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Experimental Study on Air-Side Heat Transfer Enhancement of Fin-Tube Heat Exchanger under Vibrational Conditions

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Extended Abstract

Fin-tube heat exchangers have been used in wide range of industries including refrigeration, air conditioning, and food processing owing to its unique configuration. In most applications of fin-tube heat exchangers, the performance is highly constricted by the heat resistance of air, owing to its low heat transfer coefficient. Thus, to make more effective and compact heat transfer system, it is essential to enhance the air-side heat transfer coefficient.

The heat transfer enhancement technique is largely divided into two parts: passive and active techniques. Passive technique refers to an enhancement method which does not require additional energy input. In terms of the active technique, which requires additional energy input, various enhancement techniques are under research. Among those, enhancement by forced vibration attracted the interest of many researchers.

Dan et al. [1] experimentally studied the effect of vertical vibration on the heat transfer performance of a fin-tube vehicle radiator. Their experiment was held under standard driving vibration condition (QC-T468-2010). For the convenience of experiment, they used water as a working fluid inside the radiator. Dan used ε-NTU method to calculate the air-side heat transfer coefficient. While calculating water-side heat transfer coefficient, they used the Gnielinski correlation, neglecting the effect of vibration on water-side. They insisted that air-side Nusselt number was increased from 2.98% to 16.82% by forced vibration.

This study focused on transverse vibration on fin-tube heat exchanger which has a large fin pitch. Fin-tube heat exchanger with a large fin pitch (5 mm) was selected to observe the effect of boundary layer development and forced vibration. The experiment was conducted inside the psychrometric chamber. Ethylene glycol – water mixture (EGW) of 16.2% mass fraction was used as the working fluid. The air temperature and EGW temperature were fix at 0 °C and 21 °C, respectively. EGW's volumetric flow rate was fix at 1.7 LPM, and vibrational frequency was fix at 15 Hz. The experiment was conducted by varying air-side volumetric flow rate from 1.2 to 3.6 cubic meter per minute (CMM), and varying vibrational amplitude by 1 to 5 mm. For data reduction, the LMTD method was used and EGW side heat transfer data was induced by the Dittus-Boelter correlation owing to the turbulent boundary condition of EGW. Pressure drop data was neglected since fin-tube heat exchanger with large fin pitch had extremely small pressure drop. Also, a gap existed between heat exchanger and air tunnel for vibration, which made pressure drop more negligible. Similar data reduction was held by Choi et al. [2].

In vibration conditions of 15 Hz frequency and 5 mm amplitude, the Nusselt number enhancements turned out to be from 2.5% to 12%. When the boundary condition of air was within laminar condition, the Nusselt number enhancements were 6% to 12%. In the transition region, the enhancement was fixed around 6%. With further increase in the Reynolds number, the boundary layer between fins did not interrupt each other, which resulted in a further decrease in the Nusselt number enhancement from 2% to 6%. Similar trends were shown on other amplitude cases.

References

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