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EXPERIMENTAL STUDY OF A FORCED DRAFT CROSS FLOW COOLING TOWER - EFFECT OF AIR VELOCITY

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Abstract: Cooling tower is used to cool circulating water by exposing air upon it. Cooling tower has a large significance in different types of power plant such as nuclear power plant, steam power plant etc. and many industries. Generally, if there is a temperature gradient between two places and the system is not isolated, there will be heat transfer from one place to another. But it is necessary to improve the rate of heat transfer by using different technique in cooling tower so that better heat rejection from the system can be obtained. This paper illustrated an experimental work, which studied the performance of a forced draft cross flow cooling tower with vertical corrugated fill at different air velocity. During the experiment the air velocity was varied in the range of 1.4 to 3.1 m/s while water flow rate and inlet water temperature were maintained constant at 7.5 L/min and 55^{o}C respectively. It was observed that the effectiveness, cooling capacity, and range were increased, and approach was decreased with the increase of air velocity.

Keywords: Cooling tower, forced draft, cross flow, effectiveness, cooling capacity.

1. INTRODUCTION

Cooling towers cool water by contacting it with air and evaporating some of the water. Cooling towers are used in large thermal systems such as steam power plants, refrigeration and air conditioning plants, industrial process plants etc. to control cooling water temperature. The theory of cooling tower operation was first proposed by Walker et al. [1]. In the cooling tower heat and mass transfer take place from water to the unsaturated air. There are two driving forces for the transfer: the difference in dry bulb temperatures and the difference in vapor pressures between the water surface and the air. These two driving forces combine to form the enthalpy potential [2]. There are different types of cooling towers. In cross flow cooling towers air flows horizontally and water flows downward. The fill materials are used to distribute the water flow and provide large air-to-water interfacial contact area. There are three types of fills in use namely film, splash and film grid fills [3]. Goshayshi and Missenden [4] experimentally investigated the mass transfer and pressure drop characteristics of different types of corrugated packing, including smooth and rough surface corrugated packings. Gharaghezi et al. [5] conducted experiments to investigate and compare the effect of the liquid to air flow ratio on the performance and mass transfer coefficient of the mechanical cooling tower for vertical corrugated packing (VCP) and horizontal corrugated packing (HCP).

In this work, a cross flow, forced draft with vertical corrugated fill was used to investigate the effect of air velocity on range, cooling capacity, effectiveness, and approach.

2. EXPERIMENTAL

Figure 1 shows the experimental set up used in this investigation. It consisted of a hot water reservoir, pump, regulating valve, rotameter, water distribution system, fill and a fan. Two thermometers were used to measure the inlet and outlet temperatures of water. The cooling tower had dimensions of 450 mm×450 mm×450 mm and was fabricated from transparent plastics. The filling portion had height of 290 mm with horizontal cross-sectional area 290 mm×290 mm and vertical cross-sectional area 290 mm×240 mm. The filling portion was made from 1 mm thick vertical corrugated fill (290 mm×290 mm). It had corrugation pitch of 76 mm and corrugation height 17 mm. Average fill spacing was 15 mm. The water distribution system was made from mild steel and had dimensions 310 mm×310 mm× 40 mm, which had 2 mm diameter holes at 10 mm spacing. Hot water from the hot water reservoir was taken to this distributor using pump (0.5 hp). The hot water reservoir was fitted with a heater and a thermostat. The flow rate was maintained at 7.5 L/min by the regulating valve and measured by the rotameter. The fan was placed at the central portion of the fill bed to produce horizontal air flow. The water was allowed to fall from the distributor, which was placed 70 mm above the fill. The inlet water temperature was maintained at 55^{o}C and it was controlled by heater and thermostat. The inlet and outlet air dry bulb and wet bulb temperatures were measured by hand held thermometers.

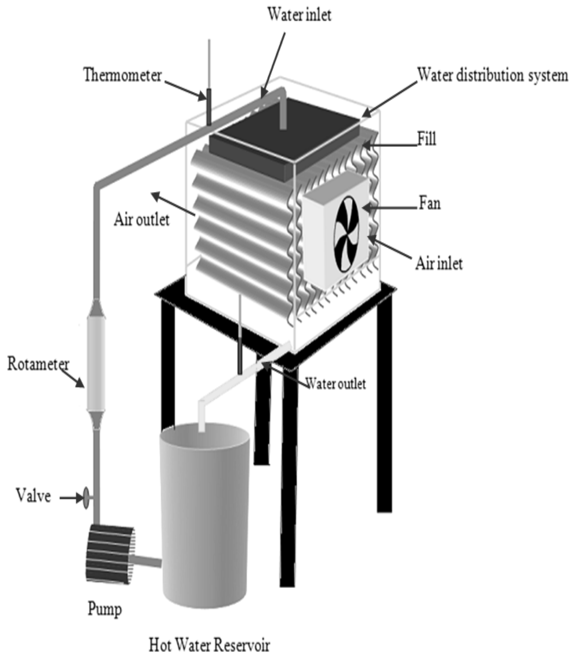

Fig. 1: Schematic diagram of the wet cooling tower.

3. RESULTS AND DISCUSSIONS

Experiments were conducted to investigate the effects of air velocity on range, cooling capacity, approach, and effectiveness. The water inlet temperature and water flow rate were maintained constants to 55^{o}C and 7.5 L/min respectively for all the experiments. Figure 2 shows the effect of air velocity on range and cooling capacity. Range is the difference between water inlet temperature and water outlet temperature which is expressed by,

$$R = T_{wi}-T_{wo} \tag{1}$$

Air velocity was considered from 1.4 m/s to 3.1 m/s. It was observed that with the increase of air velocity, range and cooling capacity were increased. An increased amount of air flow rate was responsible for increased heat transfer coefficient as well as mass transfer coefficient, resulting higher cooling rate of water i.e. increase of range and cooling capacity. With the increase of air velocity from 1.4 m/s to 3.1 m/s the range was found to be increased from 3^{o}C to 7^{o}C respectively. Cooling capacity was calculated by,

$$\text{Cooling capacity} = m_w \times c_{pw} \times (T_{wi}-T_{wo}) \tag{2}$$

For 1.4 m/s air velocity cooling capacity was found to be 1.58 kW and this increased to 3.68 kW at 3.1 m/s air velocity. The water properties were considered at average temperature of water between inlet and outlet.

Figure 3 represents the effect of air velocity on approach and effectiveness. Approach is defined as the difference between water outlet temperature and ambient air wet bulb temperature. It is expressed as,

$$\text{Approach} = T_{wo} - T_{wb} \tag{3}$$

With the increase of air velocity the approach was found to be decreased. As with the increase of air flow rate, cooling capacity was increased (Fig. 2), which resulted in decrease in water outlet temperature, T_{wo}, i.e. decrease in approach. With the increase of air velocity from 1.4 m/s to 3.1 m/s the approach was found to be decreased from 26^{o}C to 21.5^{o}C respectively. The ambient air wet bulb temperatures were found to be varied between 26 and 26.5^{o}C. The effectiveness showed increasing trend with the increase of air velocity. The effectiveness was found to be increased from 10.5% to 24.6% with the increase of air velocity from 1.4 m/s to 3.1 m/s respectively. The same trends of increase of effectiveness with the increase of air flow rate for corrugated packing were observed by Gharagheiz et al. [5]. Cooling tower effectiveness is the ratio of range to the difference between cooling water inlet temperature and ambient wet bulb temperature i.e.,

$$\eta = \frac{T_{wi} - T_{wo}}{T_{wi} - T_{wb}} \tag{4}$$

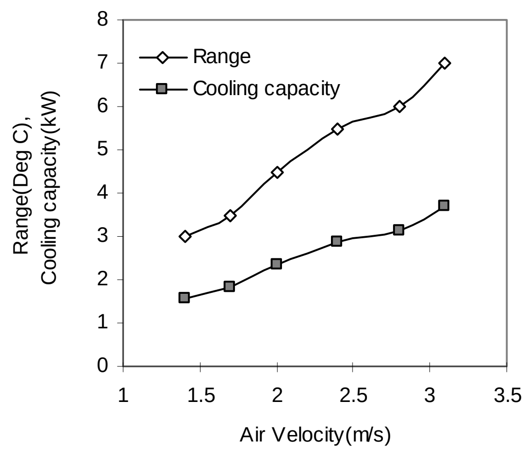

Fig. 2: Effect of air velocity on range and cooling capacity.

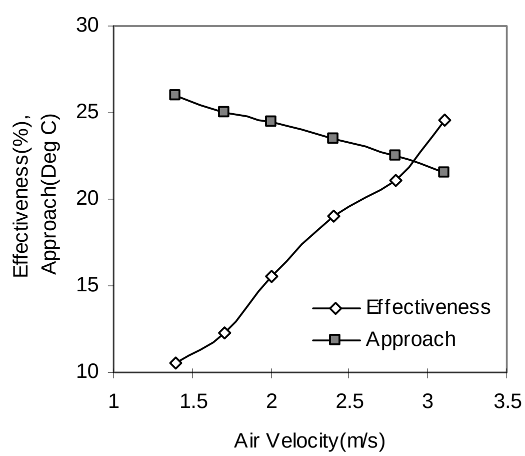

Fig. 3: Effect of air velocity on approach and effectiveness.

5. CONCLUSION

An experimental investigation was carried out to see the effect of air velocity on range, cooling capacity, approach and effectiveness for cross flow cooling tower with vertical corrugated fill. The water inlet temperature of 55°C and water flow rate of 7.5 L/min was used in the experiments. The following observations were found,

- The range was found to be increased from 3°C to 7°C with the increase of air velocity from 1.4 m/s to 3.1 m/s respectively.
- The cooling capacity was found to be increased from 1.58 kW to 3.68 kW with the increase of air velocity from 1.4 m/s to 3.1 m/s respectively.
- With the increase of air velocity from 1.4 m/s to 3.1 m/s the approach was found to be decreased from 26°C to 21.5°C respectively.
- The effectiveness was found to be increased from 10.5% to 24.6% with the increase of air velocity from 1.4 m/s to 3.1 m/s respectively.

6. REFERENCES

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7. NOMENCLATURE

Symbol	Meaning	Unit
c_{pw}	Specific heat of water	kJ/kg.K
m_w	Water mass flow rate	kg/s
R	Range	°C
T_{wb}	Ambient air wet bulb temperature	°C
T_{wi}	Water inlet temperature	°C
T_{wo}	Water outlet temperature	°C
η	Effectiveness	-