the condenser, where heat is rejected through the condensation process. Condensation performance is strongly influenced by surface characteristics and cooling conditions; therefore, surface modification has become one of the most promising approaches to enhance heat transfer performance. This study aims to investigate the characteristics of external condensation heat transfer on a horizontal tube, evaluate the effects of surface variations and chiller temperature on the heat transfer rate *(q)*, heat flux (q''), condensation heat transfer coefficient *(h)*, and degree of subcooling (ΔT_{sub}) and determine the configuration that provides the best condensation performance.

An experimental study was conducted using a horizontal tube condensation heat transfer facility with water vapor as the working fluid and distilled water as the cooling fluid. Three surface conditions were investigated, namely a smooth tube, a rough tube, and a hydrophobic-coated tube. The cooling fluid temperature supplied by the chiller was varied at 20°C, 15°C, and 10°C. During the experiments, temperature, pressure, and flow rate were measured continuously. The collected data were then processed to determine the heat transfer rate, heat flux, condensation heat transfer coefficient, and degree of subcooling. Furthermore, the effects of the experimental variables and the condensation mechanisms on each surface were analyzed based on the experimental results and visual observations.

The experimental results demonstrated that both pipe surface characteristics and chiller temperature significantly affected the condensation heat transfer performance. Compared with the smooth pipe, the hydrophobic-coated pipe increased the heat transfer rate (q), heat flux (q''), and condensation heat transfer coefficient (h) by up to 94.12%, 98.00%, and 113%, respectively. Reducing the chiller temperature from 20°C to 10°C increased the heat transfer rate and heat flux by up to 83.85%, and the condensation heat transfer coefficient by up to 65.9% for all surface conditions. The condensation mechanism analysis indicated that the hydrophobic surface promoted condensate removal, thereby reducing thermal resistance and enhancing heat transfer effectiveness. Based on all evaluated parameters, the optimum performance was achieved using the hydrophobic-coated pipe at a chiller temperature of 10°C, yielding a heat transfer rate of 2.01 kW, a heat flux of 584.43 kW/m², and a condensation heat transfer coefficient of 7.63 kW/m²·°C..

Keywords: external condensation, heat transfer, horizontal tube, hydrophobic coating, heat flux, condensation heat transfer coefficient, degree of subcooling, chiller temperature