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Effect of louvres on the thermal efficiency of panel radiators

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ABSTRACT

In this study, two radiators on which louvres had been made up on either outer surface or inner surface, were experimentally contrasted within an experimental setup which heats water between an average temperature difference range of $\Delta T = 30$ K to 60 K. Constructive details and dimensions of experimental test section's orientations having 6 different positions were given in detail in the paper. Positions include the situation of the panel radiator without louvre, louvres on front surface-single slice, louvres on back surface-single slice, louvres on back surface-single slice, and louvers on back surface-single slice with a chimney, louvres on back surface- 3 slices in a row. Detailed uncertainty analyses were given in order to calculate the uncertainties of water inlet and outlet temperatures, and heat output values. CFD analyses have been carried out to have air velocity and temperature distribution around the sample panel radiators after the validation with experiments. CFD results were found to be in good agreement with experiments having tolerable deviation varied from 10.73% to 24%. Almost all experimental findings including measured data points were declared in a Table for other researchers' usage for their validation issues. 8 number of empirical correlations have been proposed in order to determine the heat outputs regarding with the different configurations of the test section. Finally, effect of louver space on the heat outputs was also shown in the paper.

1. Introduction

The radiators emit heat by means of radiation and convection. It can by and large be stated that approximately 20–40% of heat is spread through radiation, while major portion is provided by convection. Rather than what the radiator is made of, type of dye applied over its surface, along with the geometry of radiator affect radiative heat transfer. In this context, by dull and black painted radiators, radiation is much more remarkable. Bright metallic dyes significantly diminish radiation. Metallic dyes such as aluminum and bronze deteriorate radiative and total heat output at the ratios by 50% and 10%, respectively. Heat amount transferred to living places varies with water temperature, dimensions of the radiator and its design. Radiators with larger exterior surfaces bring with higher rates of radiation. Therefore, thin casting radiators and panel radiators enable higher ratios of radiation. Since, aluminum radiators are made of fins, the fins do not have a direct contact with water and hence they are at lower temperatures. That is why they have had lower proportions of radiation. Surface smoothness has also had an influence on radiative heat transfer. Rough casting surfaces emit slightly more radiation than that of smooth surfaces.

The detailed information on investigating the effect of louvers regarding with thermal efficiency can be obtained from [1–24].

Numerous ingredients affecting the thermal efficiency of radiators exist. Some of them depend on their locations and operating conditions. Thermal outputs of radiators can be improved by diminishing the distance of them from the floor and increasing their distance to the wall, whereas, reducing the flow rate along the radiator descends the thermal output, while attaching fins increases convective heat transfer. Furthermore, radiator connection may influence their performance. Given the details and a dense literature review abovementioned, it is noticeable that except a few investigations, no further research has been met regarding the effect of geometry made up above radiator panes on thermal efficiency of radiators. To this end, two radiators on which louvres had been made up on either outer surface or inner surface, were experimentally contrasted within an experimental setup which heats water between an average temperature difference range of $\Delta T = 30$ K to 60 K. In addition to this, after determining the model having higher thermal efficiency, the thermal efficiency results of models having one and three louvres, as well as models which are equipped with louvres with different louvre intervals, were compared. Finally, CFD analyses have been accomplished by means of the validation with experimental results in order to see air velocity and temperature distribution around sample heat exchangers.

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Nomenclature

A	radiator slice surface area (m^2)
$c_{p,w}$	specific heat of water ($kJ\ kg^{-1}\ K^{-1}$)
d_s	thickness of radiator model (mm)
d_t	inner diameter of water pipe on radiator (mm)
E	blackbody emissive power of examined surface ($W\ m^{-2}$)
G_S	louvre pitch
H_s	height of louvre
K_M	model constant
L_r	height of radiator model (m)
m_w	water flow rate (kg s^{-}1)
n	exponential constant
Q_c	convective heat output (W)
Q_r	radiative heat output (W)
Q_T	total heat output (W)
S	louvre space (mm)
T	temperature (°C)
T_{30mm}	radiator surface temperature at 30 mm (°C)
T_{255mm}	radiator surface temperature at 255 mm (°C)
T_{482mm}	radiator surface temperature at 30 mm (°C)
$T_{w,i}$	water inlet temperature to radiator (°C)
$T_{w,o}$	water outlet temperature from radiator (°C)
W_r	width of radiator model (mm)

Greek letters

ε	emissivity
σ	Stefan – Boltzmann constant ($W\ m^{-2}\ K^4$)
ΔT	Mean temperature difference of radiator inlet and outlet temperatures (K)

2. Experimental setup

Photographs and a sketch of the experimental setup are illustrated in Figs. 1 and 2, respectively. As can be seen from the figures, in a 50 l tank that has a heater and a thermostat, water is heated until the temperature differences values of ΔT = 30 K, 50 K, and 60 K are reached. When the water temperature has come to the desired level, entering valve to the radiator is opened and the water is flowed into the radiator model, by gravitation effect. In the sketch of the experimental setup, radiator model with 3 slices is demonstrated. Water inlets to the second and third radiator models are carried out by means of different outlets from the water tank. On each model's water inlet, one thermocouple has been placed. Water passing through the radiator model transfers a portion of energy on the radiator slice and afterward leaves the model. Water flow rate is adjusted by valves laid on each model's outlet. On the radiator surface, from three discrete points' temperature is measured and the variations in temperature are recorded. Throughout the experiments, water amount leaving models is collected in a pot, and thus water flow is controlled.

As experimental models, various radiator slices over which slots were made in the shape of louvre, were prepared. Radiator slices are made from aluminum and at the height, width, and thickness of 520 mm, 74 mm, and 1.5 mm, respectively. Details on louvre intervals, and louvre spaces along with model geometry are presented in Figs. 2 and 3, and Table 1. It should also be noted that louvres were formed by means of a pressing machine.

In the study, 15 T-type thermocouples were used and each entered two data loggers having 8 channels in each. From data logger to computer, by means of a USB cable, the connection was made.

The experimental setup was filled with water and afterward it was checked whether any water leakage occurred from the connections of thermocouples placed in the inlet and outlet of model, the water tank and the model itself. Thermocouples mounted on the experimental model were stretched perpendicular to the surface for not to affect air flow in the vicinity and for the same reason the data loggers were hanged on upwards by a specific distance from the ground. Since the outlet of water from the model takes place through gravitation, for not to impact on precision balance whereby the flow measurement was carried out, it was placed below water outlet level. Prior to experiments, water in the tank was heated by means of thermostatic heaters by the desired temperature level. The temperature of water within the tank was measured by a thermocouple named "water inlet temperature". The variation of temperatures within the system was tracked by computer. It should be noted that via graphics, these variations were followed and when the variation became unchanging, it was understood that the system had come into the steady state. For the system to

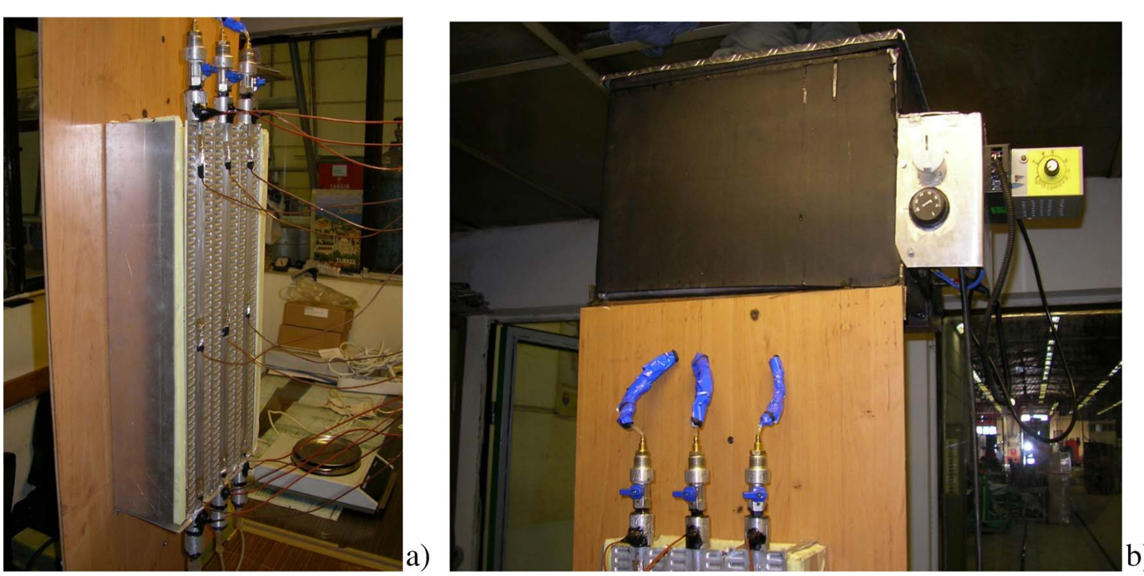

Fig. 1. General photograph of experimental setup (a) and photograph of water tank including a heater and thermostat (b).