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Experimental and numerical study of natural convection heat transfer from horizontal concentric cylinders

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ABSTRACT

Natural convection heat transfer from horizontal concentric cylinders is studied experimentally and numerically. Concentric cylinders were formed with two test cylinders made of copper, and the annulus was filled with water. Concentric cylinder system was located in the ambient air and the inner horizontal cylinder was kept at a constant temperature. Experimental study was carried out at different ambient temperatures in a conditioned room which can be maintained at a stable required value and inside a sufficiently designed test cabin. The ambient and inner copper cylinder surface temperatures (T_∞ and T_c) varied between 20 °C–30 °C and 30 °C–60 °C respectively. Also, experiments were performed for bare cylinder at the same conditions as concentric cylinders to compare results. On the basis of the experimental data average Nusselt numbers for the air side of the concentric cylinders were calculated and compared with numerical results. The effective thermal conductivity(k_{eff}) of the annulus was calculated by using the experimental data and numerical solution results and also compared with the well known correlation. Isotherms and streamlines are presented in the annulus and the air side for $Ra_L = 9 \times 10^5 – 5 \times 10^6$ and $Ra = 2 \times 10^5 – 7 \times 10^5$ respectively. It is seen that numerical and experimental results are in a good agreement. Heat transfer rates under steady-state conditions from bare and concentric horizontal cylinders were compared and heat transfer enhancement was determined. Also the effect of the decrease in the temperature of the inner copper cylinder surface (condensation temperature) on COP was investigated considering an ideal Carnot refrigeration cycle. It is found that the enhancement in COP of a Carnot refrigeration cycle is 42.6% under steady-state conditions.

1. Introduction

Energy demand is increasing as a consequence of population growth and economical development. Today, energy efficiency is a popular topic which covers almost all appliances employed in industry, infrastructure and household appliances, etc. International institutions or committees such as CECED (European committee of domestic equipment manufacturers) are aiming to decrease energy consumption especially in household appliances because of having an environmental impact. In refrigeration systems, it is possible to reduce energy consumption (compressor power) and increase COP by decreasing the condensation temperature. Decreasing the condensation temperature can be achieved by increasing either the overall heat transfer coefficient or heat transfer surface area of the condenser. Usually, the radiuses of condenser tubes of domestic refrigerators are quite smaller than the critical radius. Thus, the radius can be increased up to the critical radius by covering the bare condenser tube to increase heat transfer.

Covering the cylinder may be employed as insulation or surface augmentation. Incropera and DeWitt [1] gave the best answer to the application where the heat transfer rate increases by adding insulation and discussed it in detail. For electrical wires, thermal insulation material is needed for electrical insulation and safety. Curved surfaces such as circular cylinders having a radius smaller than a certain critical size, adding insulation to the surface increases the heat transfer. This phenomenon occurs if the increase in the conduction resistance is less than the decrease in the convection resistance and commonly called the critical radius. This is valid if the fluids in the annulus remain stationary for the concentric cylinders. In general the fluid in the annulus does not remain stationary because of the different surface temperatures of concentric cylinders. That motion enhances the rate of heat transfer through the annular space by natural convection [2]. Therefore, natural convection heat transfer from horizontal concentric cylinders is investigated numerically and experimentally.

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